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Safety Information System of Indian Unmanned Railway Level Crossings

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Abstract: *In India, the unmanned railway level crossings are of major concerns these days because of rising rail-road accidents in India. There is an urgent need to develop an information system which can inform the users before hand of the approaching unmanned railway level crossings with their characteristics. Each unmanned level crossing was surveyed to collect the unmanned railway level crossing characteristics on Shahdra-Shamli-Tapri railway route through Global Position System and sensor. These are stored and analyzed through GIS software. The locations of railway stations were also surveyed. The level crossings are stored as points with its characteristics in geographical information system database, whereas the road and railway track are stored as line feature and villages as polygon features. Unmanned crossings accident statistics are stored and analyzed from year 2008 to 2013. The traffic flow characteristics of the road crossing the unmanned railway level crossings viz. traffic volume, peak hour factor and average daily traffic are also analyzed in this study. The study may lead to development of a warning system for road users so that they are aware about the different characteristics of the unmanned railway level crossing beforehand to alert them about the safety.*
Key words: *Unmanned railway level crossing characteristics, GPS, GIS, sensor, ICT.*

I. Introduction

1.1 Problem

The railway level crossing is the one where a railway line and a road intersect with each other at the same level. There are two types of level crossings in India, i.e. manned and unmanned railway level crossings. According to [1] there are approx. 30348 level crossings (manned and unmanned) in India out of which 11563 are unmanned. Collisions at unmanned level crossings are increasingly a major problem in India. According to the report published in Times of India by [2] News Network maximum accidents i.e. 40% occurred at unmanned railway level crossings. Most of the unmanned level crossing accidents were due to the negligence of road users viz. Non-visibility of approaching train at level crossing by road users. The plan given by [3], [4] described the method of lowering accidents by decreasing human dependence and mitigation of consequential effect. This plan helped in reduction of accidents 44% in 2003 to 17% in 2013. A website of Government of India (www.sims.railnet.gov.in) [5] monitors each unmanned level crossing about the safety data. Every unmanned level crossing is assigned a unique ID, which therefore provides the necessary useful information viz. unmanned railway level characteristics and accident data to the user about each unmanned level crossing.

1.2 Previous Work

The study [6] extracted and analyzed the Turkish State railways characteristics using Geographical Positioning System (GPS), sensors, like non-contact photography (remote sensing technology), video, laser, acoustic, radar, and infrared sensors and therefore developed a Geographical Information System (GIS) database. The database contained the knowledge about stations, segments, traffic accidents, maintenance, and renewal works and track data. The track data was classified into equal segments. The information could be gathered by a click on the segments viz. material type, work history information, track structures (tunnels), weather conditions (flooding and snowy places), and natural soil conditions (landslide, stone falling). The track geometry graphically representation was also done in this study. The graphical representation was used in calculation of normalized standard deviations and Quality Index (QI) and was stored in GIS. The GIS database of turnout having a symbol of small train had attributes viz. turnout ID, kilometers, type, direction, angle, radius, length, sleeper and station and could be retrieved on a single click. The study in [7] discussed information and communication computer controlled system which extracted processed, stored, analyzed, logically associated and graphically displayed. The GIS-based Advanced Traveler Information System (ATIS) was developed to store huge amount of GIS data information of Hyderabad City, India. The Hyderabad City features viz. road networks, hospitals, government and private offices, stadiums, bus and railway stations, and tourist places within the city limits were stored as attributes in GIS database. The traveler's information could easily access information system of travelers through this system. In [8], an integrated GPS, GIS and wireless sensors based data collection system was developed. GPS based Automatic Vehicle Location (AVL) system collected the locations at fixed time interval for road-rail network. The database inventories consisted of the digital maps, high resolution satellite imagery, and digital elevation models which are mapped through GIS. The data is transmitted through wireless sensors. The data base inventory mapping was also done for accident site on digital maps, establishment of the post accident responder, and cost effective measures for timely relief. Crossing Inventory Information Management System (CIIMS) [9] developed by Visual Basic (VB) 6.0 to manage the Kansas department of transportation (KSDOT)'s accidental data of rail/road crossings. The spatial analysis was done by GIS functionality inserted in the VB software. The application of GIS helped in maintaining grade crossings data efficiently. Therefore, identification of the higher accident prone rail/road crossings helped in improving the safety of motorists across Kansas. A Rail Safety Information System (RSIS) [10] which contained all railroad safety related information and acted as Database Management System (DBMS). The functionality of the RSIS includes- firstly, the location inspection. Secondly, the railroad data reporting have to be done. Afterwards the data is to be tested, processed and stored. Approximately 750,000 records are reported and verified every year. In [11] a geographic database of Switzerland railway level crossing using GIS. GIS stored and presented every route of level crossing data in a GIS pictorially. The project aimed at infrastructure representation by electronic means. The project again aimed at improvement of whole infrastructure and plan security. Afterwards all geographic databases were to be spread through Intranet. The study [12] provided the level crossing safety by using a knowledge base and studied the level crossing existing in European countries and Japan. The study again analyzed the accident data at railway level crossings. The study again proposed the reporting level crossing accidents in European countries. They again prepared an integrated accident information system for accident database retrieval. They again examined the new technological innovations to upgrade railway level crossings. They finally resulted in creation of Thematic Maps of level crossing through web portal. The SELCAT in total enhanced the road and rail safety and also helped in traffic congestion avoidance. The railway level crossing data was collected, analyzed, coded, compared and harmonized by use of new technological innovation and also regular database maintenance helped in reducing the accidents at railway level crossings. The budget requirements used for completion of the project was 850 Euro and duration to complete the project was 22 months.

1.3 Purpose of Work

- To collect data and identify unmanned railway level crossings locations and routes on railway route.
- To create a database using GIS Interface (Arc Map) (ARC GIS) [13] for digitization, adding attributes and database retrieval of unmanned railway level crossing characteristics.
- To create spatial map, query analysis of unmanned railway level crossings locations to map and retrieve the accidental crossings.
- To analyze the total traffic volume, average daily traffic (ADT), highest peak hour factor (PHF) of unmanned railway level crossings.

1.4 Contribution of the Study

The study contributes in the way that with an information database created of unmanned railway level crossings on railway route, it is easy to track the accidental crossings. When the road users approach these unmanned level crossings, they might be attentive before hand of the approaching the crossings with its characteristics already known.

II. Methodology

The system flowchart for safety information system using GIS is shown in Fig. 1. The methodology is discussed as-

1. Data collection and identification of unmanned railway level crossings locations on Shahdra-Shamli-Tapri railway route.
2. Identification of routes crossing all the unmanned railway level crossings.
3. Used GIS Interface (Arc Map) for spatial mapping, query analysis and database retrieval of accidental unmanned railway level crossings.

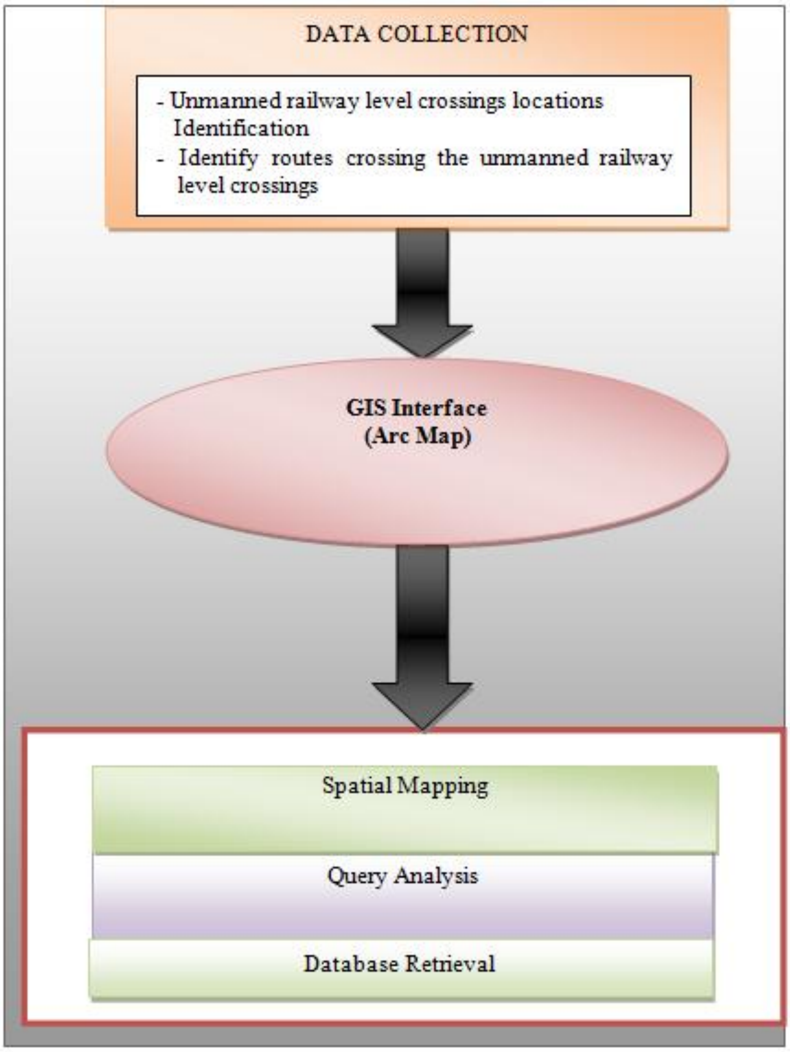

Fig. 1. System flowchart for safety information system using GIS

2.1 Data Collection and Identification of Railway Line Network

The unmanned railway level crossings on Shahdra-Shamli-Tapri (DSA-SMQL-TPZ) railway route have been identified. The Shahdra-Shamli-Tapri railway line connects Shahdra in Indian capital Delhi to Tapri, near Saharanpur in Uttar Pradesh. The railway line is about 165 km in length and it has 145 railway level crossings and 71 of them are unmanned railway level crossings. The railway line connects the major cities of Uttar Pradesh and Delhi. The unmanned railway level crossings on this railway route are situated mostly near rural areas i.e. (approximately 95%).

The railway route operation and maintenance is done by Northern Railways (NR), a division of Indian Railways (IR). The study has been conducted on 19 road vehicle-train collision prone unmanned railway level crossings situated on DSA-SMQL-TPZ railway route with railway line chainage between 0 km to 165 km. The study route map (Fig. 2). According to Safety Information Management System (SIMS), the maximum design and booked speed on the DSA-SMQL-TPZ section is 75 km/hr and in foggy conditions the maximum permissible speed of the train is 48 km/hr. The study area with directions is given in Table 1.

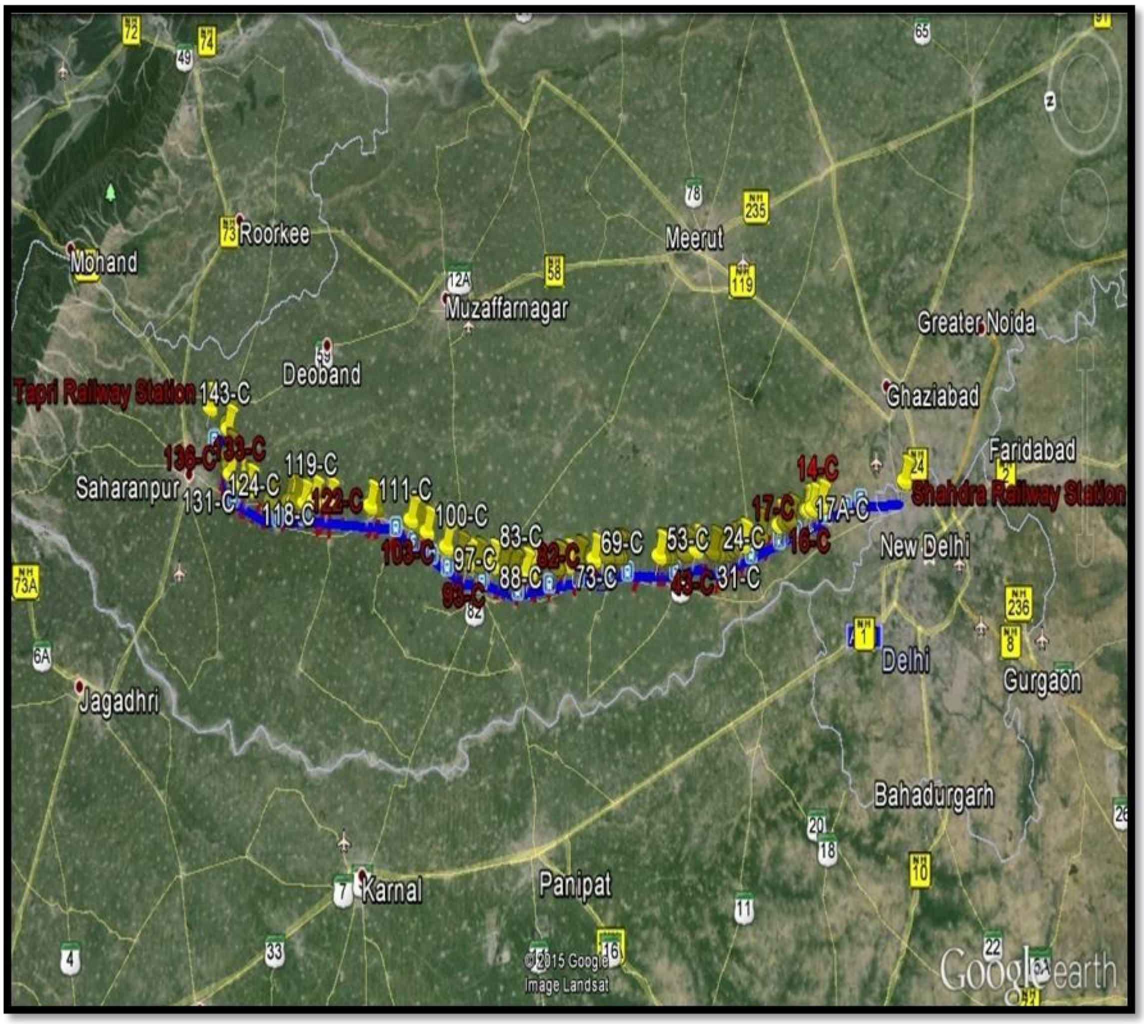

Fig. 2. Study route map of DSA-SMQL-TPZ

Table 1. Study area with directions

S. No.	Unmanned Railway Level Crossing	Direction 1	Direction 2
1.	14-C	Gotra/Mandula to Fakharpur	Fakharpur to Gotra/Mandula
2.	16-C	Khekra to Fakharpur	Fakharpur to Khekra
3.	17-C	Khekra to Fakharpur	Basi/Khekra to Sunhera
4.	21-C	Sunhera to Basi/Khekra	Basi/Khekra to Sunhera
5.	34-C	Saroorpur Kalan to Gaadhi	Gaadhi to Saroorpur Kalan
6.	35-C	Saroorpur Kalan to Sujra	Sujra to Saroorpur Kalan
7.	43-C	Irdispur to Badka	Irdispur to Badka
8.	50-C	Baoli to Latifpur to Sabha Kheri	Sabha Kheri to Baoli to Latifpur
9.	67-C	Ramala to Budhpur	Budhpur to Ramala
10.	72-C	SH-57 to Ailum	Ailum to SH-57
11.	82-C	PanjaKhara to Jasala	Jasala to PanjaKhara
12.	87-C	Lilion to Balwa	Balwa to Lilion
13	93-C	Gohrani to Karodi	Karodi to Gohrani
14.	103-C	Raseedgarh to Hararfatehpur	Hararfatehpur to Raseedgarh
15.	110-C	Ambeta YakubPur to Jalabad	Jalabad to Ambeta YakubPur
16.	122-C	Tipra to Sambhalkheri	Sambhalkheri to Tipra
17.	133-C	Jhandera to Nalhera	Nalhera to Jhandera
18.	136-C	Chunneti to NainKhera	NainKhera to Chunneti
19.	140-C	Fatehpur to Mavikhurd	Mavikhurd to Fatehpur

2.2 Data Collection

GPS locations of unmanned railway level crossings on Shahdra to Tapri route were collected by Trimble Juno SB as shown in Fig. 3. The unmanned railway characteristics data collected include level crossing number, name, chainage, division, major section, block section, latitude and longitude, type, number of tracks, gate width, station limit, track alignment, whistle boards presence, track gradient, visibility up and down and Train Vehicle Unit (TVU), road crossing unmanned crossing type, road connecting village or town or city, distance of gate posts form centerline of track, no of lanes, speed breaker distance from centerline of track, stop board presence, visibility of road up and down. Accident statistics are stored and analyzed from year 2008 to 2013.

Fig. 3. GPS location data collection at unmanned railway crossings selected for the study.

2.3 Creating a Spatial Map of Railway Line Network

The spatial map creation is done by first digitizing the different parts of Shahdra-Shamli-Tapri railway route using the Arc GIS 9.3 software. The buffer was created of 6 km around the railway line network covering the all the input features inside it. The spatial map consisted of different GIS layers, such as railway line, railway line buffer, unmanned railway level crossings (accidental/non-accidental), villages, stations, roads crossing the unmanned railway level crossings. Unmanned level crossings (Fig. 4) that are being stored as black pushpins. The railway track are stored as rail-road sign, roads are stored as red path and villages as polygon features are shown as light brown polygons. The railway stations are stored as green flags.

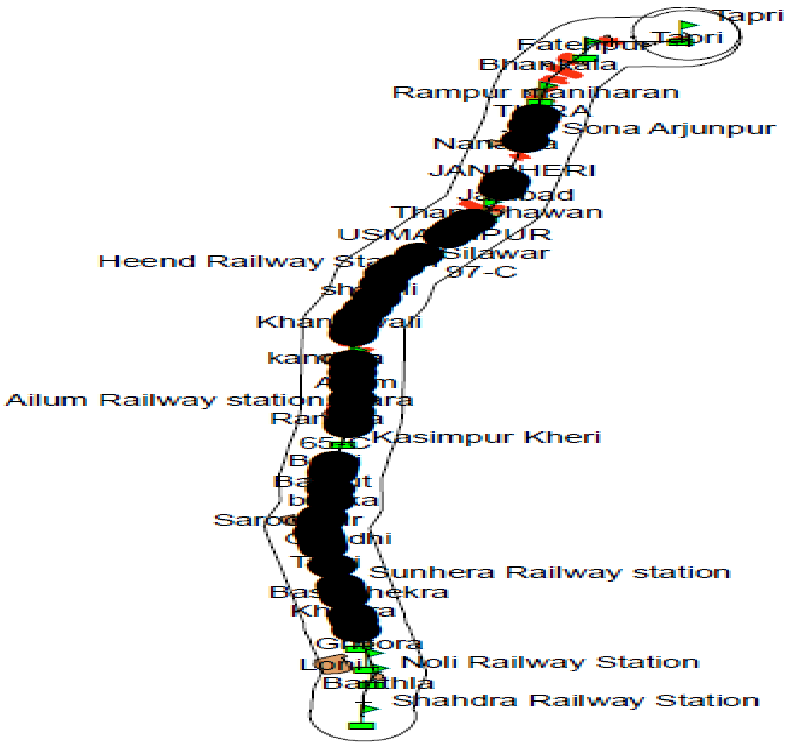

Fig. 4. Spatial map of railway line network from Shahdra-Shamli-Tapri railway route

2.4 Spatial Map Attribute Data Storage

The attribute data has been associated to the spatial map. The attribute data of all unmanned railway level crossings on Shahdra-Shamli-Tapri railway route viz. are attached to each unmanned railway level crossings.

2.5 Query Analysis of Unmanned Railway Level Crossings

The query analysis of the spatial map is done by firing a query based on some predefined condition on attribute data of unmanned railway level crossings. Therefore it results in the identification and selection of the particular unmanned railway level crossings satisfying the particular predefined query firing condition. The following query statement has been used to identify the accidental unmanned railway level crossings (Fig. 5).

Select * FROM unmanned railway level crossings (Shahdra-Tapri Railway Route) WHERE "Accidents">0

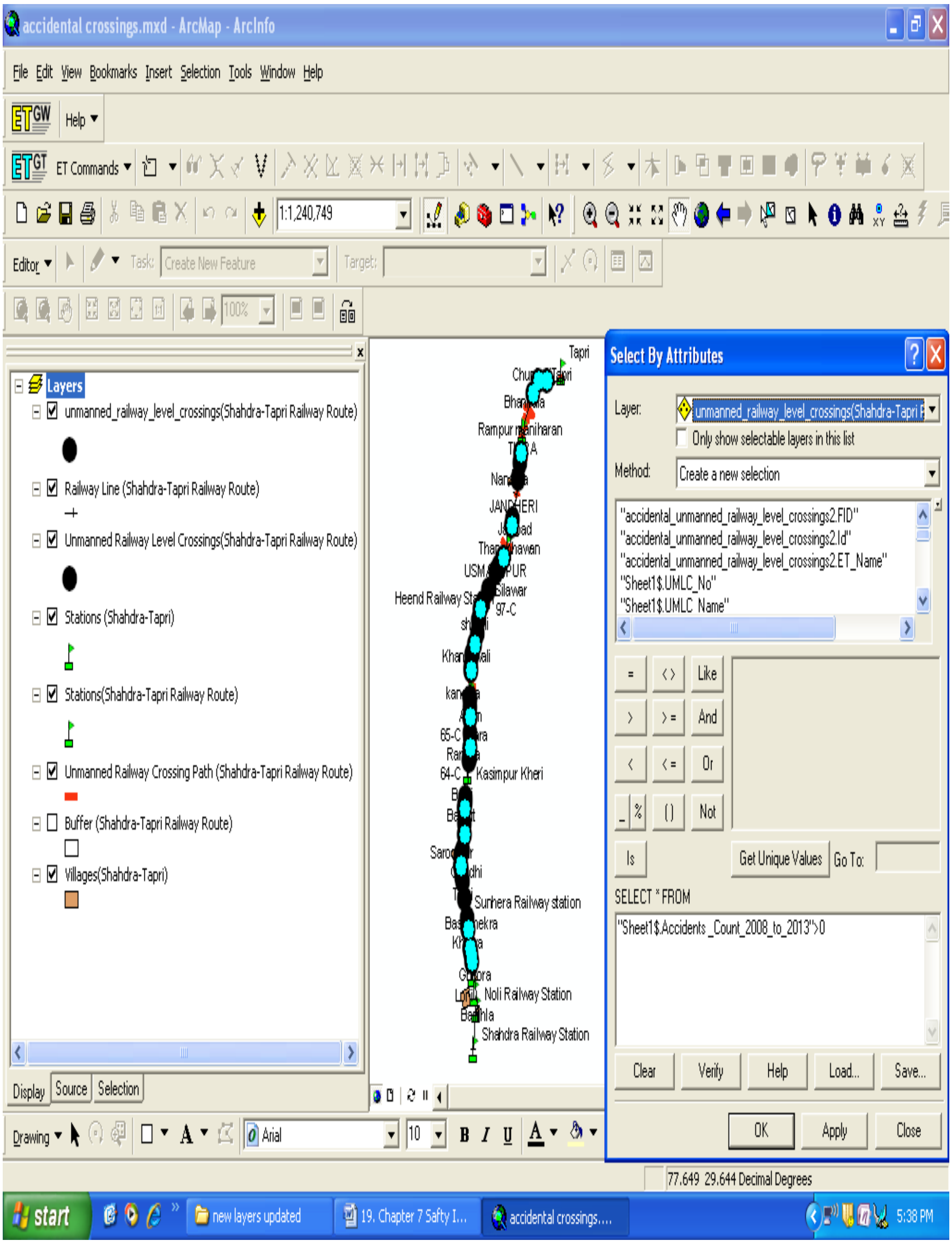

Fig. 5. Query analysis of accidental unmanned railway level crossings

Out of unmanned railway level crossings 19 unmanned railway level crossings viz. 14-C, 16-C, 17-C, 21-C, 34-C, 35-C, 43-C, 50-C, 67-C, 72-C,82-C, 87-C, 93-C, 103-C, 110-C, 122-C, 133-C, 136-C and 140-C were found to be accidental unmanned railway level crossings. The frequently accidental unmanned railway level crossings of spatial map are depicted in 'cyan' colour. The attribute data of 19 accidental unmanned railway characteristics data collected by Information aand Communication Technology (ICT) and field data collection viz. level crossing number, name, chainage, division, major section, block section, latitude and longitude, type, number of tracks, gate width, station limit, track alignment, whistle boards presence, track gradient, visibility up and down and TVU (2008-2014), road crossing unmanned crossing type, road connecting village or town or city, distance of gate posts form centerline of track, no of lanes, speed breaker distance from centerline of track, stop board presence, visibility of road up and down. Accident statistics are stored and analyzed from year 2008 to 2013.

Table 2. Attribute table of attached to spatial map

Attributes of umlc5

FID	UMLC_No	UMLC_Name	from_Chainage(km)	to_Chainage (km)	State	Division	Major_Section	Block_Section
0	14-c	Main	18/4	18/5		Delhi	Shahdra-Tapri(DSA-TPZ)	Noli Delhi-Tapri (NO-KEX)
1	16-c	Kharkhari	20/1	20/2		Delhi	Shahdra-Tapri(DSA-TPZ)	Noli Delhi-Tapri (NO-KEX)
2	17-c	Kharkhari	21/0	21/1		Delhi	Shahdra-Tapri(DSA-TPZ)	Noli Delhi-Tapri (NO-KEX)
3	21-c	Sunhera	25/1	25/2		Delhi	Shahdra-Tapri(DSA-TPZ)	Khekra-Baghpat (KEX-BPM)
4	34-c	Soranpur	38/1	38/2		Delhi	Shahdra-Tapri(DSA-TPZ)	Baraut- Baghpat (BTU-BPM)
5	35-c	Canal	38/4	38/5		Delhi	Shahdra-Tapri(DSA-TPZ)	Baraut- Baghpat (BTU-BPM)
6	43-c	Badka	44/8	44/9		Delhi	Shahdra-Tapri(DSA-TPZ)	Baraut- Baghpat (BTU-BPM)
7	50-c	Baoli	50/1	50/2		Delhi	Shahdra-Tapri(DSA-TPZ)	Baraut-Quasimpur Kheri (BTU-KPKI)
8	67-c	Main	62/8	62/9		Delhi	Shahdra-Tapri(DSA-TPZ)	Quasimpur Kheri -Baraut(KPKI-BTU)
9	72-c	Allum	68/7	68/8		Delhi	Shahdra-Tapri(DSA-TPZ)	Quasimpur Kheri-Kandhla(KPKI-KQL)
10	82-c	Khandrawali	78/8	78/9		Delhi	Shahdra-Tapri(DSA-TPZ)	Kandhla-Shamli (KQL-SMQL)
11	87-C	By-pass	84/0	84/1		Delhi	Shahdra-Tapri(DSA-TPZ)	Kandhla-Shamli (KQL-SMQL)
12	93-c	Silwas	91/1	91/2		Delhi	Shahdra-Tapri(DSA-TPZ)	Shamli-Heend(SMQL-HD)
13	103-c	ThanaBhawan	103/8	103/9		Delhi	Shahdra-Tapri(DSA-TPZ)	Heend-ThanaBhawan(HD-THBN)
14	110-c	Delhi Sahranpur	111/1	111/2		Delhi	Shahdra-Tapri(DSA-TPZ)	Thanabhwan-Nanauta(THBN-NNX)
15	122-c	Amola	125/9	125/10		Delhi	Shahdra-Tapri(DSA-TPZ)	Rampur Maniharan-Nanuta (RPMN-NNX)
16	133-c	NH	138/9	139/0		Delhi	Shahdra-Tapri(DSA-TPZ)	Rampur maniharan-Manani (RPMN-MNZ)
17	136-c	Delhi Road	142/1	142/2		Delhi	Shahdra-Tapri(DSA-TPZ)	Manani-Tapri (MNZ-TPZ)
18	140-c	Sahranpur-Bargaon	144/7	144/8		Delhi	Shahdra-Tapri(DSA-TPZ)	Manani-Tapri (MNZ-TPZ)

2.6 Data Base Retrieval of Information of Unmanned Railway Level Crossings

The data base of the accidental unmanned railway level crossings from Shahdra-Shamli-Tapri have been associated as an attribute with their respective road section in the spatial map, created in GIS.

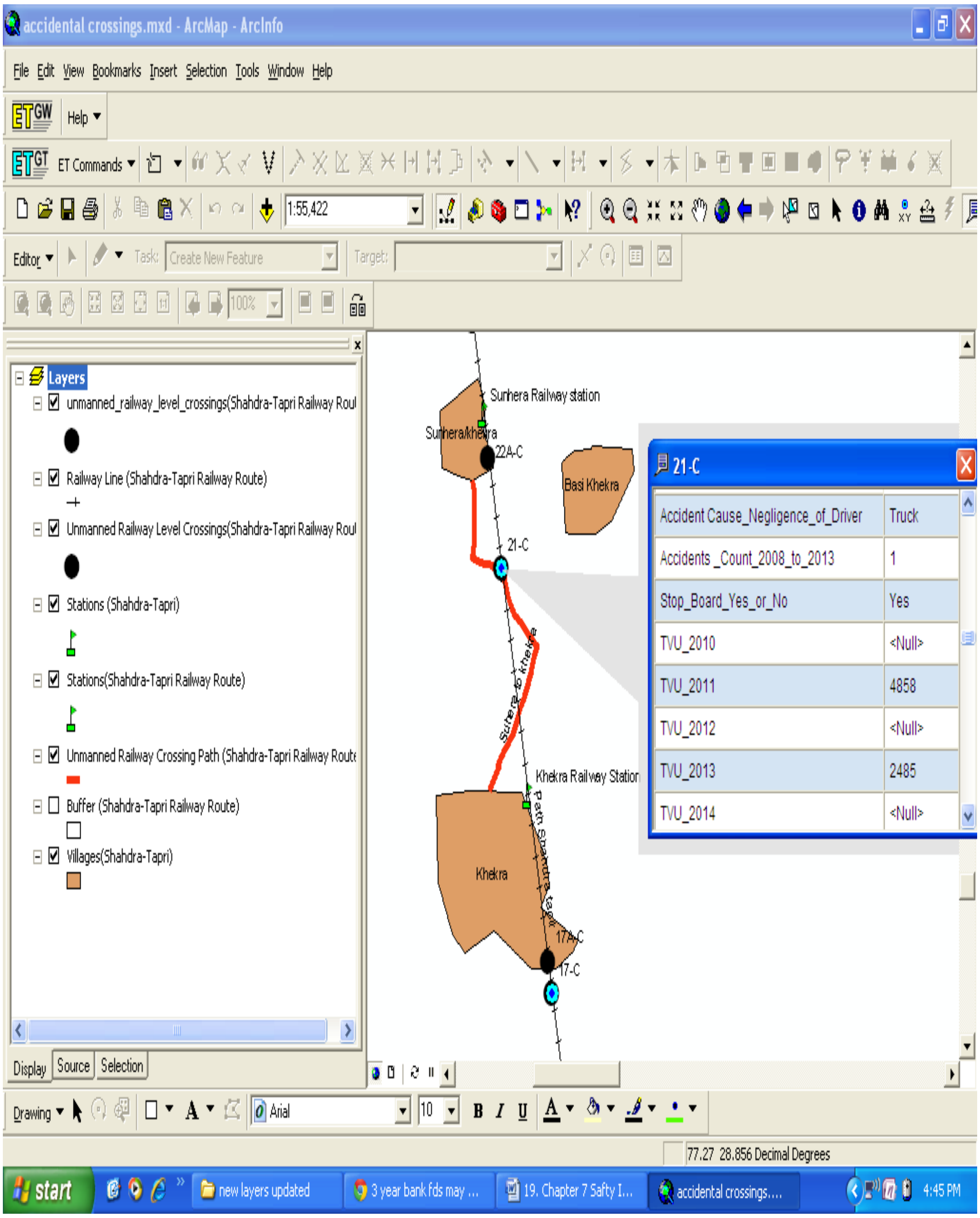

Fig. 6. Data base retrieval of information of unmanned accidental crossings

In order to decrease the time of searching in attributes tables directly about the different characteristics details of a particular unmanned railway level crossing on spatial map. Thereby, it is done clicking 'HTML popup' tool of Arc GIS of spatial map of unmanned railway level crossings. Fig. 6 shows all attributes of the unmanned railway level crossing 21-C. Again attributes of other unmanned railway level crossings can be just by clicking on the unmanned railway level crossings.

The use of ICT for data information system of unmanned railway level crossing characteristics is expected to help in developing a warning system for the users beforehand providing the characteristics of unmanned railway level crossings. The users can get alert about by understanding the different characteristics of the unmanned railway level crossings. This can help to avoid collision of road users with the train at unmanned railway level crossings by using already stored unmanned railway level crossings characteristics, accidents statistics data, while approaching the particular unmanned railway level crossing.

3. Accident Analysis

The accident analysis of nineteen unmanned level crossings is done (Fig. 7). It was observed that from year 2008 to 2013, the highest number of accidents were observed in year 2010 and 2013 at UMLC 14-C,16-C, 17-C,21-C,34-C,35-C,67-C,72-C,87-C,122-C and 133-C.The lowest accidents were observed in year 2008 at UMLC 136-C.

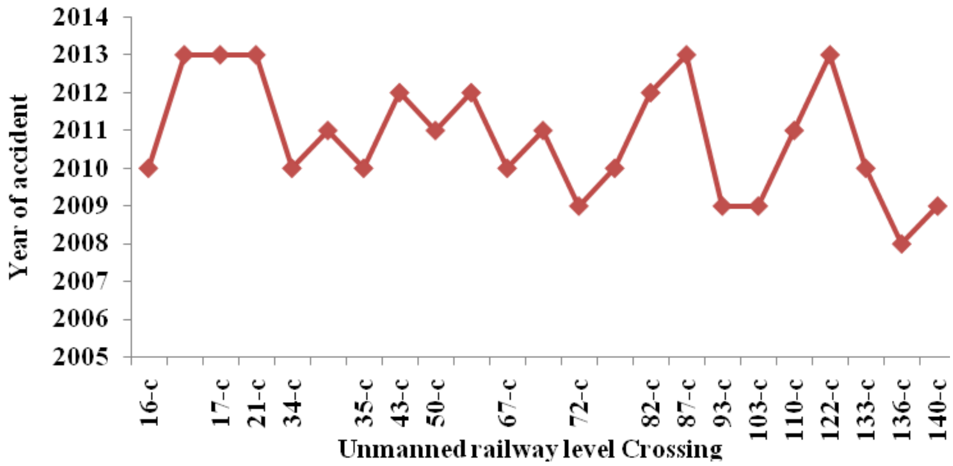

Fig. 7. Unmanned railway level crossing with respect to year of accident

4. Traffic Volume Analysis

The traffic volume analysis (Fig. 8) shows that –

1. The direction1 traffic volume is about 26.09% (approx.) higher than the average traffic volume. In case of direction2 the traffic volume is about 24.12 % (approx.) higher traffic volume than the average traffic volume.
2. The unmanned level crossing 17-C has highest traffic volume in direction1 and 16-C in direction2. The traffic volume of 17-C in direction1 is 48.34% (approx.) higher than the average traffic volume. Again, in direction2 the unmanned level crossing 16-C traffic is 49.59% (approx.) higher than the average traffic volume.
3. The unmanned level crossing 133-C has lowest traffic volume in direction1. 140-C was observed to have lowest traffic volume in direction2. In direction1 133-C has 46.4 % (approx.) and 140-C in direction2 has 54.6 % (approx.) lower traffic than the average traffic volume respectively.

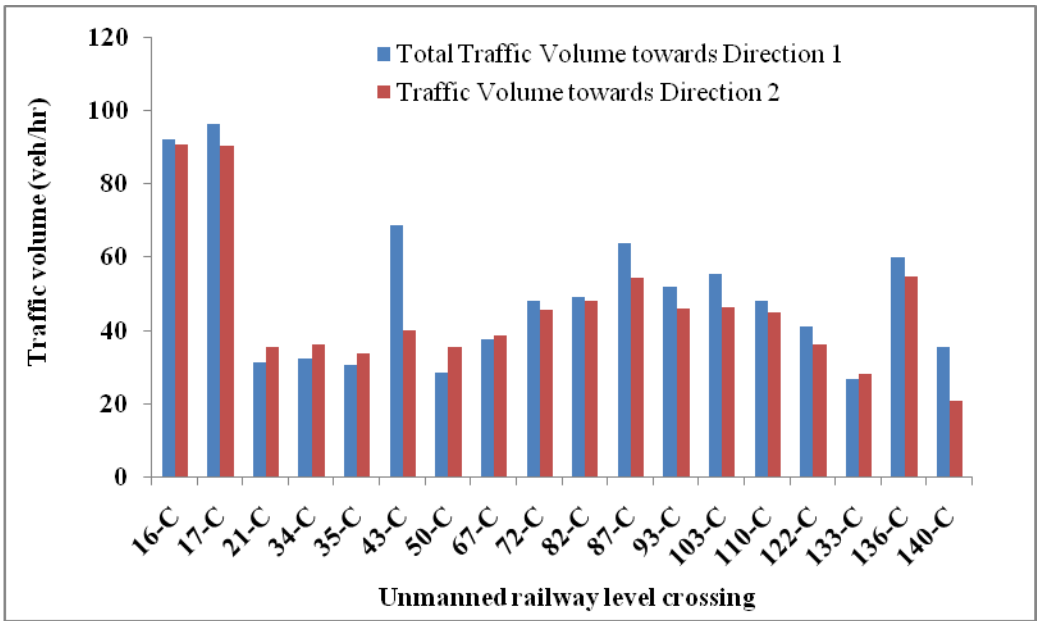

Fig. 8. Unmanned level crossing with respect to traffic volume.

5. PHF Analysis

The PHF analysis (Fig. 9) shows that –

1. Out of 19 unmanned level crossings 47.3% (approx.) unmanned level crossings has higher PHF than the average PHF in both directions.
2. The unmanned level crossings 110-C and 103-C has highest PHF in direction1 and direction2 respectively.
3. The lowest PHF being observed at unmanned level crossings 35-C in both directions.

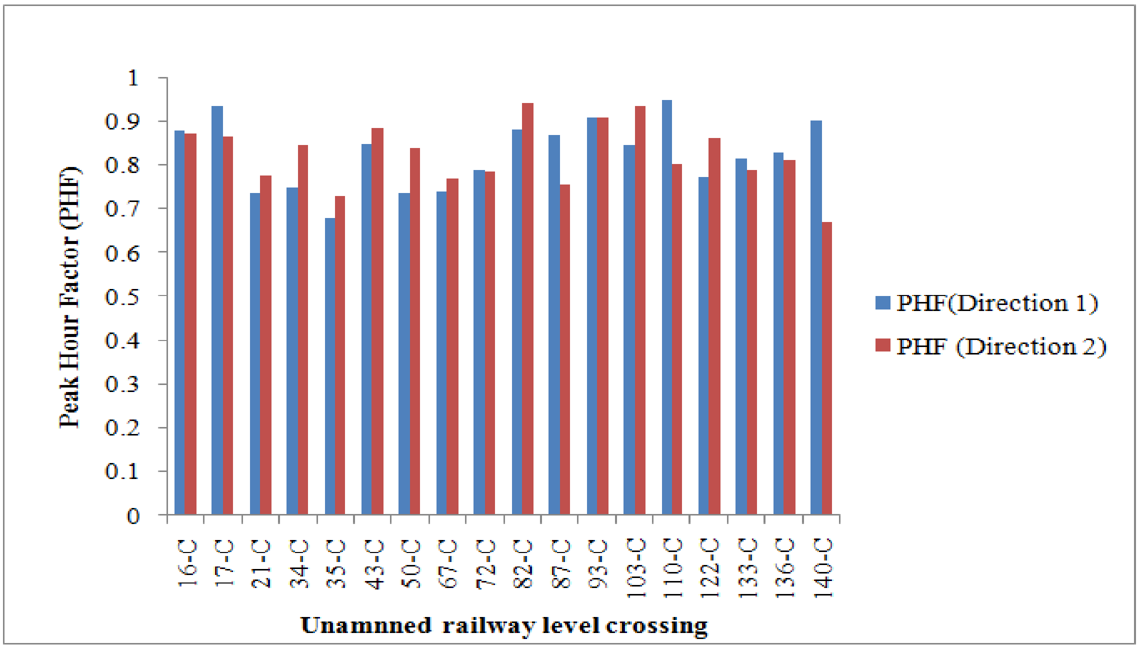

Fig. 9. Unmanned level crossing number with respect to PHF

6. ADT Analysis

The PHF analysis (Fig. 10) shows that –

1. ADT of 11 unmanned level crossings out of 19 unmanned level crossings is higher than the average ADT in both directions.
2. The unmanned level crossing 17-C has highest ADT in direction1 and 16-C has highest ADT in direction 2.
3. The unmanned level crossing 133-C has lowest ADT in direction1 and 140-C has lowest ADT in direction 2.

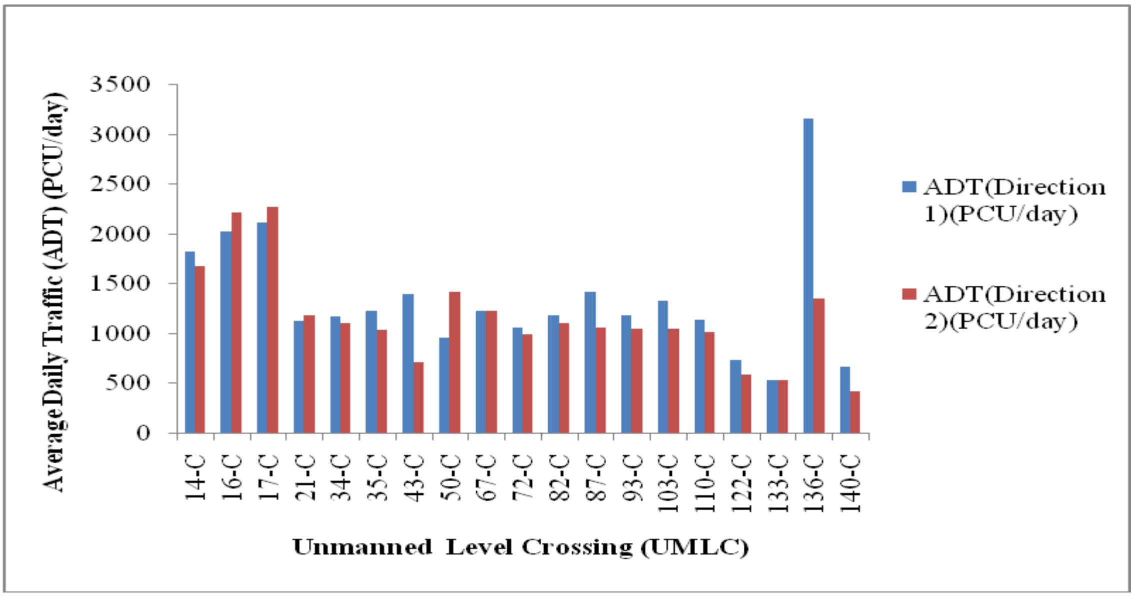

Fig. 10. Unmanned level crossing number (UMLC) with respect to ADT

II. Conclusions

The following conclusions have been drawn based on the present study-

1. The Shahdra-Shamli-Tapri railway route has a total of 71 unmanned railway level crossings along the route; however the GPS data and video data were collected only for 19 unmanned level crossings. The selection of 19 unmanned level crossings was on the basis of the number of accidents at these crossing.
2. Parameters viz. unmanned railway level crossing name and number, from_chainage, to_chainage, state, division, major section, block section, latitude and longitude, type, number of tracks, gate width, station limit, track alignment, whistle boards presence, track gradient, visibility up and down and TVU, road crossing unmanned level crossing type, road connecting village or town or city, distance of gate posts form centerline of track, approach road gradient, track gradient, single or multiple road, speed breaker distance from crossing, stop board presence, visibility of road up and down, duration gate closure, date of accident, accident cause negligence of driver, accidents count from year 2008 to 2013, train vehicle unit from year 2009 to 2012 were collected for 19 unmanned level crossings with the help of ICT based system and published reports and organization i.e. railway engineering section, Shamli, India
3. Three parameters i.e. unmanned railway level crossing number, accident statistics, traffic volume were onsidered to be the most important for the study, and therefore were analyzed to assess the problems in specific unmanned railway level crossings.
4. The spatial map of Shahdra-Shamli-Tapri railway line network with railway line, railway line buffer, unmanned railway level crossings (accidental/non-accidental), villages, stations, roads crossing the unmanned railway level crossing is created.
5. The attribute data viz. geometric features, road characteristics, traffic control characteristics, unmanned railway level characteristics, environmental conditions, accident data (2009-13), TVU survey (2009-2014) etc. of a spatial map is stored by just clicking on the particular unmanned railway level crossing.
6. The query analysis of unmanned railway level crossings helped in data base retrieval of information of unmanned railway level crossings.
7. In general it is observed that-

i. Unmanned railway level crossing number 17-C and 16-C had highest total traffic volume and ADT in direction 1 and direction 2 respectively. 133-C and 140-C had lowest total traffic volume and ADT in direction1 and direction2 respectively.

ii. The unmanned level crossings 93-C and 82-C has highest PHF in direction1 and direction2 respectively. The lowest PHF was observed at unmanned level crossings 35-C and 140-C in direction1 and direction2 respectively.

iii. Year 2010 and 2013 were observed to have highest number at 14-C, 16-C, 17-C, 21-C, 34-C, 35-C, 67-C, 72-C, 87-C, 122-C and 133-C. Therefore, these unmanned railway level crossing are found to be critical and needs further detailed study.

The use of ICT for data information system of unmanned railway level crossing characteristics is expected to help in developing a warning system for the users beforehand providing the characteristics of unmanned railway level crossings. The users can get alert about by understanding the different characteristics of the unmanned railway level crossings. This can help to avoid collision of road users with the train at unmanned railway level crossings by using already stored UMLC characteristics, accidents statistics data, while approaching the particular unmanned railway level crossing. The total traffic volume, highest peak hour factor and average daily traffic analysis of unmanned level crossings were also done in this study.

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