Road Accident Data Collection Management and Analysis System- Developing a Suitable Framework for Varanasi City

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Abstract: The numbers of road accident fatalities are alarmingly high in Varanasi city of India. Accidents are multi-factor events which are clustered at a place due to various factors. In order to understand pattern of accidents and therefore reduce their number and severity, need of reliable and comprehensive road accident database and analysis system is obligatory. However in existing system, accident data is recorded by police department with other crime records. Limited information's are collected on paper records to fulfill legal requirements and could not be utilized for detailed accident analysis. A framework for road accident data collection management and analysis system is proposed which comprises of GPS, GIS and Oracle system. In order to collect comprehensive data for better analysis, a new accident report form is proposed which includes all factors responsible for accidents. This would lead to detailed analysis, which enables superior road safety intervention and performance monitoring.

Keywords: Road accident data analysis system, Police report, Road safety, GIS, Safety management

1. INTRODUCTION:

Road accidents are considered to have most negative impact on development of transportation infrastructure. According to WHO's Global status report, middle income countries suffered the most in terms of road accident fatalities. 80% of road traffic deaths occur in middle-income countries which constitute of 72% of world's population but only have 52% of registered vehicles (WHO, 2013). Situation is much more troublesome for India, since it has highest number of fatalities caused due to road traffic accidents. Varanasi is one of the major cities of India which is suffering from alarmingly high annual road accidents rate. Although, numerous efforts have been made by government in order to improve road safety, however, Varanasi lacks a comprehensive road accident database management and analysis system. It is known that, collection of accurate, quality and reliable accident data is essential in order to comprehend factors responsible for road accidents (Lyon et al., 2008). Accident data is critical to monitor and analyze the effectiveness of road safety measures introduced by road authorities. An advance accident data collection, management and analysis system is needed to strategize road safety initiatives and inculcate improved understanding of road accident causation.

Although there is already an existing system in Varanasi to capture road accident data, it is a manual paper record system suffers from several issues especially with quality and quantity of reliable data. Captured accident data were not fully utilized for performance monitoring because, existing system is unable to perform extensive and accurate analysis on road safety. Hence accident data is often kept just for record keeping purposes rather than utilizing it as source of intelligence. Hence, a new system is needed for reliable data collection and effective accident management and analysis for Varanasi. This study proposed framework which collectively uses GPS and GIS to reference an accident location on GIS map using portable mobile data terminals (MDT). This study is first of its kind for this region which addresses issues regarding data collection, database design, data retrieval and detailed accident analysis and visualization of obtained results. This system is expected to be beneficial for engineers, planners, policy makers, and researchers at local, regional and national level.

2. PRESENT SCENARIO AND NEED FOR ROAD ACCIDENT DATABASE MANAGEMENT AND ANALYSIS SYSTEM IN VARANASI

In this study, several police stations of Varanasi were visited and various police records were analyzed. In Varanasi, road accident data are collected by police department under various clauses stated in Indian Penal code (IPC) as specified in Table 1. All accidents whether it is fatal, grievous, minor or property damage only, are required to be investigated by police department at the time and location of accidents. There is no separately maintained record for accidents and they are recorded along side with other crime in First Information Report (FIR) records. No detailed electronic record of accidents is maintained and all accidents are currently recorded manually on FIR records. There is absence of proper format to record accident data and most of the information is written long hand. Only limited amount of data is recorded, which resulted in incomplete and inaccurate data. Since no GPS devices are provided to police officers, road accident locations therefore were described in words general terms with often name of road and nearby landmark. In case of long roads, it impossible to accurately determine the location at which accident actually took. In some cases, the distance of accident location was given with respect to police station without providing any direction. Important factors such as road geometry, road surface characteristics and road environment are also found to be absent. Other than that, absence of condition, collision diagram or any photographs of accident site is observed.

Table 1: IPC Clauses under which accidents are registered in Varanasi

IPC Clause	Remarks
IPC 279	Applicable for rash driving
IPC 337	Minor accidents register under this clause
IPC 338	Grievous accidents register under this clause
IPC 304(a)	Fatal accidents register under this clause
IPC 427	Property damage only accidents register under this clause.

There is also no formal exchange of data between police department and other agencies except for some high level reporting to higher ministry which have a requirement to produce periodic statistics. Some amount of under reporting of minor incidents was also observed, which showed the negligence of people towards reporting of minor incidents. Due to limited

quality and quantity of information in accident databases, detailed analysis of accidents and determination of responsible factors for them is not possible by traffic engineers. Therefore the current system was found to be inaccurate and inconsistent in terms of data collection and management and needed to be updated.

3. INTERNATIONAL PRACTICES IN ACCIDENT DATA COLLECTION AND ACCIDENT DATABASE MANAGEMENT AND ANALYSIS SYSTEM

3.1 Accident data collection

Road accidents by can be reduced by understanding the pattern of their causation and applying potentially viable area-specific countermeasures. Hence, it is mandatory to identify the factors associated with them by developing a comprehensive database. As it is previously discussed, no exhaustive format is currently exists which covers all the associated factors with the accidents. Hence, survey of commonly recorded causative factors of accidents in 20 countries (including India), as defined in their methodology was done based on existing literature (CARE, 2006; Jahl et al., 2006; Luoma and Sivak, 2007; NHTSA, 2004; Tessmar, 2002). The causative factors stated in databases of 6 countries namely, China, Germany, India, Japan, Korea and USA along with 14 European countries associated with CARE (Community Road Accident Database) were compiled. CARE is a road accident database which includes 14 European countries namely; Austria, Belgium, Denmark, France, Finland, Greece, Italy, Ireland, Luxembourg, Portugal, Sweden, Spain, Netherlands, and United Kingdom (CARE, 2006; Luoma and Sivak, 2007). The data is presented in tabular form (Table 2) and categorized in various factors which include accident related factors, driver related factors, occupant related factors, other road user related factors and vehicle related factors. Apart from this, various factors influencing road accidents are also determined on based on previous studies around the globe (Table 3).

3.2 Accident database management and analysis system

In India, in most of the places record management is done manually and large records are stored in form of hard copies which are difficult to store and maintain. Many countries in the world has already established traffic and accident managements system or working over it. BOBSTAR system of U.K calculates average numbers of accident on a particular site which enables engineer to determine blackspot or high accident locations on the roads. HSS an American software package can generate collision diagrams. TRL's MAAP was developed can display accident plots on digitized map and can perform cluster analysis. Different weights can be applied to targeted areas to provide realistic scenario (Baguley, 2001). Road Crash and Victim Information System (RCVIS)developed by Cambodian government utilize GPS equipped police vehicle to provide accurate, continuous and compressive information on road injuries and victims. Data provided by RCVIS act as a reference for all road safety stakeholders (NRSC, Ministry of Health, WHO, GRSP) to develop strategies and proposals, for the Cambodian road safety sector (Sem & Ou, 2010). In 2003, government of Argentina established "Injury Sentinel Surveillance System" which gathers injury data from emergency departments of hospitals using prescribed form and can compare data among different participant hospitals over a period of time In 2008, Tamil Nadu a southern Indian state has implemented Road Accident Data Management System (RADMS) in his 1350 police stations which is a GIS-GPS based database system. This system incorporates various accident data, vehicular data, and collision and driver details to generate various results using customized

queries. This can be utilized for corridor analysis, monitor site analysis and safety and benefit utilization (Vigneswari & Minachi, 2013).

Table 2: Various commonly recorded causative factors for road accidents in various countries

Factor Category	Factor type	China	Germany	Japan	Korea	USA	CARE	India
Accident	Accident type	✓	✓	✓	✓	✓		✓
	Number of person killed	✓	✓	✓	✓	✓	✓	✓
	Number of person injured	✓	✓	✓	✓	✓	✓	✓
	Number of pedestrian	✓	✓	✓	✓	✓	✓	✓
	Number of bicyclist	✓	✓	✓	✓	✓	✓	✓
	Year	✓	✓	✓	✓	✓	✓	✓
	Date	✓	✓	✓	✓	✓	✓	✓
	Time	✓	✓	✓	✓	✓	✓	✓
	Type of Vehicle	✓	✓	✓	✓	✓	✓	✓
	Number of Vehicles	✓	✓	✓	✓	✓	✓	✓
	Class of Road		✓	✓	✓	✓	✓	✓
	Environment (Urban/Rural)		✓	✓	✓	✓	✓	✓
	Road Condition	✓	✓	✓	✓	✓	✓	✓
	Light Condition	✓	✓	✓	✓	✓	✓	✓
	Weather Condition	✓	✓	✓	✓	✓	✓	✓
	Speed Limit		✓	✓	✓	✓	✓	
Vehicle	Vehicle type	✓	✓	✓	✓	✓	✓	✓
	Vehicle identification no.			✓	✓	✓		
	Vehicle model year	✓	✓	✓	✓	✓	✓	
	Travel speed estimate	✓		✓	✓	✓		
	Occupants in vehicle	✓	✓	✓	✓	✓		
	Number of people killed in vehicle	✓	✓	✓	✓	✓		✓
	Maneuver	✓	✓	✓	✓	✓	✓	
	Pedestrian action	✓	✓	✓	✓	✓	✓	
Driver	Gender	✓	✓	✓	✓	✓	✓	✓
	Age or date of birth	✓	✓	✓	✓	✓	✓	✓
	License Compliance	✓	✓	✓	✓	✓	✓	
	Alcohol test result		✓	✓	✓	✓	✓	✓
	Violation	✓	✓	✓	✓	✓	✓	
	Seat belt use			✓	✓	✓		
	Medical cause of death			✓				
Occupant	Gender	✓	✓	✓	✓	✓	✓	✓
	Age or date of birth	✓	✓	✓	✓	✓	✓	✓
	Use of seat belt	✓		✓	✓	✓	✓	
	Seat location of person killed			✓		✓	✓	
	Medical cause of death	✓		✓				
Other road user related factors	Gender	✓	✓	✓	✓	✓	✓	✓
	Age or date of birth	✓	✓	✓	✓	✓	✓	✓
	Alcohol test result		✓	✓	✓	✓		✓
	Violation	✓	✓	✓	✓			
	Use of helmet		✓		✓			✓
	Medical cause of death	✓		✓				

Table 3: Various influencing factors on road accidents

Authors	Study Area	Influencing factors on road accidents
Valent et al., (2002)	Italy	Gender of driver, Vehicle type
Wang et al., (2002)	Australia	High speed, less sight distance, pedestrian conflict
Ghosh et al., (2004)	India	Vehicle type, age of driver, time of accidents
Chang and Wang (2006)	Taiwan	Vehicle type
Keay and Simmonds (2006)	Australia	Road surface conditions
Erdogan et al., (2008)	Turkey	High speed, carelessness, imprudence, successive curves
Pai (2009)	UK	Rider age, weather type, right of way violation, heavy vehicles
Smolensky et al., (2011)	USA	Drowsy driving
Krishnamurthy, (2011)	India	Fault in geometrical design of pavements, Absence of speed limit signs
Azadeh et al., (2016)	Iran	High speed, improper maneuvering, violent driving, lack of seatbelts

4. PROPOSED METHODOLOGY

The suggested present methodology is derived not only on the basis of existing global literature on database management systems, but also on analysis of the existing scenario of accident data collection system in Varanasi. Its structure consists of five major components,

1. Creating an optimum database collection methodology
2. Database structure
3. Web oriented user interface
4. Dissemination of data using Web GIS

Brief description of each component is given below.

4.1 Creating an optimum database collection methodology

In Varanasi, traffic accident data can be obtained from the two sources; primary and secondary. Primary sources consist of police records and hospital records. Secondary sources consist of Non Governing Organizations (NGO) and media reports. Out of the aforesaid sources, police records are the most elaborate form of reporting amongst all. Police usually maintains a record in form of First Information Report (FIR), in which accidents are reported under various clauses of Indian Penal Code (IPC) along side with other crimes (Table 1). Road accidents happening on the roads are usually caused due to multiple factors acting simultaneously. However, as it was discussed earlier, details regarding pavement and roadway conditions, vehicular conditions, accident description and driver details are lacking in Varanasi. This is due to absence of a well defined accident data collection form which incorporates all the details which are necessary for detailed accident analysis such as black spot, area and cluster analysis.

A study was made to determine essential parameters that are needed to be collected for not only for legal reasons but also carry out detailed accidental analysis as specified above. It is necessary that all parameters should be properly grouped and easily understandable by investigative agencies. An accident report form is proposed to consider every significant detail which can be utilized by different stakeholders at local, regional and national levels. This form could be implemented in electronic format and similar to existing practices a hardcopy of it can also be printed for record keeping purposes.

The data is grouped under various sections and a part of this data will be confidential in nature. However, non-specific data such as location details, road details, environmental details and vehicle details can be provided to traffic engineers. They could utilize this data to monitor the performance of road network and identify and rectify any inherent faults. Hence an independent comprehensive database consists of sub-set of collected details should be maintained. This will enable authorities to achieve subsequent reduction in traffic accidents.

Another major concern is the identification of exact location of accident. The most accurate and effective way to determine exact location of accident is by simultaneous use of GPS receiver and GIS map of Varanasi. A portable GPS receiver along with a mobile data terminal (MDT) which consists of georeferenced map of Varanasi should be provided to police officer. With the help of GIS map, accurate coordinates of accident location can be pin pointed, once the officer reaches the accident location. This would not only can provide accuracy but also can relate accident locations with surrounding features such as road name, intersection name and nearby landmark. The details of accidents should be stated in language of familiarity of officer and since majority field of details are stated in terms of check marks, it would be easy and less time consuming to fill. Proper digital camera and electronic diagramming tool can be assigned to officer to capture photographs of site and to draw collision diagrams respectively. All data should be efficiently transferred to local police database server and should be further checked and validated by quality assurance technicians. After conducting all the quality checks final data can be uploaded to central police server.

ACCIDENT REPORT FORM

1) GENERAL DETAILS:

1.1) FIR Number: **1.2) Under Section (check whatever applicable):** IPC 279 ☐

IPC 337 ☐ IPC 338 ☐ IPC 304 (A) ☐ IPC 427 ☐ if others (specify)

1.3 Digital ID number **1.4) Date:** **1.5) Day:**

1.6) Police station: **1.7) Block/Village:** **1.8) Town:**

1.9) District: **1.10) State:**

1.11) Accident Severity: Fatal ☐ Grievous ☐ Minor ☐ Non injury ☐ Property damage ☐

2) ROAD DETAILS:

2.1) Name of road: **2.2) Type of Area:** Rural ☐ Urban ☐

2.3) Road type: NH ☐ SH ☐ MDR ☐ ODR ☐ VR ☐ **2.4) Road width:**

2.5) Pavement type: Bituminous ☐ Concrete ☐ Other (specify) **2.6) Speed limit:**

2.7) Road Geometry: Junction ☐ Mid-Block ☐ Curve ☐ Narrow Bridge ☐ Other (Specify)

3) VEHICLE/DRIVER DETAILS:

3.1) Type of Accident: Head-On ☐ Head-Tail ☐ Right Angle ☐ Side Swipe ☐ Overturn ☐

Hit Pedestrian ☐ Hit stray animal ☐ Hit road side object ☐ Hit tree ☐ other (specify)

3.2) Vehicle type: Motor Bike/ Scooter ☐ Auto Rickshaw ☐ Car/Jeep/Van ☐ Cycle Rickshaw ☐

Bicycle ☐ Mini Bus ☐ Bus ☐ Light Goods Vehicle ☐ Heavy Goods Vehicle ☐ Tractor/ Trailor ☐

Animal Drawn ☐ Other (specify):

3.3) Vehicle Maneuver: Straight ☐ Turning Left ☐ Turning Right ☐ U-Turning ☐ Sudden Stopped ☐

Overturning (same side) ☐ Overturning (wrong side) ☐ Reversing ☐ Parked on road ☐ Contra flow ☐

Other (specify):

3.4) Driver's Age **3.5) Driver's Sex:** Male ☐ Female ☐ **3.5) Driving License Number**

3.6) Use of seat belt/ Helmet Y ☐ N ☐ **3.7) Alcohol consumption** Y ☐ N ☐

3.7) Vehicle damage (if any):

4) ENVIRONMENTAL DETAILS:

4.1) Road surface condition: Dry ☐ Wet ☐ **4.2) Lighting conditions:** Good ☐ Poor ☐

4.3) Road Surface Quality: Good ☐ Pot holed ☐ Improper Camber ☐ Rutting ☐ other (specify) ☐

4.4) Presence of medians: Y ☐ N ☐ **4.5) Presence of Footpath:** Y ☐ N ☐

4.6) Cause of accidents: Defect in road surface ☐ overloading ☐ shoulder drop ☐ careless driving ☐

Alcohol intoxication ☐ fault of other driver /pedestrian ☐ poor lighting ☐ neglect of civic bodies ☐

Bad weather ☐ defect in mechanical condition of vehicle ☐ other (specify)

Figure1(a). Proposed accident report form

5) LOCATION DETAILS:

5.1) Nearest Landmark: | **5.2) Distance from nearest police station:**

5.3) Direction from nearest police station: | **5.4) Chainage from nearest Km stone:**

5.5) Location Coordinates: Latitude | Longitude

6) INJURY DETAILS:

6.1) Number of Fatalities: | **6.2) Number of Major injuries** | **6.3) Number of Minor injuries**

6.4) Names /Sex/Age of Fatal Victims:	Name	S	A

6.5) Names/Sex/Age of Major Injury Victims:	Name	S	A

6.6) Names /Sex/Age of Minor Victims:	Name	S	A

6.7) Details of Property damage accident

7) POLICE REPORT

8) PHOTOGRAPHS/COLLISION DIAGRAMS OF INCIDENT AND INCIDENT SITES

PHOTOGRAPH NUMBER	COLLISION DIAGRAM	**Brief description of photograph**

9) DETAILS OF INVESTIGATION OFFICER:

9.1) Name: | **9.2) Rank:**

9.3) Date of filing of report: | **9.4) Time of filing of report:**

9.5) Special remarks (if any) | **9.6) Signature of investigating officer:**

Figure1(b). Proposed accident report form (continued)

4.2 Database Structure

The proposed database structure consists of

1. Digitization of accident locations using Geographical Information System (GIS) software.
2. Integration of spatial and temporal attributes of registered accidents using GIS.
3. Storage of data in Oracle database.
4. Analysis of stored data.

The first step of creating a database structure is digitization of raw accident data collected during site visit of police inspectors. The raw data includes spatial (location details), temporal (time, date and month of occurrence) and other attribute data.

The next step is to develop a spatio-temporal database which should be integrated with attribute data. In order to ensure combined analysis, it is needed that a linkage should be

established between various datasets. This operation could be performed easily using GIS technology. GIS has ability to store, share and manage a huge amount of data. It not only can provide an interactive platform for data visualization and analysis, but also can provide graphical and non graphical outputs (Booth, 2004). GIS helps analyst to merge spatial and attribute data, geocode accident locations, calculate frequencies and rate of accidents and also calculate mean and standard deviation of accident rates (Liang et al., 2005). A digital accident map can be prepared and location of each accident point can be georeferenced and linked to a unique ID number. Any accident can be recognized by unique ID and described by its various attributes such as time, date and month of occurrence, vehicle involved, pavement condition, vehicle involved etc. All the information is stored against ID of each accident and can be managed using GIS. The linkage between spatial and temporal data is done on one to many basis, where entire dataset in linked by common ID allotted to them.

After the attainment of linkage, data should be stored in RDBMS-Oracle and should be linked to GIS. RDBMS is a program module which creates and manages a relational database. In this, users can store and manipulate data in manner consistent with a relational model (Pradhan et al., 2013). Linkage of RDBMS and GIS into a web based client service environment will allow management and visualization of variety of accident data. This would be helpful in adding any new category without any need to modify all the existing modifications. Spatial, attribute and temporal information would also be easily managed using RDBMS-Oracle in form of text, report, table and maps.

Majority of open access and proprietary GIS platforms has powerful query, relational and spatial analysis facilities which would allow numerous detailed accident analysis operations. These include road segment analysis, intersection analysis, density analysis, cluster analysis, proximity analysis, pattern analysis, spatial query analysis and spatial accident analysis modeling techniques. Numerous methods have been developed for point pattern analysis and for detecting black spots or high accident locations based on GIS software modules. These methods can be classified under two categories: a) methods which analyze first-order effects, which calculate the variation in mean value of process such as Kernel Density Estimation (K), quadrant count analysis etc; and b) methods which examine second-order effects that calculates spatial autocorrelation of points for spatial patterns like Moran's I Index, Geary C ratio and Getis-Ord Gi* statistics etc (O'Sullivan and Unwin, 2002). Identification of black spot will helpful in designing and implementing countermeasures to reduce accidents and improve road safety with a very small investment.

4.3 Web Oriented User Interface

There is serious problem regarding underreporting of minor incidents (minor injuries and property damages) due to lack of interest of people to deal various legal formalities. Due to underreporting, many high accident locations or black spots can be ignored which may responsible for minor accidents. Hence there is a need to incorporate civilian participation in analysis and detection of black spots without bothering them with legal formalities. Facilities to register minor incidents could be provided via World Wide Web. An additional database could be created based on users opinion which could be helpful to identify the locations which were ignored due to underreporting of data. To ensure the security of database, all users will have to register providing their mandatory details. This would help administration to identify the person reporting the incident. Access to database and feedback platform could

be provided via a user name and password. The data provided by the user will not directly input into database, but first verified by system administrator. The verified incident would be updated into existing database ensuring no repetition of same incident. Feedback form should be designed to be simple, interactive and it should also have an option to upload digital photographs of any incident or location.

4.4 Data Dissemination Using WebGIS

Online accident database is a viable platform for storage and dissemination of valuable data to all the stakeholders. Accident data and analysis of various results in form of tables and maps could be published online using WebGIS. Any standard internet browser could be utilized to create WebGIS environment and operations such as preparation of thematic maps, access to online database and visualization of various map attributes could be done. Combination of GIS and Internet could be very beneficial. GIS is helpful for storage and management of large amount of spatial and attribute data, whereas easy visualization and accessibility can be ensured using viable internet technology. Dynamic virtual visualization process using a web based platform can help to understand the spatio-temporal distribution of accidents and various factors affecting them. This would be helpful for various stakeholders to design various policies in order to limit road accidents using three “E’s” i.e. Engineering, Enforcement and Education.

6. CONCLUSION

Varanasi is one of the major Indian cities which suffer from alarming increase in road fatalities. To reduce the constant growth of number of casualties we have to carry out regular, in-depth analysis of pattern of accident and apply various cost effective countermeasures at target points. All this would require establishment of reliable and comprehensive road accident database management and analysis system. A review of existing road accident data collection practices in Varanasi is done and various discrepancies are highlighted. Based on existing literature around the world, framework of much reliable accident data collection, management and analysis system based on GPS, GIS and Oracle system is proposed. A new format of accident data collection form is proposed which record all the key information required for accurate accident data analysis. GIS based system and structured database platform will offer various analysis and visualization tools. This will provide superior information with greater accuracy and efficiency. Since this system combines spatial and attribute data and perform query analysis, it will require good hardware and web server. However, a standard WebGIS server can handle up to 250,000 map requests ever hour, it will more than sufficient to handle heavy traffic and will be feasible for practical applications (ESRI, 2009). The proposed system will serves as a key provider of information for effective planning at local, regional and national levels. This will lead to effective analysis, proper management and effective implementation amongst various stakeholders. However, level of success of this improved framework depends upon the speed at which authorities can implement the new system.

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