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HIGHWAY SAFTEY ASSESSMENT USING GIS

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ABSTRACT

This paper is intended to illustrate applications of Geographic Information System (GIS) in transportation planning for which authors have made an attempt to simplify road safety audit process by integrating it with a GIS based software "Gram ++". This technique will help the road auditors to differentiate different sites of a road segment having higher accident frequency with sites having low accident frequency which should be potentially improved in a cost effective manner. It will also help road safety audit experts to identify and focus on the real problems at specific site of road segment right from planning stage for which authors have presented the procedure & discussed how it can be applied so that all road features can be considered simultaneously.

In India with more than one lakh fatalities per annum accounts for about 10 % of total world's road fatalities. The share of National Highways and State Highways in the total road network is just 6 % but these cater to 70 to 75 % of total road traffic in India. However, the National Highways, which constitute less than 2 % of the total road network, account for 20 % of total road accidents and 25 % of total road traffic fatalities occurring on Indian roads. Further, the severity of road traffic accidents on National Highways is more because of higher speeds as compared to other roads. The road safety situation in India is worsening. Accidents, fatalities and casualties have been increasing dramatically over last 20 years – about 5 % growth rate over last two decades - partly due to exponential growth of vehicles. The death rate per vehicle is 10 to 20 times higher in India as compared to high-income countries like Sweden, Norway, Japan, Australia, UK and USA. It is much higher even when compared to many low-income countries like Brazil, Mexico and Malaysia. Pedestrians, bicyclists and motorized two-wheeler riders are the Vulnerable Road Users (VRU), which constitute 60-80 % of all traffic fatalities in India. This seems logical as this class of road users forms the majority of those on roads. On highways, the proportion of VRU and other motor vehicle occupants are 32 % and 68 % respectively. In addition, they sustain relatively more serious injuries even at low velocity crashes, unlike car occupants who are protected by impact absorbing metallic body of the vehicles.

Keywords: *Road safety, GIS, Accidents.*

I. INTRODUCTION

The road accidents deaths and injuries are global phenomena but more sever situation in mixed traffic condition as prevailing on Indian multilane highways. Concept of quality management and sustainable safety have gained ground in the past two decades and may have been among the factors that led policymakers and project managers to realize the need for purely safety-oriented tools. highway Safety assessment (HSA) is one of the best tools for improvement of road safety; in which experts attempt to identify potentially dangerous features on the highway environment and suggest remedial measures.highway Safety assessment (HSA) is defined as "the formal safety performance examination of an existing or future road or intersection by an independent, multidisciplinary team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users."highway Safety assessment (HSA) was originated in Great Britain (1980) is now spread in several countries around the world. The HSA system established in UK spread to USA, New Zealand, Australia, Denmark, Canada, Malaysia, China, Japan and Singapore and now it is used as a model in many countries for the formulation of guidelines and planning of their trunk roads. It is at varying stages of implementation in developing countries like India, South Africa, Thailand, Egypt, Pakistan and Bangladesh. Our present work includes conduction of road safety audit for national highway-13 from Hungund to Hospet at a chainage of km 202 to km 299 in the state of Karnataka. **National Highway 13** (*NH 13*)**,**now renamed as **NH 169** is a National Highway in India that runsfrom Sholapur in Maharashtra to Mangalore in Karnataka. The total length of NH 13 is 691 km (429 mi). The original NH 13 ran from Sholapur to Chitradurga at the intersection of NH 4. It has recently been extended to Mangalore. The project stretch passes through Ikkal (Chainage 209.200 Km) and Kustagi (Chainage236.500 Km) which are major urban areas. The project stretch has about 14 Major Intersections with National Highways, State Highways, and Major District Roads.

Though road is marked as a national highway, it is narrow along many stretches causing frequent mishaps. In particular, the stretch between Chitradurga and Hospet is extremely bad and with heavy truck traffic. Driving this stretch in a car, particularly in the nights, is not advisable due to the bad condition of the road.

So our work includes conduction of safety audit for NH-13 which is now renamed as NH-169. The safety audit work involves in the performing of inventory road studies, traffic volume studies and accident assessment and analysis.

An inventory road study contains detailed examining of the geometric design features, Pavement characteristics and surface features. Classified volume studies include calculating the performance of the road by traffic volume counts etc. While accident assessment and analysis includes collecting previous accident data and identifying the block spots by representing them in collision and cluster maps.

The safety audit work is performed by the regulations and recommendations stipulated by IRC-SP-88.

II. LITERATURE SURVEY

TITLE: **HIGHWAY WORK ZONE SAFETY AUDITS FOR SAFETY IMPROVEMENTS ZONGZHI LI**

He has given review on 10th November 2011 in a paper called emerald in USA with a topic called Highway work zone safety audits for safety improvements. Current practices of road safety audits worldwide, investigate the perceptions of experts on highway work zone safety in the USA and issues of adopting work zone safety audits in the country, and propose a framework for developing guidelines for implementing work zone safety audits for safety improvements. The paper was conducted by reviewing the existing literature of road safety audits and administering four-week questionnaire surveys of experts on highway work zone safety in the USA. – Road safety audits have been successfully adopted worldwide to maximize safety of the roadway environment for highway users. The questionnaire surveys have clarified leading causes of work zone safety problems and effective countermeasures, types of projects suitable for auditing and audit frequencies, audit team composition and funding sources, audit tasks and tools, and project staff safety training audits. A similar procedure for road safety audits could be adopted for work zone safety audits with emphasis on mitigating work zone safety impacts.

III. ARCHITECTURAL ASPECTS OF SHEAR WALLS

General Observations and Study Application:

***Horizontal and Vertical Curve details**:*

Design of horizontal curves was checked to ensure whether adequate super elevation, transition lengths have been provided for chosen radius of curve and for particular design speed. Vertical curves were checked for minimum curve length to be adopted for specific change in grade to have adequate sight distances. The horizontal and vertical curves are designed as per IRC requirements and no major deficiency has been observed in the design.

***Bus bay & Truck lay bye locations**:*

Informatory sign boards shall be installed ahead of the bus bay and truck lay byes. Pavement marking needs to be carried out. Raised pedestrian footpath needs to be constructed for safety of passengers. Proper transition in carriageway shall be provided.

***Speed regulatory measures at junctions**:*

As per Indian Road Congress specification, it is necessary to provide road hump with necessary sign boards on minor arms at a distance of 10m from the edge of main carriageway to regulate the speed of vehicles entering the project road.

Locations of vehicular skidding and surface pounding:
There were no locations with excessive bleeding and corrugations in pavement surface. Median opening/median drains for efficient drainage of surface water is under construction in super elevated sections. On high embankments, rain cuts have been observed on the earthen slopes. This needs to be rectified. Excessive filling in medians have resulted in spilling over of earth on carriageway in some of the stretches. This needs to be removed by dressing the filled earth to kerb height or even less.

Toll Plaza:
Toll plaza with various facilities is still under construction and to be completed. Proper lanes marking with adequate channelization have to be provided at toll plaza. Lighting to meet required lux level along with high mast lighting shall be provided as per the requirements of the project. Proper flaring in carriageway shall be provided.

Highway patrolling:
The pavement maintenance agency should provide route patrols round the clock to assist motorists. The patrol personnel should be adequately trained in traffic management, road safety and in primary First Aid. The road agency should also provide ambulances having all facilities of emergency assistance required like stretcher to carry the patient, Emergency Medicines, oxygen etc. The Concessionaire should have cranes of sufficient capacity having all requisite arrangements of pulling and lifting of accidental/break down vehicles.

Service Roads:
Service Roads are to be constructed in habitant areas which are still to be completed in the some stretches. Proper flaring at start and end of Service Roads should be provided before merging or diverging. Road signs should also be installed at all flaring locations. Proper chevron marking should be provided at start of separator between Main Highway and Service Road. Hazard Marker shall also be installed at start of divider.

Drainage:
Pucca Drain is provided in Urban Areas / Service Roads which are in progress. It is noted that Gratings are to be provided for outfall of water in the drain. These drains should be covered to ensure safety of pedestrian.

Median openings:
Most of the Median openings have been provided with storage lane for 'U-turn' vehicles. 'STOP' line and 'U-turn' marking has to be taken-up to guide the drivers properly. No vegetations have to be planted in median (up to 100.0m) to maintain clear sight distance at median opening locations. Median opening sign boards have been installed in most of the locations. Arrow marking is still to be done in storage lanes. It is observed that at some locations of the project stretch, the local people were damaging the median kerbs and using as unauthorized median openings. These should be restricted and all such openings should be closed.

Site Selection for Study Area:
The stretch from Km 202.00 to Km 299.00 of National Highway 13 had been selected for candidate analysis. The selected highway stretch has been newly reconstructed and upgraded to four lanes. The two important obligatory points on the study area are Hungund and Hospet of the highway in the state of Karnataka, India. The road stretch traverses through a flat and rolling terrain of mostly agricultural and urban settlement land. The location map terrain map and route map are shown in Figure 1, respectively. This National Highway is maintained and operated by National Highway Authority of India (NHAI) under the Ministry of Road Transport and Highways (MOR&TH).

Specific Location Observations
Our observations specific to location are presented with photographs which had been taken during Safety Audit.
Location & problem encountered are described along with photographs below.

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Figure . Unauthorized Median Cut at Km 226.300:

Unauthorized Median cut should be closed wherever possible.
Temporarily proper sign board should be installed.

Figure : Unauthorized Median Opening at Km 232.050

Temporary proper sign board should be installed

Figure .Service Road & Start of Underpass

Hazard Marking and Chevron marking are missing.

Figure . Confusing information board Truck lay bye

IV. METHODOLOGY APPROACH

Safety Audit can be applied on (a) new roads and (b) existing roads. On new roads, safety audit will lead to avoiding building accident-prone situations and on existing roads, audit will lead to improved roads from the safety point of view. It should be realized that safety audits are a necessary cost, and not an additional expense. As project is audited, it provides further scope to improve/ enhance safety. In projects where there is a choice of route or standards, or there are known safety problems, the designer should discuss these with auditors at the initial stage. The safety audit shall be carried out on road and traffic improvement projects. Safety audit during construction stage is a new concept and no country has developed any checklists for carrying road safety audit during construction stage.

a) New Construction

During Feasibility Study	Stage1 Audit
During Preliminary Design	Stage2 Audit
Completion of Detailed Design	Stage3 Audit
Construction Stage	Stage4 Audit
Completion of Construction (Pre-opening)	Stage5 Audit

b) Existing Roads

On Existing Roads	-Monitoring

Procedure of Road safety audit for new roads:

4.4.1 Stage 1 Audit (During Feasibility Study)

Stage 1 recommended for major schemes, including in urban areas, in order to influence route choice, alignment selection, standards, impact on and continuity with the existing network, junction provision, possible hazards from roadside development etc. Reviews of initial project/planning study. Important subjects for assessment at this stage will include:

- Choice of route options
- Alignment and ease of achieving design standards
- Standards and cross-section
- Effects on existing network
- Number of junctions, their types, etc.
- Possible hazards from roadside development

The road safety auditor should not question on planning information or reassess matters of strategy. Auditor should only concern himself with the presented planning information.

4.4.2 Stage 2 Audit (Completion of Preliminary Design)

Stage 2 is recommended on completion of preliminary design, to assess horizontal and vertical alignments, sight lines and layout of junctions including slip roads and lay-byes. After this stage, land acquisition may be taken up.

Examination when preliminary design is completed i.e., where the alignment has largely been decided, but can still be modified before approval. Important subjects for assessment at this stage are:

- Project changes since Stage 1 Audit
- Alignment
- Cross-section
- Arrangement of Junctions
- Any Interim Measures

All groups of road users, including those who have special needs and users of the adjoining areas should be taken into consideration. If there is any risk of special road safety problem occurring during the construction phase, the risk must be assessed.

4.4.3 Stage 3 Audit (completion of detailed design)

Stage 3 is recommended on completion of detailed design and before preparation of contract documents, to assess detailed junction layout, markings, signs, signals, lighting details, etc.

Examination when detailed design is completed and the limits of expropriation have been set, but before the tender documents are prepared and tenders are invited. Vital subjects for assessment at this stage are:

- Project changes since Stage 2 Audit
- Detail Design of junctions
- Design of geometrics
- Cross-fall
- Markings and Signs
- Side drains
- Embankment slopes
- Presence of clear zone
- Traffic Signals
- Lighting
- Interim Measures

4.4.4 Stage 4 Audit (During construction stage)

Construction zone is that area of the road which is affected by the works and which affects traffic flow and safety of workers and road users. In this context it can also be called Traffic Control Zone. In rural areas, problem at these zones is accentuated by the reduced availability of carriageway, acquisition of land for diversions, etc. In urban areas, the problems are even more acute as diversions may have to be over adjacent road street of the road network as well as the sharing of road space by different categories of road users. Traffic control zone can be divided into three major components i.e., Advance Warning Zone, Transition Zone and Work Zone. Manual on Traffic Management at Construction Zones is published by the Indian Roads Congress as IRC: SP:55 should be referred to

- Examination of terminal transition zone, work zone, approach transition zone and advanced warning zone with respect to safety point of view.
- Examination of safety measures adopted for workmen and road users.
- Examination of traffic control devices adopted at construction zone.

Major problems in work zones are attentiveness and speed. It is necessary to help the drivers to be more attentive by using signage's, rumble strips and anything that brings alertness and gets them to realize that there is something different about this stretch of road and there would be lower speed limits in the work zones. Work zone safety measures should be aggressive and comprehensive. It should include public service announcements, safety training for workers in work zones, lower speed limits in work zones, rumble strips and other speed reducing measures, proper signage's, flagman to control and guide traffic, stepped-up enforcement.

4.4.5 Stage 5 Audit (Completion of Construction) (Pre-opening)

Stage 5 is recommended immediately prior to opening of scheme, involving the site staff and local traffic police in car and truck. This should take the form of driving and when appropriate, walking and/or cycling the new route. This is checked during nighttime also to ensure that required night time safety standards have been achieved.

- A final review of the finished construction, to check from the standpoint of road safety that it is ready to be opened for traffic. It is particularly important to check the location and visibility of markings and other traffic control devices especially where changes were made during the construction period. The finished scheme should be assessed from the road users' point of view in daylight and in darkness.
- After opening for one or two months, the auditor should examine whether or not road users are using the project facility in an appropriate manner.

Many schemes are constructed with the road open to traffic throughout the entire construction phase. When there is no question of an actual opening for traffic, overall examination is to be carried out to audit whether the markings and all traffic control devices are in place. This examination is to be carried out by the auditor independently in the first instance and thereafter along with the Project Manager of the Contractor.

Safety Focus in Different Stages of the Project:

The safety focuses during different stages of the project are summarized as below

Table 4.1 Safety Focus in Different Stages of the Project

Feasibility	Safety issues associated with options such as route locations, fixing of fixing intersections and interchanges, access control, number of lanes, traffic control, functionality, future needs.
Preliminary Project Report (PPR)	Evaluation of general design standards, alignment, sight distance and lines of sight, layout of intersections, grade separators and

	interchanges, lanes and shoulder widths, cross-slopes and super elevation, provision for cycles, pedestrians, emergency vehicles, bus bays, truck lay byes, rest areas, parking, etc, provision of traffic control devices, safety during construction.
Detailed Project Report (DPR)	Examining safety issues of specific geometric design features, Traffic control devices. delineators, roadside clear zones, detailed and lighting, safety issues related to landscaping, provision for special road users like elderly, school children, persons with disabilities, buses, equestrian, rail roads, heavy trucks, etc.
•Construction sites • During Construction	Examining the maintenance of existing lanes during construction, Ensuring safe and smooth flow of traffic, safety of all road users, Construction workers, required road signs, markings and other traffic control devices, lighting at work zones.
Pre-opening	Final check prior to opening the facility to ensure that the safety concerns of all road users have been addressed and that there are no apparent hazardous conditions. The Audit team needs to actually travel both during the day and the night on a bus, on a truck as well as a car. Should include day/night checks; evaluation considering dry/wet weather; and driving/ riding and walking.

4.5 Procedure for Audit of Existing Roadway Sections:

Existing road also can be audited to assess their accident potential. It provides a systematic way of being proactive in reducing the future likelihood of accidents. Audits of existing roads involve a similar approach to that for new road projects. Accident records will be an important part of the information to be assessed, but they must be supplemented by informed judgments about the potential for other types of accidents. The aim is to identify any existing safety deficiencies of design, layout and road furniture, which are not consistent with the roads function and use.

For conducting safety audit on existing roadway sections field studies like road inventory, classified volume counts, speed survey and study of first information reports from police records are essential. Ideally audits of an authority's existing road network should be done on a regular basis. As the road is already built, the inspection plays an important role. As with a road safety audit of any type of project, the road should be inspected from the point of view of all the likely road user groups. The road should be inspected for each user group and for the different types of movement.

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V. ANALYSIS

VI. 5.1 Inventory Studies:

The safe and efficient operation of highway depends upon road geometric parameters, traffic control devices, lighting system of the stretch, composition of traffic, drainage condition, junction layout, parking facilities, cross drainage structures and the adjoining land use of the stretch, road width, shoulder width, footpath, height of embankment, sight distance, horizontal curvature, vertical curvature, etc. The traffic control devices comprise signs, markings, delineators, crash barriers, guard rails, etc.

So, in this road inventory study the proposed highway is checked against all the above highway geometric features. The plans of this highway are collected from the national highway authority of India (NHAI). These plans indicate the existing conditions of the project road along with details of facilities and details of utilities and specifications. The proposed project improvements were examined against various guidelines, stipulations as mentioned in the Indian Safety Guidelines / Manuals. Also the latest Indian Road Congress (IRC) guidelines along with circulars,

The design plans were checked for the following alignment inconsistencies

- 5.1 Highway alignment
  - 5.1.1 Design Speed
  - 5.1.2 Radii of horizontal curves
  - 5.1.3 Super elevation
  - 5.1.4 Widening on horizontal curves
  - 5.1.5 Vertical curves
- 5.2 Visibility / Sight distance
  - 5.2.1 Stopping sight distance
  - 5.2.2 Overtaking sight distance
- 5.3 Longitudinal gradients
- 5.4 Transition areas
- 5.5 Acceleration / deceleration ramps
- 5.6 Truck / bus lay byes

5.1.1 Design speed:

The design speed is the main factor on which geometric design elements depends. The sight distances radius of horizontal curve, super elevation, extra widening of pavement, length of horizontal transition curve and the length of summit and valley curve are all dependent on design speed. Design speed of roads depends upon

- Class of the road
- Terrain

The design speed (ruling and minimum) standardized by the IRC for different classes of roads on different terrains are given in table

Table 5.1 DesignSpeeds as per IRC-38

TERRAIN	DESIGN SPEED IN KMPH	
	RULING	MIN
PLAIN	100	80
ROLLING	80	65
MOUNTAINOUS	50	40
STEEP	40	30

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Recommendation:
The design speed is the major deciding factor for deriving many of the highway geometric features. For the present highway of NH-13 which comes under plain terrain classification a design ruling speed of 100kmph and a min speed of 80kmph is assumed. The above assumption is based on the IRC-38 (standards for highway designing)

5.1.2 Radii of Horizontal Curves:
For a certain speed of vehicle the centrifugal force is dependent on the radius of the horizontal curve. To keep the centrifugal ratio within a low limit, the radius of the curve should be kept correspondingly high. The centrifugal force which is counteracted by the super elevation and the lateral friction is given by

$$e + f = \frac{v^2}{127R}$$

Thus making "R" as the subject of the formula we get:

$$R = \frac{v^2}{127\ (e+f)}$$

Where,

R = Radius of horizontal curve

e = Rate of Super elevation, taken as 0.07
f = Coefficient of friction, taken as 0.15
V = Design speed.

As per IRC-38 (standards for highway designing) the minimum recommended radius of horizontal curves on highways are as given below.

Table 5.2 Design Speeds as per IRC-38

TERRAIN	DESIGN SPEED IN KMPH	
	RULING	MIN
PLAIN	100	80
ROLLING	80	65
MOUNTAINOUS	50	40
STEEP	40	30

Calculating, the min safe radius for a horizontal curve between chainage of Ch. 256.919 to Ch. 259.941 LHS. Of NH-13 we get

$$R = \frac{v^2}{127\ (e+f)}$$

For that particular stretch we have v = 100kmph, e = 0.07, f = 0.15

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$$R = \frac{100^2}{127(0.07+0.15)}$$

R = 357.06

Working out radius of horizontal curve for a curve of chainage Ch. 256.919 to Ch. 259.941 LHS. On NH-13 we get the radius of horizontal curve as 357.06 which is slightly less than the minimum standard of IRC-38 (standards of highway safety design).

The horizontal curves which have the radius less than the desired one are as given below.

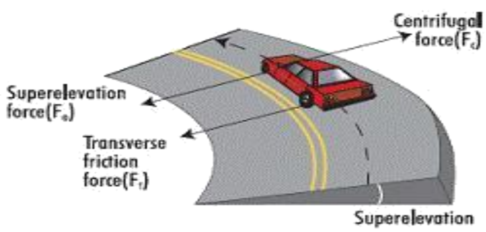
Table no-5.3 Horizontal Curves having less Radii

S.no	LHS/RHS	Chainage	
		From	To
1	RHS	Ch. 281.960	Ch. 282.070
2	RHS	Ch. 287.975	Ch. 288.045
3	RHS	Ch. 289.964	Ch. 290.078
4	LHS	Ch. 291.910	Ch. 292.183
5	RHS	CH.295.960	CH.297.380

Recommendation:
Radius on horizontal curves less than the minimum recommended level results in severe geometric mishaps like decrease in sight distance and thus causes increase in road accidents, thus to decrease those defects either the radius has to be increased by set backing on the above chainages or proper road signs has to be installed.

5.1.3 Super Elevation:
A horizontal highway curve is a curve in plan to provide change in direction to the centre line of a road. When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally outwards through the centre of gravity of the vehicle.

In order to counteract the effect of centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to the inner edge, thus providing a transverse slope through out the length of the horizontal curve.



Super elevation can be calculated by the formula

$$e = \frac{v^2}{127R} - f$$

Where,

R = Radius of horizontal curve

e = Rate of Super elevation, taken as 0.07
f = Coefficient of friction, taken as 0.15
V = Design speed.

As per IRC-38 (standards for highway designing) the minimum recommended super elevation on highways are as given below.

Table no-5.4 Minimum Super Elevation recommended

S.no	TERRAIN	MIN SUPER ELEVATION
1	Plain and rolling	0.07
2	Hilly roads	0.1

Calculating, the super elevation for a horizontal curve between chainage of Ch. 256.919 to Ch. 259.941 LHS. Of NH-13 we get

$$e = \frac{v^2}{127R} - f$$

$$e = \frac{100^2}{127 * 357.06} - 0.15$$

$$e = 0.047$$

Working out super elevation for a curve of chainage Ch. 256.919 to Ch. 259.941 LHS. on NH-13 we get the rate of super elevation as 0.047 which is less than the minimum standard of 0.07 as per IRC-38 (standards of highway safety design).

Crash Analysis:
The main purpose of crash analysis is to improve safety by identifying crash patterns, mitigating crash severity, and reducing the number of crashes by adopting suitable countermeasures:

Key Steps to a Crash Analysis Study:

1. Review of Crash Data considering the Section as a whole.
2. Identify the High Crash locations
3. Create Collision Diagram.
4. Quantify the main crash trend(s) for the Location.
5. Determine the source of problem(s).
6. Evaluate types of improvements to address the crash problem(s)

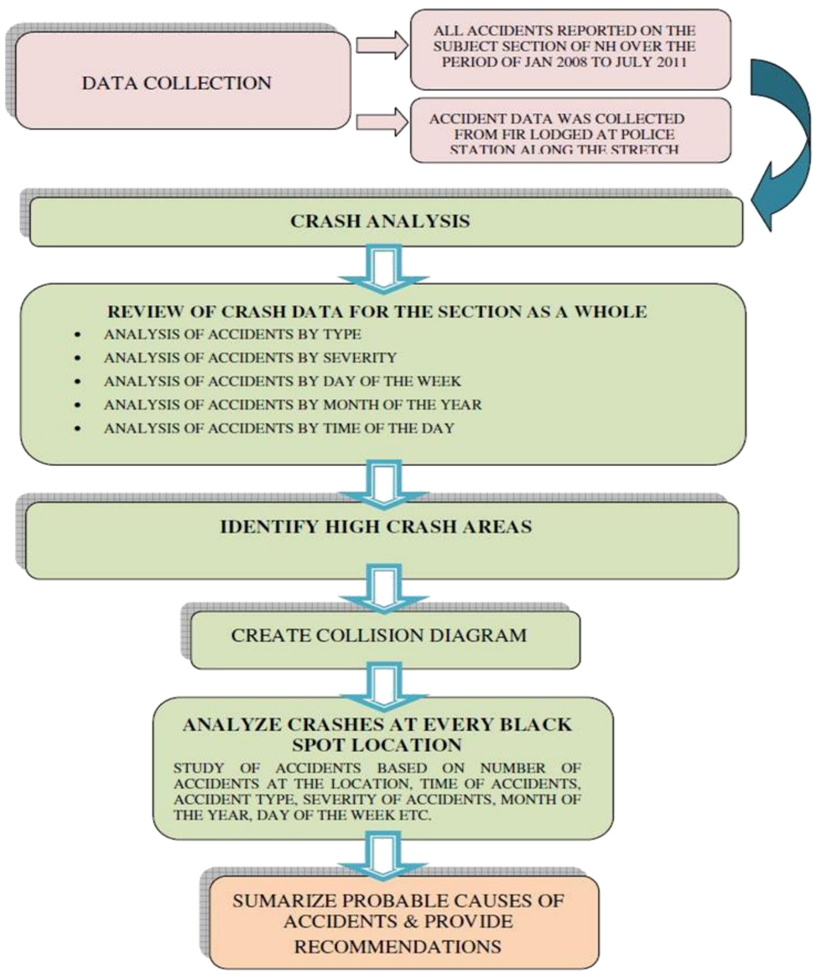


Table no 5.1ssss1– flow chart showing accident assessment and analysis

Review of Crash Data considering the Section as a whole:

Total **555** numbers of accidents were recorded from January 2008 to July 2011 along the stretch 100 Kms long. Amongst the 555 number of total accidents recorded **242** were **head on collisions** accounting **43.60%** of the total (refer Fig. 3 for detailed analysis). It was alsoobserved that most the accidents occurred between **3 to 4 am and 7 to 11 am** in the morning. The undivided Single Carriageway, absence of overtaking zones, narrow bridges, and inadequate road signs and markings probably could be the major reasons for most of the accidents on the subject stretch. Most number of accidents was recorded on Sundays. Accident Summary Sheet as given in Table

ACCIDENT SUMMARY SHEET

HIGHWAY NO: 13		**SECTION:**	Hospet to Hungund
STATE: Karnataka		**FROM & TO CHAINAGE:**	202.00 to 299.00 Kms
ANALYSIS START DATE:	Jan 08	**ANALYSIS END DATE:**	July13

ACCIDENT SUMMARY BY NATURE

Nature of Accidents	# Acc	%
Overturning	127	22.88
Head on collision	242	[illegible]
Rear End Collision	63	11.35
Collision Brush/Side Wipe	29	5.23
Right angle Collision	7	1.26
Skidding	25	4.50
Right Turn Collision	0	0.00
Others	62	11.17
Total accidents	**555**	

ACCIDENT SUMMARY BY SEVERITY

Severity	# Acc	%
Fatal	154	27.75
Grievious Injury	254	45.77
Minor Injury	38	6.85
Non Injury	109	19.64
Total accidents	**555**	

ACCIDENT SUMMARY BY WEEKDAY

Day	# Acc	%
Sun	98	12.43
Mon	66	13.66
Tue	79	16.46
Wed	71	13.84
Thurs	74	14.71
Friday	79	15.94
Sat	88	12.96
Total accidents	**555**	

ACCIDENT SUMMARY BY MONTHS

Months	# Acc	%
Jan	55	9.91
Feb	62	11.17
Mar	43	7.75
April	54	9.73
May	56	10.09
June	52	9.37
July	63	11.35
Aug	40	7.21
Sep	32	5.77
Oct	32	5.77
Nov	26	4.68
Dec	40	7.21

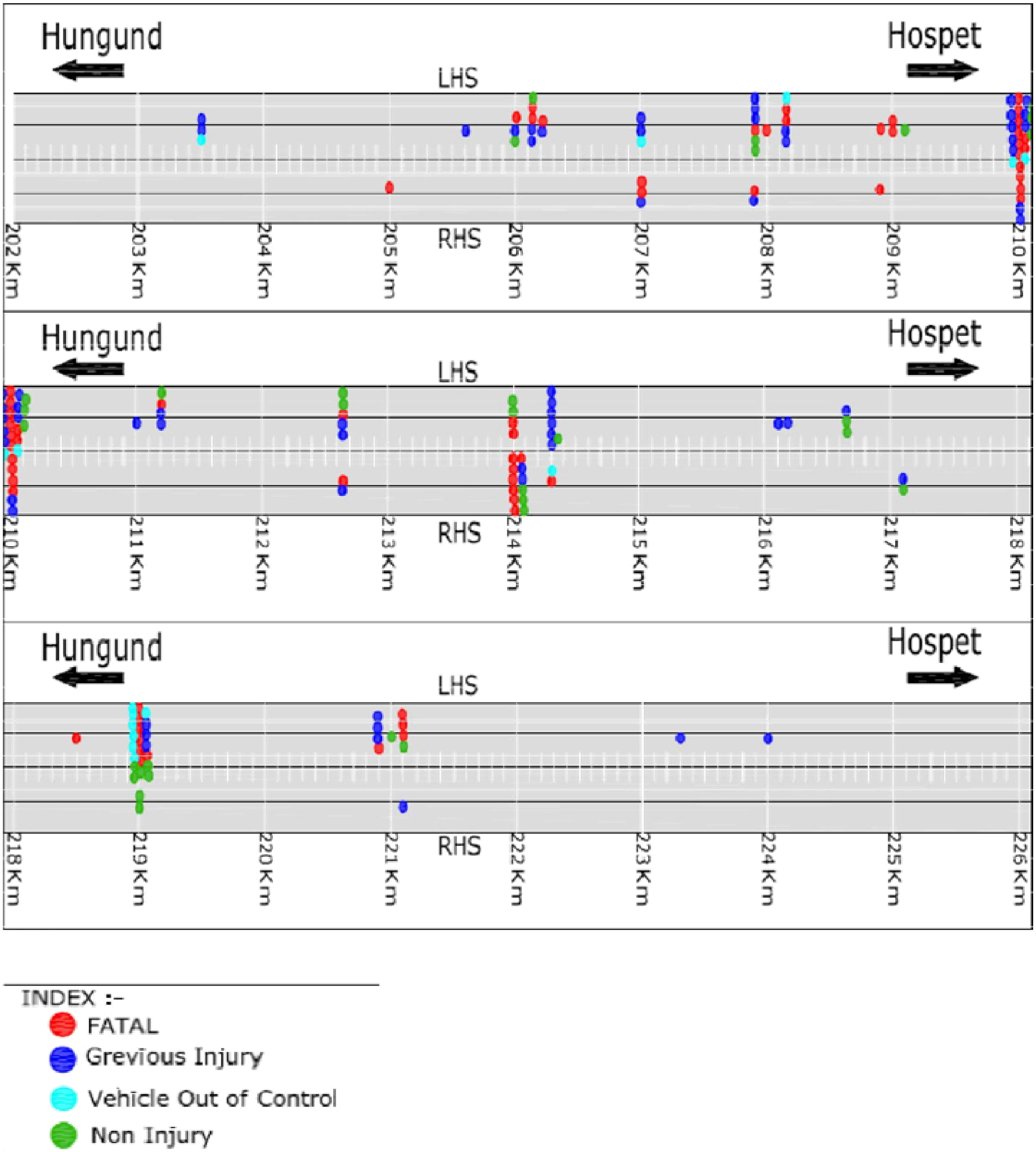
ACCIDENT SUMMARY BY TIME OF THE DAY

Time of Day	# Acc	%
0 hrs	7	1.26
1hrs	30	5.41
2hrs	28	5.05
3hrs	22	3.96
4hrs	35	6.31
5hrs	21	3.78
6hrs	26	4.68
7hrs	19	3.42
8hrs	35	6.31
9hrs	30	5.41
10hrs	35	6.31
11hrs	25	4.50
12hrs	25	4.50
13hrs	17	3.06
14hrs	19	3.42
15hrs	26	4.68
16hrs	27	4.86
17hrs	22	3.96
18hrs	18	3.24
19hrs	20	3.60
20hrs	14	2.52
21hrs	24	4.32
22hrs	19	3.42
23hrs	11	1.98
TOTAL	**555**	

ACCIDENT SUMMARY BY YEAR

	2008	2009	2010	2011 (till July)
Fatal	42	64	33	15
Grievious Injury	90	50	74	40
Minor Injury	13	12	4	9
Non Injury	41	29	24	15
TOTAL	**186**	**155**	**135**	**79**

No. 3 sums up the review findings of the Crash Data.



VII. USING GIS – CASE STUDY

6.1 Intelligent GIS-Based Road Accident Analysis and Real-Time Monitoring Automated System using WiMAX/GPRS:

Road traffic accident is complicated to analyze as it crosses the boundaries of engineering, geography,and human behavior. Therefore, there is a need for a more systematic approach, which can automatically detect statistically significant spatial accident clusters and offering repeatable results. To implement traffic accident countermeasures effectively and efficiently, it is important to identify accident-prone locations and to analyze accident patterns so that the most appropriate measures can be taken for each specific location.

6.2 Research Motivation

The research undertaken intends to find a completed solution to covering all aspects in managing andmonitoring accident data. The system is based on GIS and telecommunications infrastructurestechnologies. In this case, IRAS (Intelligent Road Accident System) is used to get the better results from accident data, which includes the most effective and useful queries, reports, charts and advanced graphical user interface. The work evaluates for performance of a GIS-based solution in order to integrate infrastructure communication systems such as WiMAX and GPRS to develop a multiplatform middle-ware for real-time monitoring, automated services. The development is based on aspect and object oriented software design. In addition, the other objective is to be established a dataware house for the real-time smart decision support system for automated services and analysis. Also, this system offers Location Based Services (LBS) for Clients' cell phone, PDAs, smart phones and laptops.

6.3 System Architecture

6.3.1Enabling Telegeoinformatics

Telegeoinformatics is enabled through advanced in such fields as geopositioning, mobile computing, and wireless networking. There are different architectures possible for Telegeoinformatics, but one that is expected to be widely used is based on a distributed mobile computing environment where clients are location aware, that is capable of determining their location in real-time, and interconnected to intermediary servers via WiMAX/GPRS or even wired networks. Telegeoinformatics can be based on different architectures to meet different requirements of applications, where clients and servers are connected via wireless networks. The middleware is used for performing many computations and activities and linking the different components of Telegeoinformatics. One of the key responsibilities of the middleware is ensuring interoperability among heterogeneous data, software, and functions. Figure 1 shows an ideal middleware for Telegeoinformatics.

6.3.2 Interoperability of Telegeoinformatics:

In order to make Telegeoinformatics interoperable, the middleware must be based on special mechanism and protocols. Insomuch as geospatial data and geoprocessing are central to Telegeoinformatics, providing geospatial interoperability, eg., in Location-Based Services (LBSs) led by the Open GIS Consortium (OGC), should be one of the objectives of the middleware (OpenLS, 2001).

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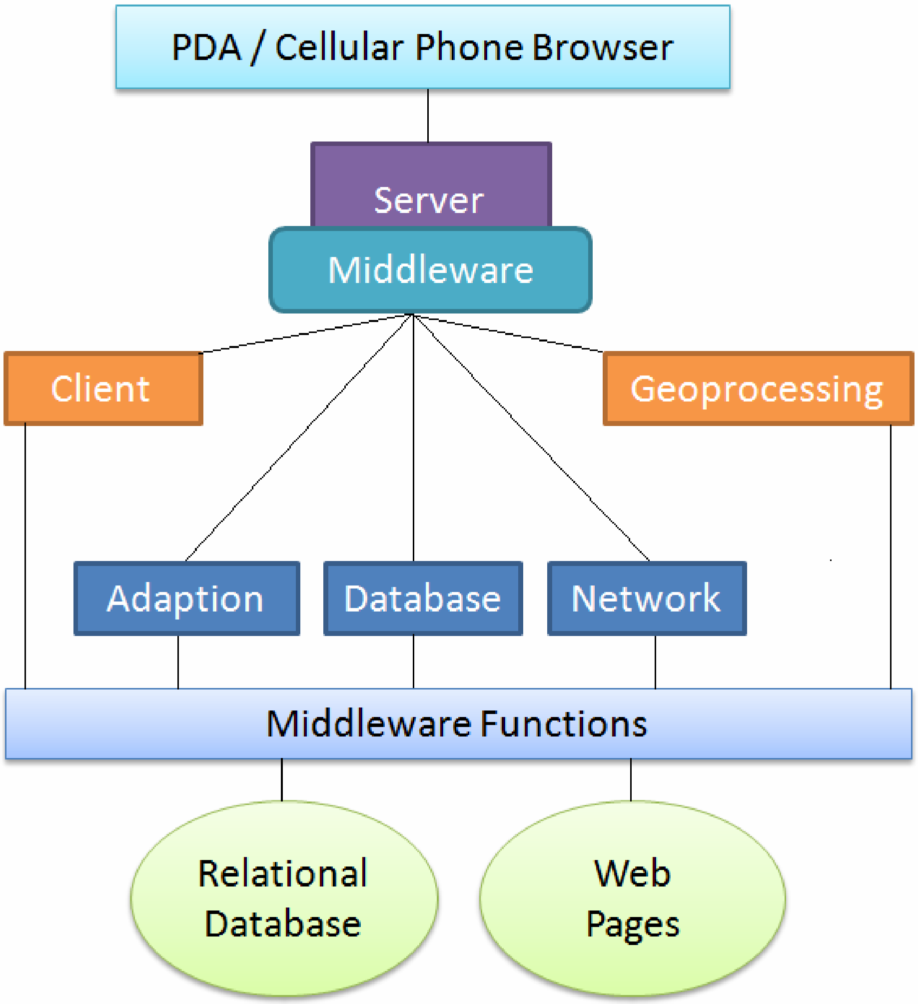

Fig : Interoperability of Telegeoinformatics

6.3.3 Strategies and Adaptation:

One adaptation strategy in Telegeoinformatics is to adapt to the client machine the user would use to access the system. There are several client variations: PDA, Desktop PC, laptop, cell phone. Differences include storage capacity, processing power and user interface. Telegeoinformatics should have knowledge about these client's limitations with respect to the output interface and adjust its output information presentation to the capabilities available. Heineman (1999) has analyzed and evaluated various adaptation techniques for software components. On such technique is active interface.

This technique acts on port requests between software components, which is where method request are received. Another technique is Automatic Path Creation (APC), which is a data format, and routing technique that allows multi data format adaptation and adapts to current network conditions (Zao and Katz, 2002). Adaptation is not the modification of components by system designers; this is considered component evolution. Adaptation should be accomplished automatically by the system with little user intervention. In addition, adaptation should be considered a design capable of adapting to users with respect to the user's needs (Stephanidis, 2001).

6.3.4 Terminal-Centric Positioning:

The Terminal-Centric methods rely on the positioning software installed in the mobile terminal. The method, which is used in this research, is Network Assisted GPS (A-GPS); this method can also be used in the network-centric mode, according to Andersson (2001). A-GPS uses an assisting network of GPS receivers that can provide information enabling a significant reduction of the time-to-first-fix (TTFF) from 20-45 s, to 1-8 s, so the receiver does not need to wait until the broadcast navigation message is read. It only needs to acquire the signal to compute its position almost instantly. For the timing information to be available through the network, the network and GPS would have to be synchronized to the same time reference. According to Andersson (2001) the assistance data is normally broadcast every hour, and thus it has a very little impact on the network's operability.

6.3.5 Network-Centric and Hybrid Positioning:

Cell Global Identity with Timing Advance (CGI-TA) is one of the network-centric and hybrid positioning methods, which is used in this research. CGI uses the cell ID to locate the user within the cell, where the cell is defined as a coverage area of a base station (the tower nearest to the user). It is an inexpensive method, compatible with the existing devices, with the accuracy limited to the size of the cell, which may range from 10-500 m indoor micro cell to an outdoor macro cell reaching several kilometers (Andersson, 2002). CGI is often supplemented by the Timing Advance (TA) information that provides the time betweenthe start of the radio frame and the data burst. This enables the adjustment of a mobile set's transmit time to correctly align the time, at which its signal arrives at the base (Snap Track, 2002).

6.3.6 Network-Based Service

The deployment of wireless-based LBSs relies on a common standards-based network infrastructure.The telecom market is currently experiencing a transition in the delivery of services from proprietary and network closed implementations to an open, IP-based service environment. The positioning service will be an important component in this open, IP-based service environment. The building of positioning information with LBSs, personalization, security, and messaging will be key for any operator when offering service packaging to the clients. The LBSs request/response flow is generally carried out within a wireless carrier network that includes mobile phone, the wireless network, the positioning server, gateway servers, geospatial server and the LBS application. The mobile phone provides a keypad for query and either a numeric or graphical interface for display. The positioning server, usually embedded in the wireless carrier's infrastructure, calculates the position of the device using one or more positioning approaches. The various wireless location measurement technologies fall into two broad categories: network-based and handset-based solutions (Campbell, 2001). Network-based solutions rely on base station radios to triangulate the position of a roaming mobile device, either with received radio signals or with transmitted synchronization pulses. The advantage of this approach is that it enables every user to access LBS without the need to upgrade the handset. Handset-based solution are systems that incorporate the measuring and processing of the location information within the handset. GPS is the principal technology and has been further enhanced by the development of A-GPS, which allows faster and more accurate service (Moeglein, 2001).

6.4Multi Criteria Decision Making (MCDM)

The MCDM tool, which is embedded in server-side application, indicates AHP (Analytical Hierarchy Process) method, which can be used for decision making in GIS-based solution using input numeric values by the user. This tool is based on pairwise comparison method that developed by Tomas Saaty in 1970 in context of MADM (which is refer to attributes) method. It represents a theoretically founded approach to computing weights that are representing the relative importance of criteria. In this technique, weights are not assigning directly, but represent a "best fit" set of weights derived from the eigenvector of square reciprocal matrix. The objective of the AHP is to ensure that evaluation of weighting is consisted or not. The AHP relies on three fundamental assumptions:

i. Preferences for different alternatives depend on separate criteria, which can be reasoned about independently and given numerical scores.
ii. The score for a given criteria can be calculated from sub-criteria. That is, the criteria can be arranged in a hierarchy and the score at each level of hierarchy can be calculated as a weighted sum of the lower level scores.
iii. Suitable scores can be calculated from only pairwise comparisons.

AHP is a mathematical decision making technique that allows consideration of both qualitative and quantitative aspects of decisions. It reduces complex decisions to a series of one-on-one comparisons, and then synthesizes the results. Compared to other techniques like ranking and rating, the AHP uses the human ability to compare single properties of alternatives, it not only helps decision makers choose the best alternative, but also provides a clear rational for the choice.

6.5 Methodology

The develop system consist of the main module that operate as a real-time monitoring system. The system started with a field data collection which perform as client. All data which are related to accident, can be categorizes into spatial data and non-spatial data which are merged into one database. The merged data is transferred to the dataware house via internet by using WiMAX/GPRS. Dataware house will then be established with two different reference of data includes Road Networks (map data) and Datacenter (description data). The main system uses integrated data from the dataware house and analyzes on them to achieve various types of statistical reports, these reports can be customized and improved with different elements by interaction through the designed GUI. The main system will be able to recycle the outcome of the primary analyses into the system and pass the statistical reports to MCDM unit (Multi Criteria Decision Making). Under the module, AHP (Analytical Hierarchy Process) technique is used for decisions making process. The results will then be used in the next module, which is SDM (Smart Decision Maker). In this module, reports can be compared together,

make the best decision for diagnosis, and define the proposed solution related to current situation. SDM unit has potential to modeling suggested solution based on GIS interface. Figure 2 shows the process and relations between main system and the other parts to provide the proposed solution.

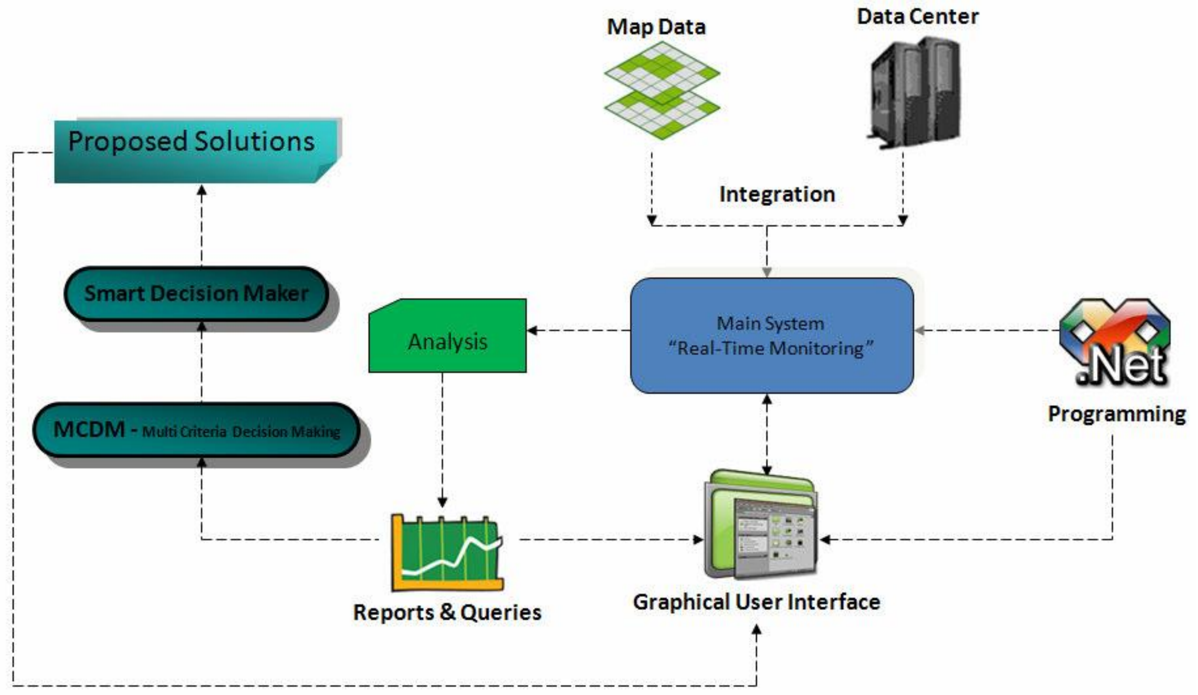

Figure 2: The relationship between main system and MCDM and SDM modules

There are two types of clients that should be defined to the system, Police and end users (citizens). After each accident, the clients (citizens) can provide necessary information to the main system by using their Mobile Phone (SMS) or using their PDA (WiMAX/GPRS). The main system automatically will search and announce the nearest police vehicle via internet around the accident location and suggest the best path to get to the accident location based on the traffics information, time and distance. In this case, police officers using PDA via internet directly to the main system will key all accident information in and then the system will automatically send data to the dataware house and update the database. Also at the same time, system will be able to inform other involved organizations and

companies such as medical emergency services, insurance and car service companies. Figure 3 shows the relationship between
main system and clients.

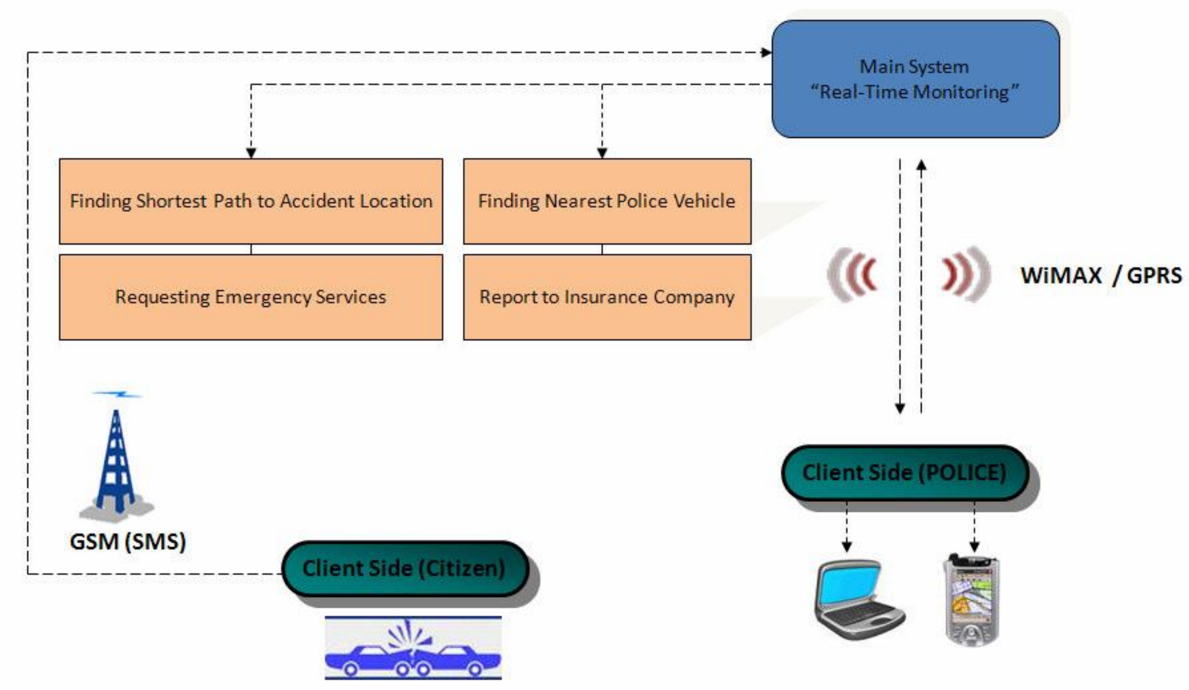

Figure 3: The relationship between main system and clients

The system being developed manage to support online communication through the GSM/GPRS/WiMAX services. User who wants to use this system must have a few equipments on his/her car which call On- Board Unit (OBU). These equipments consist of GPS and wireless communication devices. The main system also consists of Auto Alarming System (AAS) to inform the system for any accident events throughout the city. In this case, when an accident occurs, the location of the accident sends to the main system by client (citizen) using GPS devices installed on the vehicle, this task is done by calling OBU which, automatically or manually send the accident position to the server via internet using WiMAX or GPRS. From the signal received, the system will find the nearest police vehicle according to the accident coordinate system and sends the primary information to client (police officer) in their PDAs via internet. Then, accident data will be send to data center and store on the system and dataware house. This system can send online data to road accident database using PDA or Smartphone by police officers in real time access. In addition, Smart Decision Making (SDM), Multi Criteria Decision Making (MCDM) and Automatically Proposed solution system (APSS) units can be applied professionally and analytically for making the particular reports and queries in a proper manner.

VIII. CONCLUSION

1. After performing the highway safety audit it is recommended that it is highly necessary to upgrade the NH-13 to four lane road. It is expected that with the completion of the four lane divided carriageway the number of head on collisions and overturning may reduce.
2. According to IRC specifications the Design Speed should be 100km/hr all over the high way but in most of the intersection it is 80km/hr which is not satisfactory.
3. According to IRC specifications Super Elevation should be of minimum 7% but in some areas the super elevation is not sufficient which should be rectified.

4. The longitudinal gradient across the highway as suggested by the IRC standards should be 0.3 which has to be scrutiny.
5. According to IRC specification the horizontal radii for the highway having design speed of 100km/hr is 500mt. But in the present highway some curves are less then 500mt so to illuminate the safe sight distance radius of horizontal curve should be increased or alternative solutions like extra widening has to be provided
6. Accident Assessment and Analysis has shown that there are some black spots present in the present highway which have to be provided with good solutions as recommended.
7. Pedestrian guardrail should be provided all along the footpath of service road and at bus stops.
8. All undeveloped major and minor intersections must be developed with adequate lighting provisions as quickly as possible since maximum accidents were observed on these locations.
9. For further works, the system should also include the ability to inform clients about the risk zones in all over the city using LBS services, based on the main system reports, queries and real time traffic monitoring
10. The system classifies and categorizes the road networks into four zones, so when a vehicle enter to each zone, the system will automatically send the risk message to alert the accident risk on that particular zone or location of the city.
11. In addition, the system shall offer some services for clients such as air download client version (for PDAs or Smartphone) of application for using these LBS services. All LBS data, which will be shown on client phone, are generated by the main system with real time updates via internet, so the clients have real time information about the traffic conditions and accident risk zones around them.

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3. *ZONGHLI LI apamukkale Üniversitesy, Mühendislik Fakültesi,İnsaat Müh. Bölümü,Kınıklı Kampüsü, 20070, Denizli, Türkiye.*

List of code books:

1. IRC-38
2. IRC-SP 88 Manual for Road Safety Audit
3. IRC-42

Textbooks:

1. Highway engineering by Justo & Khanna and tata.