Routing of Hazardous material carrying vehicles

SIBAJYOTI SAHOO

Department of Civil Engineering

National Institute of Technology

Rourkela-769008

2014

Routing of Hazardous material carrying vehicles

A thesis submitted in partial fulfillment of requirements

For the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

By

Sibajyoti Sahoo

Roll no.-110CE0055

Under the guidance of

Prof. P.K Bhuyan

Department of Civil Engineering

National Institute of Technology

Rourkela-769008

2014

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA-769008

CERTIFICATE

This is to certify that project entitled "Routing of Hazardous Material Carrying Vehicles" ***submitted by*** *Sibajyoti Sahoo* ***in partial fulfillment of the requirements for the award of*** Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela ***is an authentic work carried out by him under my personal supervision and guidance. To the best of my knowledge the matter embodied in this project review report has not been submitted in any college/institute for awarding degree or diploma.***

Prof.P.K Bhuyan

Department of civil engineering

National Institute of Technology

Rourkela-769008

ACKNOWLEDGEMENT

I would like to thank NIT Rourkela for giving me the opportunity to use their resources and work in such a challenging environment.

First and foremost I take this opportunity to express my deepest sense of gratitude to the guide PROF.PRASANTA KUMAR BHUYAN for his able guidance during the project work.

This project would not have been possible without his help and the valuable time that he has given amidst his busy schedule.

I would also like to extend my gratitude to PROF. NAGENDRA ROY, Head, Department of Civil Engineering, who has always encouraged and supported in doing my work.

My gratefulness to MR.JANAKI BALLAV SWAIN and MR. BRIJESH KUMAR for their comments and valuable discussions for my work.

Last but not the least I would like to thank all the staff members of Department of Civil Engineering who have been very cooperative with me.

SIBAJYOTI SAHOO

Contents

CERTIFICATE **1**

ACKNOWLEDGEMENT **2**

LIST OF FIGURE **2**

LIST OF TABLES **3**

ABSTRACT 1

CHAPTER 1 .... **2**

Introduction 2

1.1 Hazardous material 4

1.2 Classification 5

1.3 Risk related to hazardous material transport 6

CHAPTER 2 .... **8**

Literature Review 8

Objectives: 10

CHAPTER 3 .... **11**

Study Area and Data Collection 11

3.1 Study Area 11

3.1.1 Back Ground of hazardous material transport in the study area 12

3.2 Data Collection 13

CHAPTER 4 .... **17**

Methodology 17

4.1. Map preparation 17

4.2 Buffer Creation 19

4.3 Drawing of buffer zone in ArcGIS 19

4.4 Routing Survey for Hazardous materials 21

4.5 Observation 22

CHAPTER 5 .... **27**

Results & Discussions 27

CHAPTER 6 .... **29**

Summary and Conclusion 29

6.1 Summary 29

6.2 Conclusion 29

References **30**

LIST OF FIGURE

Figure 1.1: Disaster prevention and mitigation (Source: Boonchut, 2005)........4

Figure 3.1: National Highway 23...11

Figure 3.2: State Highway...12

Figure 4.1: Line diagram of Rourkela road map in Arc GIS............................18

Figure 4.2: Buffer of hazardous material carrying vehicles and populated area 20

Figure 4.3: Intersection Zone known as potential risk zones 21

Figure 4.4 24

Figure 4.6 25

Figure 4.7 25

Figure 4.8 26

Figure 4.9 26

LIST OF TABLES

Table 1.1 Effect of disaster (Source: Boonchut,2005)…………………………. 3

Table 1.3 potential impact area for different classes of hazardous materials…6

Table 1.4 effect of heat radiation…………………………………………………7

Table 3.1: Material Data from RSP…………………………………………….13

Table 3.2: Population data from Rourkela Municipal Office ………………..15

Table 3.3:Traffic data of NH 23 & State Highway……………………………15

Table 4.1: Equivalent for population Buffer…………………………………..19

Table 4.2: Buffer for area affected by accident of hazardous material carrying vehicles…………………………………………………………………………………19

Table 4.3: Risk assessment data table for number of people affected by accident of hazardous material carrying vehicles obtained from Arc GIS ….22

Table 5.1: Previous year accident data obtained from police station for NH 23 …………………………………………………………………………………………….27

Table 5.2: Previous year accident data obtained from police station for state highway……………………………………………………………………………..28

ABSTRACT

A number of accidents in the last two decades have increased public awareness of potential risks associated with hazardous material transport. Consequently, the safety management of this activity has become an issue of major importance. This paper presents a methodology and case study of Rourkela, which is to contribute a national action plan for hazardous material transport for Rourkela Steel Plant (RSP) .The main objective, is to develop a planning system for hazardous material transport. The planning system considers both economic and risk values. Risk assessment for the route system is discussed. Firstly, hazardous material identification and classification is studied and international norms for accidents of hazardous material carrying vehicle and their influence on routing decision are briefly described. . The consequences of the hazardous material accident are explosion, heat radiation, and toxicity. Secondly, intelligence phase is mainly used to understand the problem. GIS played an important role in risk assessment. The elements at risk include population, buildings and economic activitiesThirdly, Buffer analysis is done to identify the potentially hazardous road locations and necessary preventive measures are suggested for this. Accident rate is calculated from Crossthwaite, Fitzpatrick, TNO, and Gaussian equation considering the preventive measures for hazardous material carrying vehicles. The new accident rate calculated by using the above mentioned formula was compared with the previous 7 years data sets obtained from different police stations. The results obtained from the present method are promising.

The buffer analysis will be helpful for traffic planners to take decisions correctly in case of any future research in that area.

Keywords: Routing, Risk Assessment, Hazard,Links, Buffer, Geographical Information System (GIS)

CHAPTER 1

Introduction

Nowadays disasters have a high impact on the living conditions, economy, environment, properties and even human life. Their risks are rapidly increasing. In developed countries disasters mostly cause massive damage to the properties and environment while losses of human life are limited due to the availability of effective early risk prevention and reduction mitigation systems as well as good urban planning and the application of high standard infrastructure and buildings. In the developing countries, on the contrary, causalities are usually higher due to lack or inefficiency of risk prevention and reduction mitigation systems as well as worse urban planning and application of high standard infrastructure. Moreover, more than 95 percent of all deaths caused by disasters are in developing countries and losses due to disasters are also 20 times greater (as a percentage of GDP) than industrial countries. Losses from disasters include the following aspects.

Whether disasters are natural, manmade, or technological, they are usually represented by probability of occurrence (within a specific period of time in a given area) of a potentially damaging phenomenon. More specifically, United Nations ISDR (2002) proposed the risk definition as the probability of harmful consequences, or expected loss (of lives, people injured, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable/capable conditions. Hazard is defined by United Nations ISDR (2002) as a potentially damaging physical event, phenomenon and /or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro meteorological and biological) and/or induced by human processes (environmental degradation and technological hazards).hazards can be combined, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability.

Table 1.1 Effect of disaster (Source: Boonchut,2005)

	Human-social	Physical	Economic
Primary Effect	Fatalities	Ground deformation or loss of ground quality	Interruption of business due to damage to buildings and Infrastructure
	Injuries	Structural damage or collapse to buildings and infrastructure	Loss of productive workforce through fatalities,injuries and relief efforts
	Loss of income or employemt opportunities	Non-structural damage and damage to contents	Capital costs of response and Relief
	Homelessness		
Secondary Effect	Disease	Progressive deterioration Of damaged buildings and Infrastructure which are repaired	Losses borne by the insurance Industry weakening the insurance market and increasing premiums
	Permanent disability		Loss of markets and trade opportunities through short-term business interuption
	Psychological impact		Loss of confidence by investors, withdrawal of investment
	Loss of social cohesion due to disruption of community		Capital costs of repair
	Political unrest		

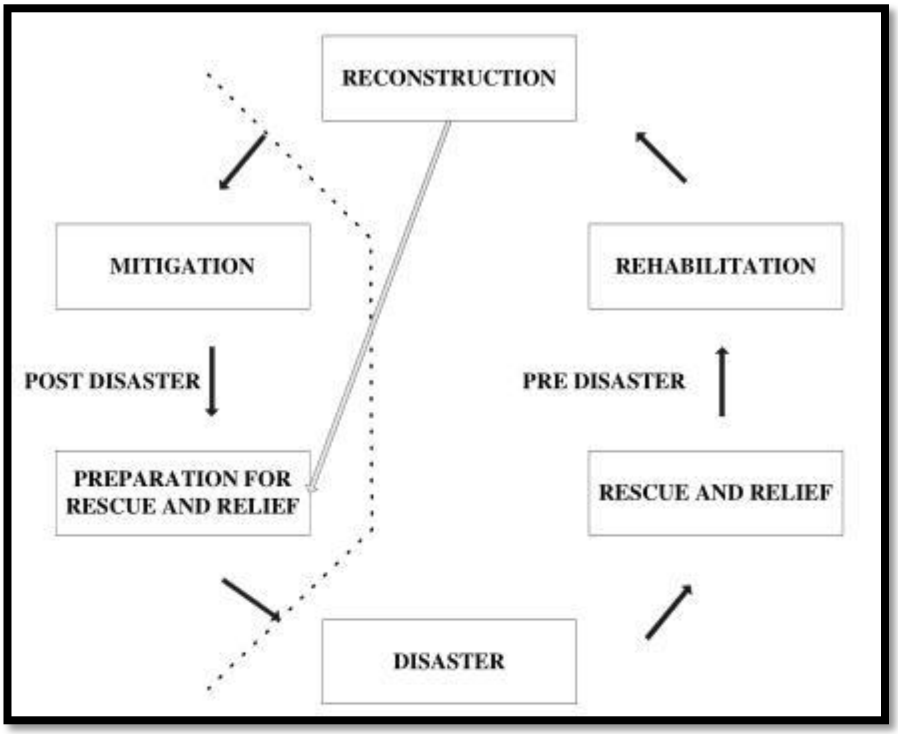

Figure 1.1: Disaster prevention and mitigation (Source: Boonchut, 2005)

Besides the natural hazard which is uncontrollable, the prevention and mitigation measure plays an important role in manmade disaster which is managable. Even though the risk is inevitable, it can be drastically reduced by good management.

1.1 Hazardous material

ADR the Indian Agreement concerning the International Carriage of Dangerous Goods by Road (ADR United nations 2002) proposed the definition of hazardous material or dangerous goods as following: Dangerous goods mean those substances and articles the carriage of which is prohibited by ADR, or authorized only under the conditions prescribed therein;

Dangerous reaction means:

- Combustion or evolution of considerable heat;
- Evolution of flammable, asphyxiant, oxidizing or toxic gases;
- The formation of corrosive substances;
- The formation of unstable substances; or
- Dangerous rise in pressure (for tanks only);

1.2 Classification

United Nations (2003) classifies the hazardous material into 9 categories in order to regulate for transporting, packaging, and labelling by considering their hazards.

Class or division is number assigned to the article or substance according to the criteria of one or more of nine UN hazard classes. Substances (including mixtures and solutions) and articles subject to these Regulations are assigned to one of nine classes according to the hazard or the most predominant of the hazards they present.

Some of these classes are subdivided into divisions. These classes and divisions are:

Class 1: Explosives

-Division 1.1: Substances and articles which have a mass explosion hazard

-Division 1.2: Substances and articles which have a projection hazard but not a mass explosion hazard

-Division 1.3: Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard

-Division 1.4: Substances and articles which present no significant hazard

-Division 1.5: Very insensitive substances which have a mass explosion hazard

Class 2: Gases

-Division 2.1: Flammable gases

-Division 2.2:Non-flammable, non-toxic gases

-Division 2.3: Toxic gases

Class 3: Flammable liquids

Class 4: Flammable solids; substances liable to spontaneous combustion; substances which, on contact with Water, emit flammable gases

-Division 4.1: Flammable solids, self –reactive substances and solid desensitized explosives

-Division 4.2: Substances liable to spontaneous combustion

-Division 4.3: Substances which in contact with water emit flammable gases

Class 5: Oxidizing substances and organic peroxides

-Division 5.1: Oxidizing substances

-Division 5.2: Organic peroxides

Class 6: Toxic and Infectious substances

-Division 6.1: Toxic substances

-Division 6.2: Infectious substances

Class 7: Radioactive material

Class 8: Corrosive substances

Class 9: Miscellaneous dangerous substances and articles

The numerical order of classes and divisions is not that of the degree of danger.

1.3 Risk related to hazardous material transport

Firstly, the factors that influence routing decision, from an environmental safety viewpoint may be grouped into three inter related categories;(1) mandatory factors such as legal and physical constraints(e.g. ,topography of the area) (2)Environment and land use risk(including various hazards and their associated risk)(3)subjective factors that reflect communities priorities and values which may not be quantified(e.g. ,population distribution, special land use, routing and emergency response).Secondly, the study defined and classified hazardous materials similar to UN classification and suggested to pay much attention on three groups;(1)those which appear to be potentially the most hazardous (2)those moved in greatest quantities according to goods movement statistics(3)various explosives and ammunitions

Table 1.3 potential impact area for different classes of hazardous materials

Class of Hazardous Material	Impact Area
Combustible Liquid	0.8 km all directions
Flammable Liquid	0.8 km all directions
Flammable Solids	0.8 km all directions
Oxidizers	0.8 km all directions
Non Flammable Compressed Gas	Downwind 2.1 km wide x3.2 km long
Flammable Compressed Gas	0.8 km all directions
Poison/Toxic	Downwind 2.1 km wide x0.5 km long
Explosives	0.8 km all directions
Corrosive	Downwind 0.8 km wide x1.1 km long

Table 1.4 effect of heat radiation

Heat radiation (kW/m^2)	**Effect**	
	Construction	**Human**
1.2	-	• Radiation received from the sun at noon in summer
2.1	-	• Minimum to cause pain after 1 minute
4.7	-	• Will cause pain in 15-20 seconds and injury after 30 seconds(at least second degree burns will occur)
12.6	• Causes the temperature of wood to rise to point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on the site away from the fire may reach a thermal stress level high enough to cause structural failure	• Significant chance of fatality for extended exposure. High chance of injury.
23.0	• Spontaneous ignition of wood after long exposure	• Likely fatality of extended exposure and chance of fatality for instantaneous exposure
35.0	• Cellulosic material will ignite with in one minute exposure	• Significant chance of fatality for people exposed instantaneously to the fire

CHAPTER 2

Literature Review

There are three purposes of the research. The first is to test whether some of the discrepancies found in the hazard and risk perception literature are due to differences between the connotations of the terms hazard and risk. The second purpose is to examine the relationship between willingness to read warnings and generalized cautious intent, as well as other relevant variables suggested by past literature. The third purpose is to examine the relation between objective measures of injury (e.g., frequencies of hospital emergency room admissions) and people's subjective perceptions. The results show that the expressions of hazardous, risky, dangerous and hazardous-to-use connote the same meaning to lay participants. Strong inter correlations are found between overall unsafeness (a composite of the four hazard-risk expressions), injury severity, cautious intent, and willingness to read warnings. (Young and Brelsford, 1990)

Unlike widely available literatures in hazardous material (HAZMAT) transportation that basically aim at finding non dominated paths for a given origin-destination pair, the main focus in this study is on vehicle routing problem with time window (VRPTW) aspect of HAZMAT transportation problem .Here presented a new multi-objective optimization model and its meta-heuristic solution technique using Ant Colony System for HAZMAT routing. In contrast to existing local routing models, minimization of risk and transportation cost considered in both route choice and routing phases of transportation process. (List and Turnquist, 1991)

Focus is given on modelling of probability of an undesirable consequence (such as injury, illness, or death) as a function of contaminant concentration. Here then applied an expected consequence approach, whereby risk is treated as the product of this probability and the population. Map algebra techniques, from Geographic Information Systems (GIS), allow us to combine concentration mathematically with the population distribution to estimate risk, for a release at any point on a network, for all parts of the study area. Map algebra further allows us to apply these risk estimates to every link in the network. (Zhang et al., 2000)

Geographic information system (GIS) platform introduced for a model of road accident risk; this platform provides the model with efficient data base management and spatial referencing capability. Both historical and statistical accident experience is taken as input in estimating accident risk at different locations and times. Myriad of risk factors are controlled explaining variations in accident involvement and injury severity. A GIS-based accident risk model developed for the Ontario highway network is described. The model provides estimates of accident risk at four levels of spatial aggregation as specified by the user: network wide, route-specific, route-section-specific and site specific. (Saccomanno et al., 2001)

A Transportation Risk Analysis (TRA) tool has been used to accurately assess the risk associated to a variety of road and rail transportation cases representative of hazardous materials transport by land in Sicily. Due to the high risk level, some risk mitigation options have been investigated: the possibility of changing route and/or transport modalities have been examined for each transportation activity, all the combinations of road, rail and intermodal (road rail) transport have been calculated and that minimizing the risk has been identified with the aid of the TRA tool. (Bubbico et al., 2004)

The study starts from a typical vehicle routing problem with time windows (VRPTW) and then considers time-dependent constraints while the traffic flow changes during the distribution processes. This affects delivery schedules, thus constituting a time-dependent vehicle routing problem with time windows (TDVRPTW). A time-dependent vehicle routing problem is constituted with time windows and split delivery (TDVRPTWSD) considering each customer can be served by multiple vehicles rather than by exactly one vehicle in one visit. The model feasibility is checked with the optimization software CPLEX, and then further applied Genetic Algorithm (GA) to solve a large-scale network problem. A revised Solomon instance with added time-dependent parameters and real wholesalers' data is tested. The results are also linked with real maps and displayed with Trans CAD. (Boonchut Prat, 2005)

GIS is used to map population density along a transportation corridor and evaluated whether there will be sufficient rider-ship to support public transit. Information on slope, soil conditions, and distance from a stream are overlaid to determine land most suitable for development and land preserved for environmental protection. Data from numerous departments, such as land-use planning, transportation, and economic development, pulled together, trends and interactions analyzed and visualized. These layers, in turn, are linked to data tables of additional information about a particular map feature, a street, ZIP Code, or census tract. Information displayed on different layers are compared and analyzed in combination. Software packages popular with planning professionals like Atlas GIS, MapInfo, and Environmental Systems Research Institute, Inc.'s ArcView and Arc Info GIS are used. (Datla, 2005)

A novel method of identifying road segments suggested that pose special hazards to drivers using a Geographic Information System (GIS).The computing focus of this paper is on spatial data analysis. The data include road centerline 3D coordinates (to identify roadway crests and troughs), aspect data(to determine ground surface slope), and sunlight data (to determine ground surface illumination values and identify shaded areas).Combining and analyzing these data sets identify potentially dangerous north facing, shaded, steep slopes over large geographic areas.(Pradhan et al.,2009)

In this research a new approach for road hazardous segment identification (RHSI) is introduced using Geospatial Information System (GIS) and fuzzy reasoning. In this research among all factors that usually play critical roles in the occurrence of traffic accidents, environmental factors and roadway design are considered. Using incomplete data the consideration of uncertainty is herein investigated using fuzzy reasoning. This method is performed in part of Iran's transit roads (Kohin-Loshan) for less expensive means of analyzing the risks and road safety in Iran. (Savelsbergh. 2013)

Objectives:

- To study the population affected by accidents of hazardous material carrying vehicles in the route joining Rourkela Steel Plant to Tarkera and Civil Township area
- To minimize number of vehicles, maximize volume delivered per km, widening of concerned road and providing regulatory traffic signs for speed limit from buffer analysis

CHAPTER 3

Study Area and Data Collection

3.1 Study Area:

The road segment taken for study is in between 22°13'18.92"N, 84°48'22.66"E and 22°12'18.11"N, 84°49'59.68"E, 22°12'18.11"N, 84°49'59.68"E and 22°13'15.01"N, 84°50'53.54"E(NH 23 joining Panposh and Rourkela Steel Plant)

Figure 3.1: National Highway 23

Second Road taken for study is in between 22°13'18.92"N, 84°48'22.66"E and 22°13'15.01"N, 84°50'53.54"E (State Highway joining Panposh and Rourkela Steel Plant)

Figure 3.2: State Highway

3.1.1 Back Ground of hazardous material transport in the study area

Most of the hazardous materials are imported to Rourkela Steel Plant by trains, trucks and pipes to their destinations or factories. Most of the trucks travel through NH 23 to carry hazardous materials to RSP and some follow the State Highway. Hazardous materials are chemical substances, which if released or misused can pose a threat to the environment or health. These chemicals are used in industry, agriculture, medicine, research, and consumer goods. Hazardous materials come in the form of explosives, flammable and combustible substances, poisons and radioactive materials. These substances are most often released as a result of transportation accidents or because of chemical accidents in plants.

The Rourkela city sprawls over an area of some 110 square kilometers. Here business hour is from 8.00 AM to 5.00PM.This indicates that rush hour with the traffic congestion problem is around 8.00-9.00AM and 5.00-6.00 P.M. At that time truck transport is not allowed through state highway, but it is allowed on NH 23.

3.2 Data Collection

According to my study area, I have collected data of raw materials carried to RSP from Rourkela Steel Plant, population data from municipal office of Rourkela and traffic volume of the 'NH 23' and 'State Highway' by traffic survey.

Table 3.1: Material Data from RSP

Origin-(BB) Brahmani Bridge, Destination-(RSPM) Rourkela Steel Plant

Time (p.m.)	Trailer Type	Orig/Dest	Trailer Placard	Material Hazard Class	Material ID	Material PSN	Number of vehicles
12.18	MC 306	BB-RSPM	3	Flammable Liquid	1993	Combustible liquid, NOS	12
12.19	MC 307	BB-RSPM	3	Flammable Liquid	1993	Combustible liquid, NOS	8
12.2	MC 407	BB-RSPM	3	Flammable Liquid	1247	Methyl Methacrylate Monomer	17
12.24	MC 306	BB-RSPM	9	Miscellaneous	3257	Elevated temperature liquid	12
12.25	Van	BB-RSPM	8	Corrosive Solid	1244	Batteries, wet, filled with acid	21
12.33	MC 312	BB-RSPM	9	Miscellaneous	2145	Combustible liquid	15
12.36	MC 306	BB-RSPM	3	Flammable Liquid	1993	Combustible liquid	12
12.39	MC 312	BB-RSPM	3	Flammable Liquid	1046	Heptanes	12

12.4	MC 312	BB-RSPM	3	Flammable Liquid	1203	Combustible liquid	12
12.44	MC 312	BB-RSPM	3	Flammable Liquid	1751	Combustible liquid	21
12.49	MC 312	BB-RSPM	3	Flammable Liquid	1203	Gasoline	14
12.56	MC 307	BB-RSPM	3	Flammable Liquid	2982	Corrosive liquid, basic, organic, NOS	3
13.05	MC 307	BB-RSPM	3	Flammable Liquid	3267	Gasoline	11
13.13	MC 307	BB-RSPM	3	Flammable Liquid	1993	Diesel Fuel	12
13.16	MC 307	BB-RSPM	8	Flammable Liquid	1244	Gasoline	12
13.22	Van	BB-RSPM	8	Corrosive	2145	Corrosive Solid, NOS	17
13.25	MC 312	BB-RSPM	3	Nonflammable gas	3077	Diesel Fuel	15
13.27	MC 306	BB-RSPM	3	Flammable Liquid	1457	Diesel Fuel	19
13.33	MC 407	BB-RSPM	3	Flammable Liquid	1884	Diesel Fuel	19
13.35	MC 407	BB-RSPM	3	Flammable Liquid	1993	Elevated temperature liquid	2

13.35	MC 407	BB-RSPM	3	Flammable Liquid	1993	Elevated temperature liquid	4

Table 3.2: Population data from Rourkela Municipal Office

Name of the Area	Deongan	Tarkera	Tina Colony	Raghunathpali	Civil Township	Orampara
Population	12,910	3,729	8,115	9,204	11,511	6000

Table 3.3:Traffic data of NH 23 & State Highway

1 hour Traffic volume Data of NH 23 away from Tarapur									
Vehicle	**Truck**			**Car (4 wheeler)**	**2 wheeler**	**Auto**	**Bus**	**pedal cycle**	**Sum**
Type	**2 axle**	**3 axle**	**multi axle**						
No. Of vehicles	80	0	20	80	244	1	1	84	
Equivalency factor	3	3	5	1	0.5	1	3	0.5	
Equivalent traffic	240	0	100	80	122	1	3	42	588
1hour traffic volume data of NH 23 towards Tarapur									
No. of vehicles	232	232	232	232	232	232	232	80	
Equivalanecy	3	3	5	1	0.5	1	3	0.5	

factor									
Equivalent traffic	696	696	1160	232	116	232	696	40	3868
1hour Traffic volume data of State Highway towards Hanuman Vatika									
No. Of Vehicles	20	12	4	148	324	44	12	64	
Equivalency Factor	3	3	5	1	0.5	1	3	0.5	
Equivalent traffic	60	36	20	148	162	44	36	32	538
1hour Traffic volume data of State Highway away from Hanuman Vatika									
No. Of Vehicles	32	12	0	104	372	60	4	160	
Equivalency Factor	3	3	5	3	3	3	3	0.5	
Equivalent Traffic	96	36	0	312	1116	180	12	80	1832

CHAPTER 4

Methodology

4.1. Map preparation

ArcGIS is a geographic information system (GIS) for working with maps and geographic information. It is used for: creating and using maps; compiling geographic data; analyzing mapped information; sharing and discovering geographic information; using maps and geographic information in a range of applications; and managing geographic information in a database. The system provides an infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the Web.

ArcGIS includes the following Windows desktop software:

- ArcReader, which allows one to view and query maps created with the other ArcGIS products;
- ArcGIS for Desktop, which is licensed under three functionality levels.
- ArcGIS for Desktop Basic (formerly known as ArcView), which allows one to view spatial data, create layered maps, and perform basic spatial analysis;
- ArcGIS for Desktop Standard (formerly known as ArcEditor), which in addition to the functionality of ArcView, includes more advanced tools for manipulation of shapefiles and geodatabases; or
- ArcGIS for Desktop Advanced (formerly known as ArcInfo), which includes capabilities for data manipulation, editing, and analysis.

First the toposheet of Rourkela is scanned by GIS scanner and saved in '.tif' format and opened in Arc GIS. Then it is georeferenced in Arc GIS by taking 4 control points chosen from google earth. The coordinates of control points are (22.253, 84.828), (22.25, 84.879), (22.223, 84.867), (22.227, 84.832). Then shape file of the road map is created in Arc Catalog with feature type polyline and saved. This shape file is opened in Arc GIS as a layer attribute on the previously opened Rourkela road map sheet. The road map is drawn on existing map using editor tool. The line diagram for road is ready for use. Similarly point diagram for areas is drawn creating shape file of feature type point and adding it to the layer attribute of the map. Then for buffer creation for showing effect of accidents of hazardous material carrying vehicle on population, a center line is drawn on NH 23 line diagram and saved. The line diagram for NH 23 is drawn because the entire hazardous material carrying vehicle moves on that road only.

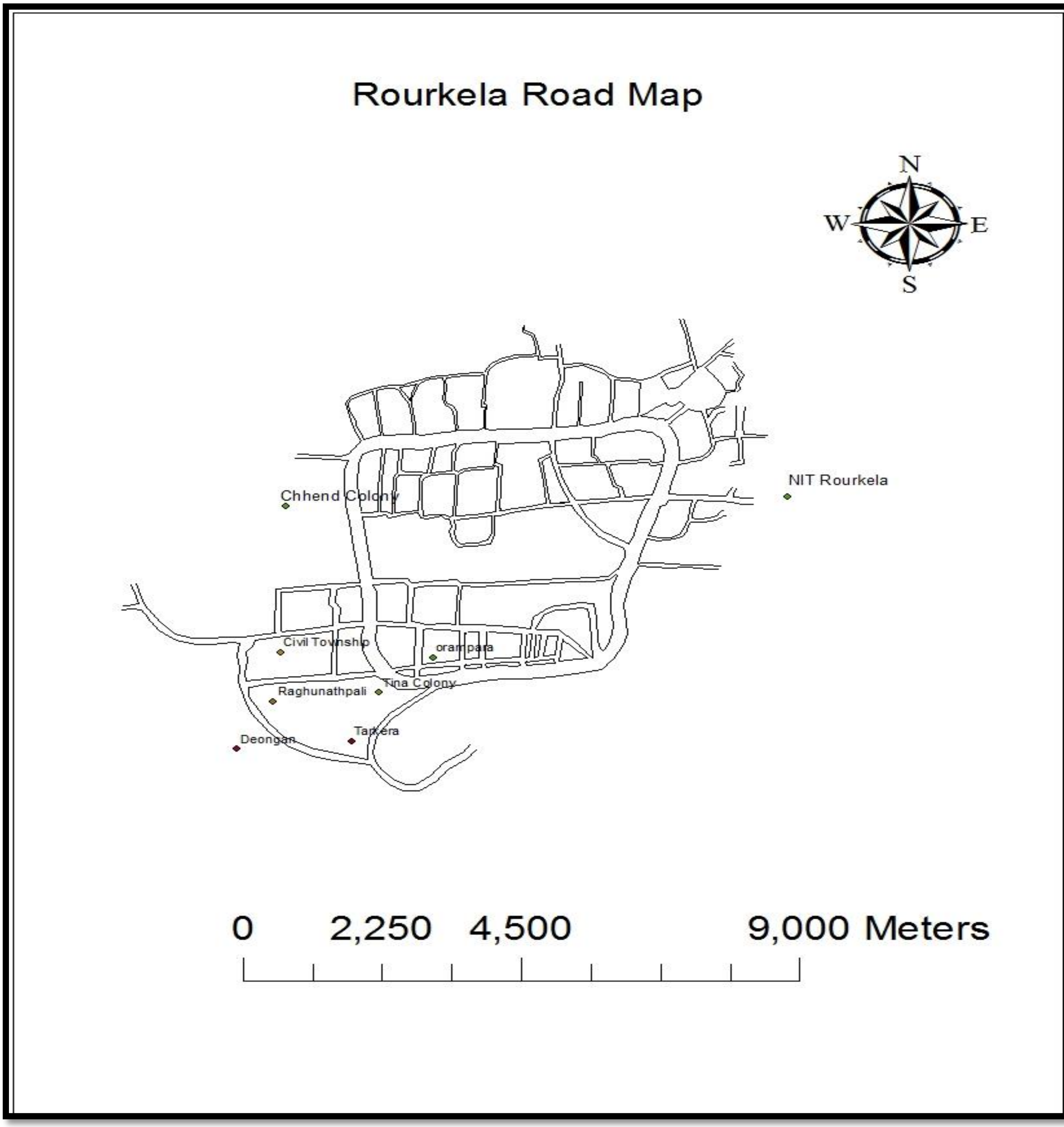

Figure 4.1: Line diagram of Rourkela road map in Arc GIS

4.2 Buffer Creation

Population buffer is made by assuming the population is uniformly distributed in the buffer area and radius for buffer taken from the center of area (center of the given area is determined from google earth)

Table 4.1: Equivalent for population Buffer

Name of Area	Deongan	Civil Township	Tarkera	Tina Colony	Raghunathpali	Oramapara
Population	12,910	11,511	3,729	8,115	9,204	6,000
Equivalent radius (m)	600	535	173	377	427.7	278.9

Table 4.2: Buffer for area affected by accident of hazardous material carrying vehicles

Material	Combustible liquid (CL)	Basic, organic, NOS (BN)	Flammable Liquid (FL)	Corrosive Solid (CS)	Diesel (D)	Non Flammable liquid (NFL)
Buffer Band	800	1700	1000	700	50	2100

4.3 Drawing of buffer zone in ArcGIS

1. When all the layers i.e. point layer for area and line layer for road NH 23 is turned on, then arc tool box window is opened. Then go to analysis tool->proximity->Buffer for drawing population buffer for the area. Radius for buffer drawing is chosen from table 5.1.
2. Then buffer for effect of accidents of hazardous material carrying vehicle is drawn by taking band width from table 5.2.Similar procedure is followed as that of population buffer except here multiple ring buffer is chosen from buffer menu instead of buffer option.

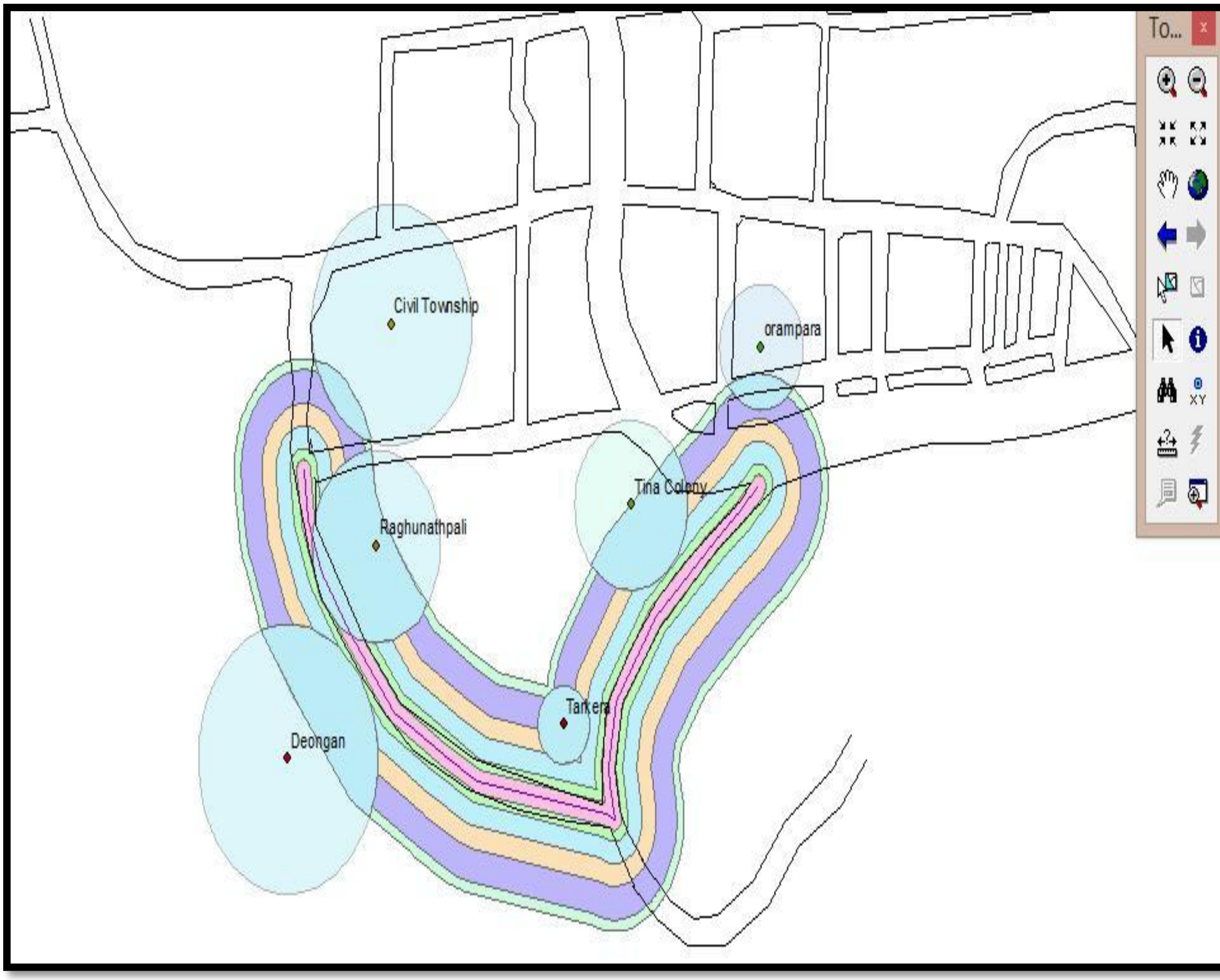

Figure 4.2: Buffer of hazardous material carrying vehicles and populated area

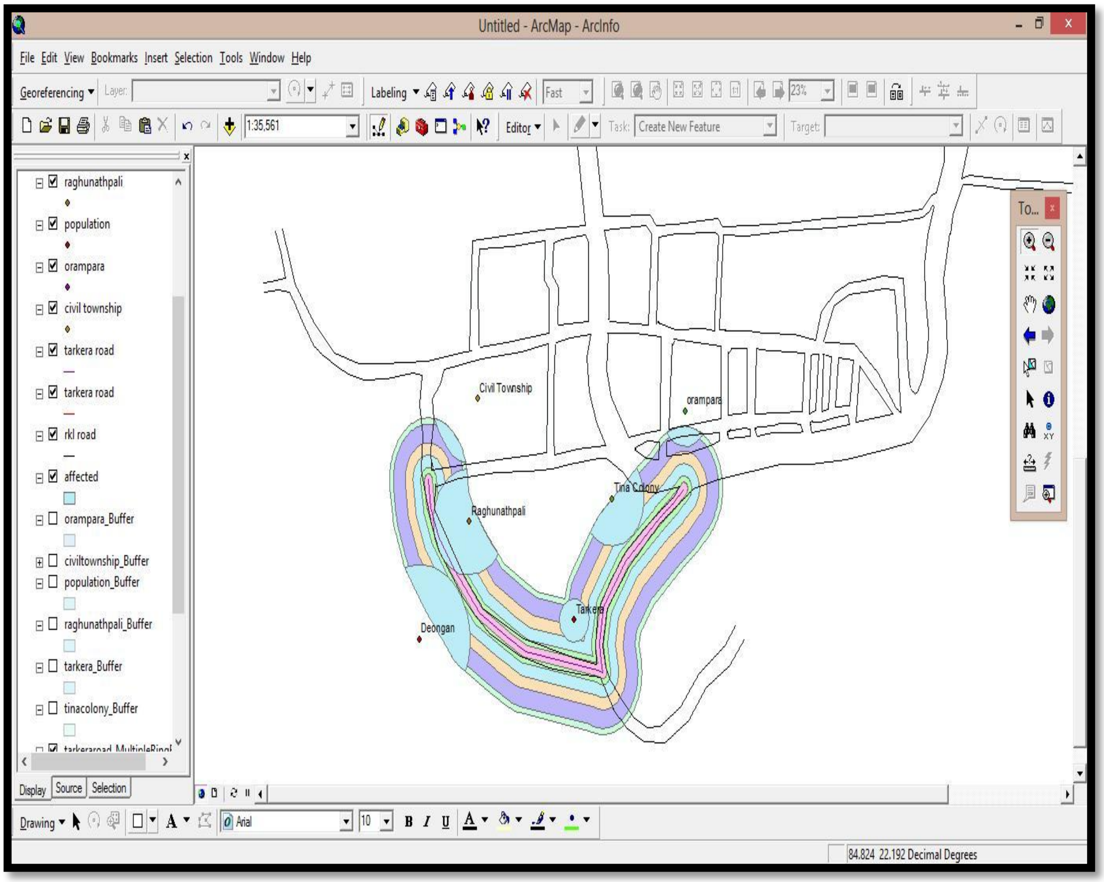

Figure 4.3: Intersection Zone known as potential risk zones

Then populated areas affected by accident of hazardous material are calculated from the intersection of population buffer and material buffer.

4.4 Routing Survey for Hazardous materials

Based on database, risk analysis has been conducted for every route involving in hazardous material transport. The analysis concerned three hazards or potential consequences; heat radiation, explosion, toxicity by simulating from Crossthwaite, Fitzpatrick et al.(1988), TNO(1980), and Gaussian equation respectively. The equation is as follows:

New accident rate = (accident rate) x P (spill) x L

Where

A = the number of accident

V= Average annual daily traffic AADT (vehicle)

P (spill) =Probability of spill

T = Time period (year)

L = Length of segment (km) Accident rate = A x 1000000/ (365xTxVxL)

4.5 Observation

1. It is observed from the map that Tarkera population is fully affected by accidents of material transportation.
2. Raghunathpali population is affected by the accident of all the hazardous materials transported.
3. Civil township population is least affected. The population affected from different area is listed in the table 4.3.

Table 4.3: Risk assessment data table for number of people affected by accident of hazardous material carrying vehicles obtained from Arc GIS

Place	Total population (P)	Total Area(A) (m^2)	(P/A)	Affected Area(a) (m^2)	population affected(P/A)*a	Material
Deongan	12910	1136611.837	0.0114	316928.16	3600	Combustible liquid
	12910	1136611.837	0.0114	260385.2043	2958	Basic, organic, NOS
	12910	1136611.837	0.0114	124938.1922	1419	Flammable Liquid
	12910	1136611.837	0.0114	50861.767	578	Corrosive solid
Raghunathpali	9204	575774.0806	0.016	381922.986	6105	Combustible liquid
	9204	575774.0806	0.016	342218.448	5470	Basic, organic, NOS
	9204	575774.0806	0.016	242007.77	3868	Flammable Liquid
	9204	575774.0806	0.016	161377.218	2580	Corrosive Solid
	9204	575774.0806	0.016	85487.243	1366	Diesel

	9204	575774.0806	0.016	45298.96	724	Non Flammable liquid
Tarkera	3729	94077.652	0.0396	94077.652	3729	Combustible liquid
	3729	94077.652	0.0396	93013.18	3687	Basic, organic, NOS
	3729	94077.652	0.0396	52583.386	2084	Flammable Liquid
	3729	94077.652	0.0396	7633.8752	303	Corrosive solid
Tina Colony	8115	447592.418	0.0181	223945.3211	4060	Combustible liquid
	8115	447592.418	0.0181	185676.99	3366	Basic, organic, NOS
	8115	447592.418	0.0181	85679.2612	1553	Flammable Liquid
	8115	447592.418	0.0181	30098.897	546	Corrosive solid
Civil Township	11511	900405.127	0.0128	49279.345	630	Combustible liquid
	11511	900405.127	0.0128	28219.344	360	Basic, organic, NOS
Orampara	6000	244417.142	0.0245	47975.116	1178	Combustible liquid
	6000	244417.142	0.0245	27893.82	685	Basic, organic, NOS

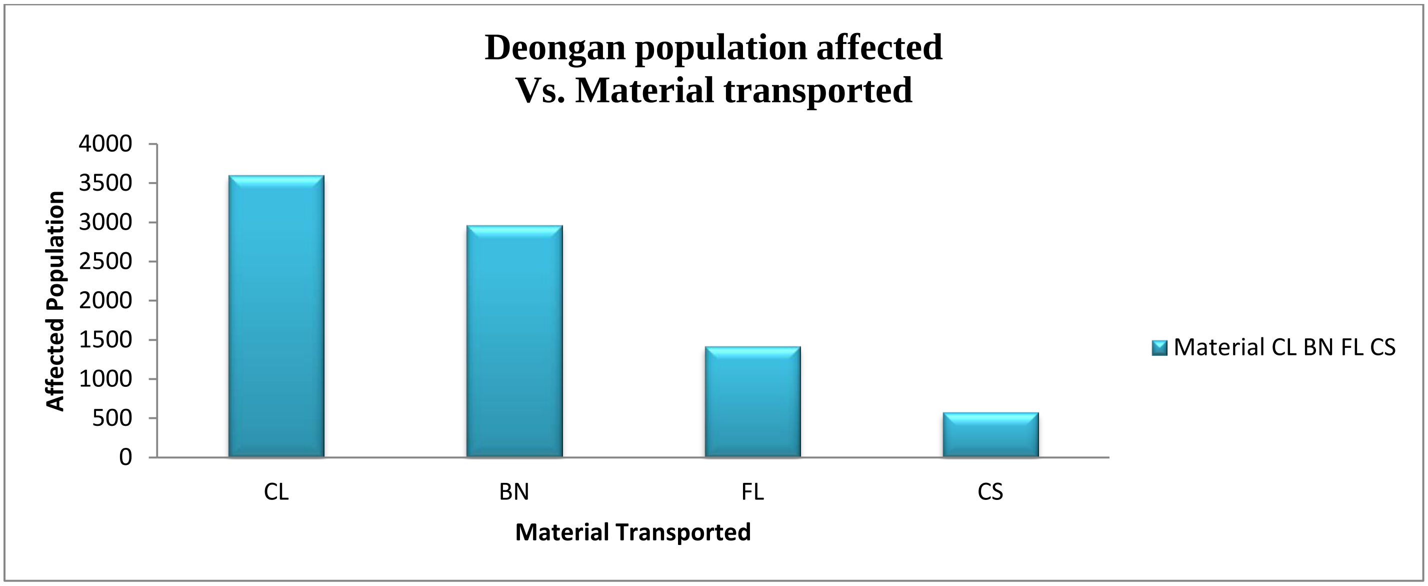

Figure 4.4

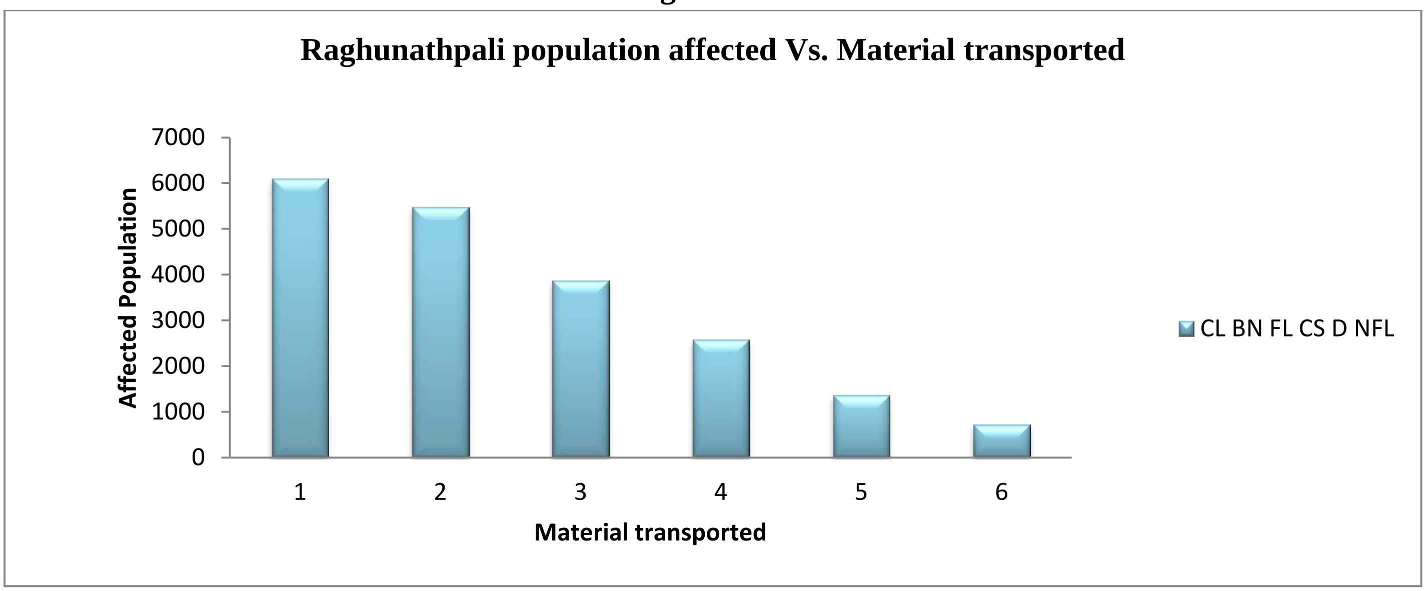

Figure 4.5

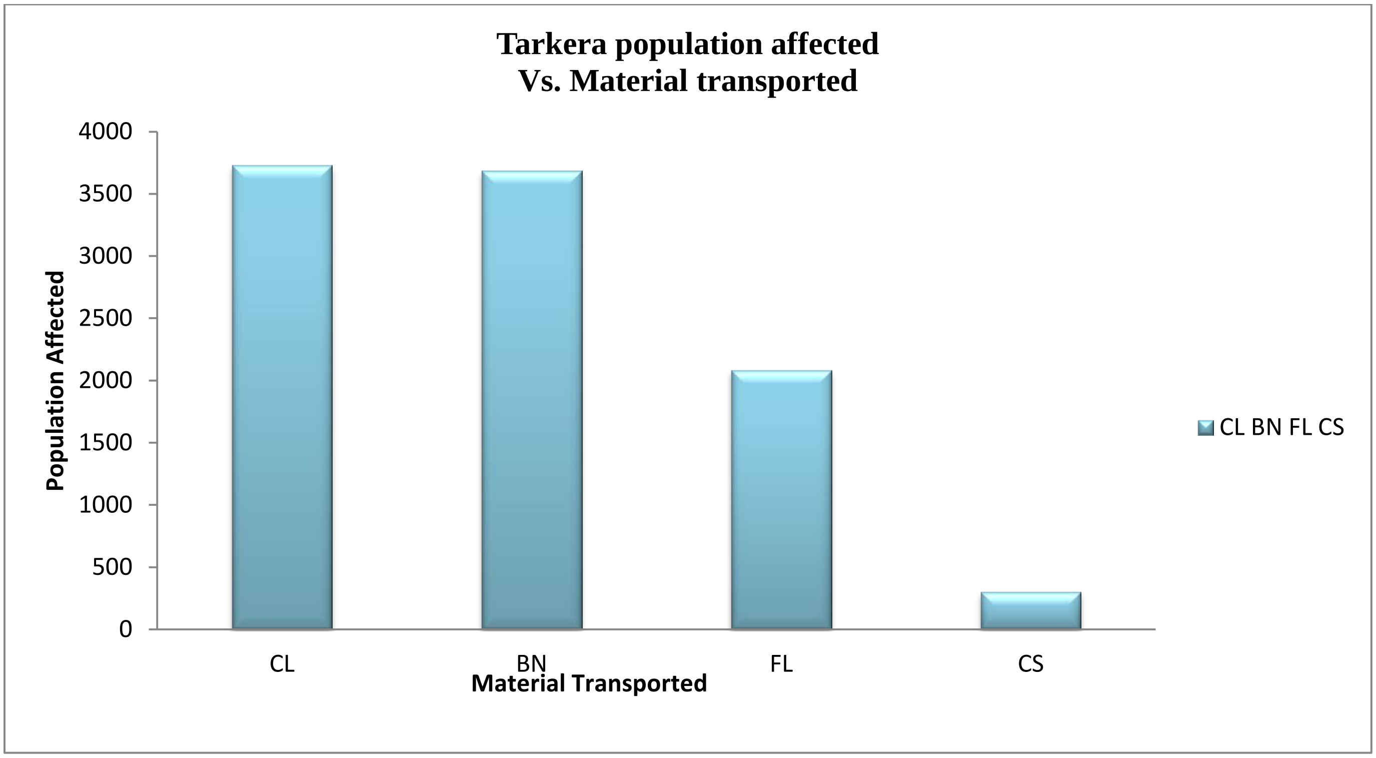

Figure 4.6

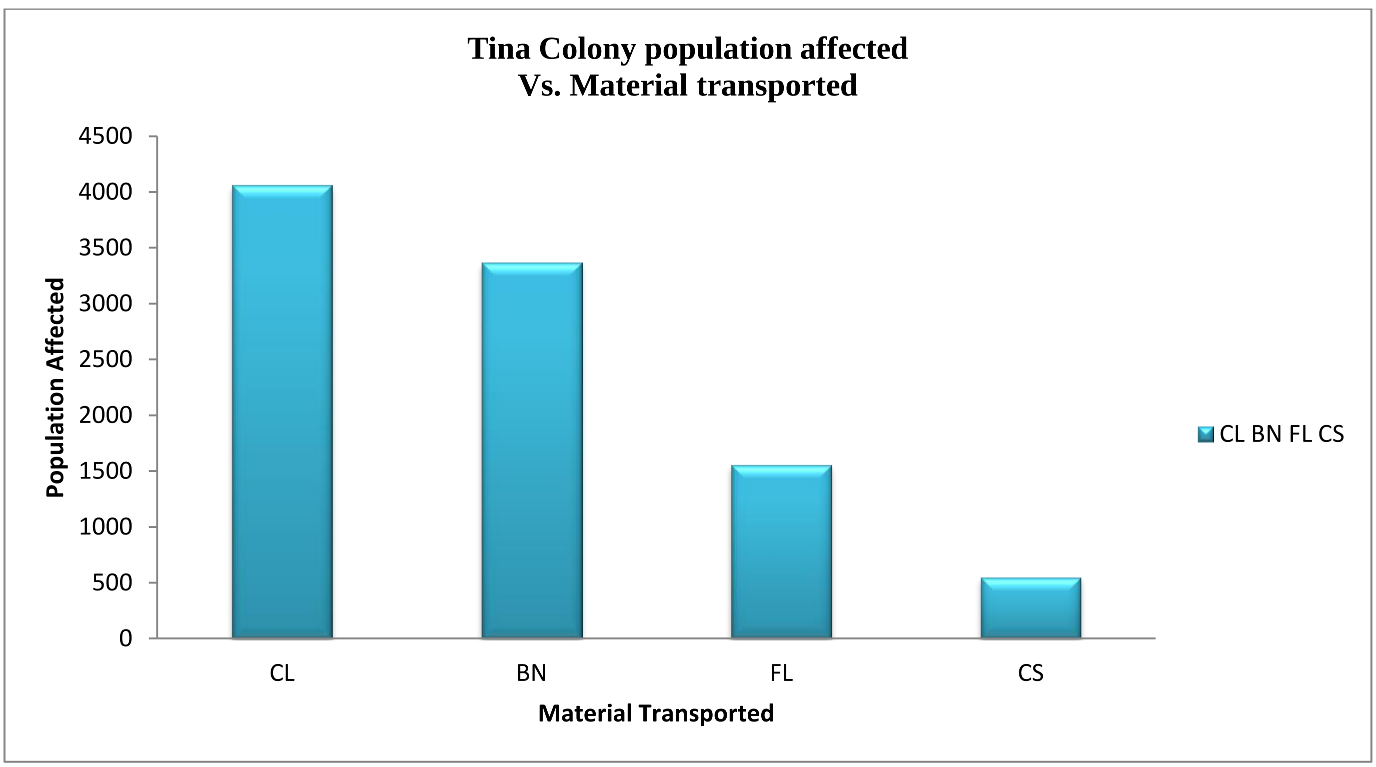

Figure 4.7

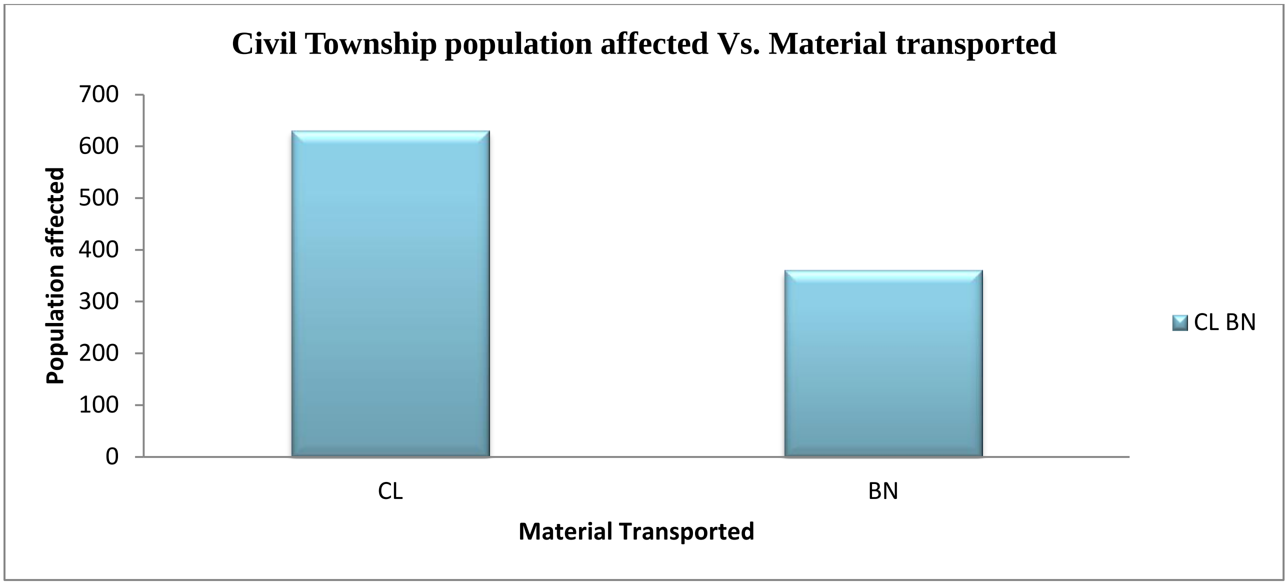

Figure 4.8

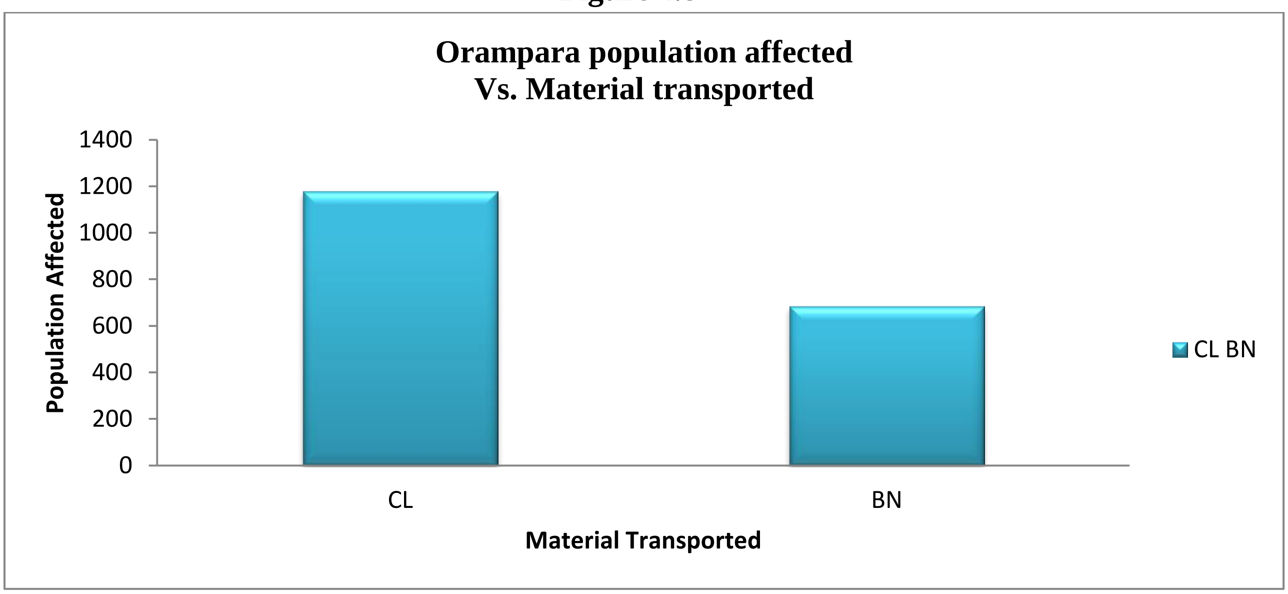

Figure 4.9

Figure 4.4-4.9 is plotted taking the population affected data as obtained from table 4.3 and material transported through the route.Here CL,BN,FL,CS,D,NFL represents Combustible Liquid,Basic organic NOS,Flammable Liquid,Corrosive Solid, Diesel and Non Flammable Liquid respectively.

CHAPTER 5

Results & Discussions

For NH 23

Table 5.1: Previous year accident data obtained from police station for NH 23:

Year	2006	2007	2008	2009	2010	2011	2012
Annual Accidents	21	18	19	21	26	21	19

Using Crossthwaite, Fitzpatrick et al. (1988), TNO (1980), and Gaussian's combined equation:

New accident rate = (accident rate) x P (spill) x L

Where

New

P (spill) =Probability of spill

Accident rate = A x 1000000/ (365xTxVxL)

A = the number of accident

T = Time period (year)

V= Average annual daily traffic AADT (vehicle)   L = Length of segment (km)

Calculation of new accident rate taking necessary preventive measure like road widening and use of traffic regulatory signs in potential risk zones:

Let the road is widened to 4 lane divided road from two lane one way road

T=1 year

V=25000 pcu/day (For 4 lane road)

L=4 kms

P (spill) =.91(considering maximum affecting hazardous material Non Flammable liquid)

Accident rate =19x1000000/ (365x1x25000x4)

= .52

New accident rate = (accident rate) x P (spill) x L

=.52x.91x4=2

So from the above calculation we observe that if NH 23, which is two lane, one way road, is converted to 4 lane divided road having capacity nearly 25000 pcu/day then the accident rate can be reduced from 19 to 2.We can also use 6 lane divided road which will result in lesser accident road but it will be highly uneconomical.

For State highway

Table 5.2: Previous year accident data obtained from police station for state highway*:***

Year	2006	2007	2008	2009	2010	2011	2012
Annual Accidents	5	3	8	4	5	7	5

T=1 year

V=25000 pcu/day (presently it is 4 lane divided road)

L=3.171 kms

P (spill) =.91(considering maximum affecting hazardous material combustible liquid obtained from Pasquil table)

Accident rate =19x1000000/ (365x1x25000x3.171)

= .65

P (accident) = (accident rate) x P (spill) x L

=.65x.91x3.171=2(nearly same accident value as that of previous years and this route has very low accident rate. So no need of road widening)

To improve safety of normal traffic, traffic regulatory sign like speed limit of 30kms should be provided in the critical zone (intersection area of population buffer and material affecting buffer) for both NH 23 and State Highway.

CHAPTER 6

Summary and Conclusion

6.1 Summary

Buffer analysis of potential hazardous road locations are carried out and necessary preventive measures are suggested and following points are concluded as:

1. Risk analysis is introduced in intelligence phase. Arc GIS 9.3 is used as a tool to implement risk assesment. Methodolgy of buffer creation is applied for the study area NH 23 and State Highway.
2. The accident rates calculated from the Crossthwaite, Fitzpatrick et al., TNO, and Gaussian's equation is compared with previous year accident rates and found to be minimum. Road widening and traffic regulatory signs as preventive measures are suggested.
3. In the end we find that hazardous material transport has its roots in a combination of faulty engineering and human weakness. Since the latter includes basic human flaws such as greed and carelessness, against which there are few reliable defenses. It is the engineering routes which offer the chance of success. There is no possibility of total risk free design and construction because it would be too expensive to build against any possibility of failure. The disasters mentioned would have been reduced, although not eliminated, if the hazardous material truck transported through low population density, low density traffic volume, or low accident rate.

6.2 Conclusion

From the observations made by using buffer analysis for risk assessment we can conclude that the Tarkera population is fully affected by accidents of material transportation while Raghunathpali population is affected by the accident of all the hazardous materials transported and the Civil township is least affected by it. Hence the road must be widened along with instalation of proper traffic regulatory signs to provide safe transportation of hazardous material on the route..

First of all come up with the best alternative as a route for hazardous material transport, the concept of risk assessment will be adapted; buffer zone, according to level of damages, will be set up as Emergency Planning Zone along the designated route for future planning by traffic planners.

References

- Boonchut Prat, *Decision Support for Hazardous Material Routing*, International Institute for Geo-information Science and earth observation enschede,the Netherlands ,March 2005

- Bubbico Roberto, Sergio Di Cave, Mazzarotta Barbara, *Risk analysis for road transport of hazardous materials: a GIS approach*, Journal of Loss Prevention in the Process Industries 17 (2004) 483–488

- Datla Sandeep, *Adaptive Design for DSS*, Database, Department of Civil Engineering, IIT Bombay, 12, Nos. 1 and 2 (Fall), 15-25(2005).

- George List, Mark Turnquist, *Logistics for hazardous material transportation: Scheduling, Routing and Siting*, University Transport Research Centers Program, Region II, october ,1991

- Pradhan Anu and Rasdorf William, P.E., F. Asce, *GIS Use for Identification of Potential Road Hazard Locations*, American Society of Civil Engineers, Volume 13, Number 2,(2009) Pages 157-167

- Saccomanno F. F., Chong K. C., Nassar S. A., *Geographic Information System Platform for Road Accident Risk Modeling*, Committee on Traffic Records and Accident Analysis(2001)

- Savelsbergh Martin., *Vehicle Routing and Scheduling*, The Logistic Institute ,Georgia Institute of Technology(2013)

- Young Stephen L., Brelsford John W., *Judgments of Hazard, Risk, and Danger: Do they differ?* ,Department of Psychology ,Rice University ,Houston, Texas, 77251 (1990)

- Zhang Jianjun, Hodgson John, Erkut Erhan. *Using GIS to assess the risks of hazardous materials transport in networks*, European Journal of Operational Research 121 (2000) 316–329