Potential use of GIS in Hazardous Waste Transportation

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Abstract

The objective of this project is to present a literature review of hazardous waste transportation and the impact on the environment by studying Canada's regulations and legislations and examining the potential use of GIS in reducing hazardous waste transportation. It is hard to find a specific definition for Hazardous Waste since the hazard could be generated form a wide variety of sources. Therefore, the hazardous wastes defined according to the Transportation Dangerous Goods Act as those wastes that due to their nature and quantity are potentially hazardous to the human health and the environment. Hazardous wastes usually contain explosive, volatile, toxic, radioactive and flammable materials, and that therefore, requires special techniques to handle the hazard to avoid creating environmental pollution or health hazards during packing, transportation, and disposals. The government of Canada and the environmental experts made tremendous efforts to reduce the potential hazardous resulted from handling, shipping, treatment and disposal for the hazardous waste and find out alternatives to control that hazard and avoid any environmental impact.

This paper also presented and discussed some studies that used to point out the important role of the GIS in minimizing the impact of potential hazard and reducing incidents regarding hazardous waste shipments through determination of the short and safety transportation routes.

3) International and between provincials movements of hazardous wastes under the legislative authority of the Transportation of Dangerous Goods Act.

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INTRODUCTION

Waste hazardous materials can have a negative impact on the environment and the human health if it is not properly controlled and managed. Hazardous waste has a significant impact on every thing around includes vegetation, water, air and human health, the damage degree based on the time of the exposure to the hazard. Hazardous wastes are mainly generated from the industries manufacturing, hospitals, agricultures pesticides, business activities, oil spills through transportation, household's activities and there are some hazardous wastes are prohibited, which are regulated under the clean air Act, and clean water Act. The hazardous waste generally contains on a different substances such as metal, chemical, pesticides, organics, inorganic, solid, liquid, and gaseous and sometimes combination of some of them, but the biggest threat comes from the chemical wastes evolved from the contaminated ground water. Hazardous wastes have the most important potential environmental impact. In the past few decades, throughout the country, the concern for hazardous waste has grown tremendously due to the dangerous that threaten public health and the environment. In response to this concern, many legislatives and potentials have designated to control the wastes hazard problems. Generators, transporters, and handlers play the most important roles of producing the hazardous wastes problems. Generator, are the institutions which produce the wastes whether manufactures or non manufacturing, which known as on site wastes hazardous waste management which present 80 - 95 percent of

hazardous waste volume, about 5-20 percent of hazardous waste are transported to off site waste hazardous facilities. There are different modes of transporter waste hazardous (highway, rail way, air, water) and each mode has it's own regulation and specifications. The transporters are responsible of transport the hazardous waste from the site to any commercial facility. Handlers are a commercial agents involved in the storage, treatment, and disposal process (3).

Sitting hazard waste facility is a very complicated issue and presents a basic political and social dilemma. Sitting hazardous waste facility is not easy since no body likes to have a hazardous waste facility in his or her community. It is therefore, the process of installing a hazardous waste management facility is very hard to achieve a compromise between the public demand for health protection and the right location from the engineering perspectives (1).

Canada has to meet the international's obligation in terms of import and export hazardous wastes trans bound movements. Canada and United States have a common interest in environment sustainability to provide a clean and healthy environment. Canada is a party of the Basel Convention on the control of the hazardous wastes trans boundary movements through the environmental sound management. The federal and provincial government cooperated together and produced a manifest system to track wastes from generator to final site of storage, treatment and disposal, and ensure that, the safety precautions information delivered to every provincial throughout the country

There is some facilities devoted just for hazardous wastes in Canada, such as: the Safety kleen Ltd. near Sarnia, in September 1997,its capacity was 7.5 million tons under the control of Environmental Assessment Act. The facility was approved without notifying public, in 1999 the facility temporary prohibited due to some hazardous problems such as ground water contamination and leaching. The other facility is Philip Service Corporation in Stony Creek, the facility approved without notifying public under the control of Environmental Assessment Act c. It was approved as a non-hazardous landfill, but it was found that, the operator accepting hazardous wastes from USA. The ministry of the Environment decided to stop the activity immediately on that landfill in 1999, the work started again later (1).

1.1 Characteristics of Solid Wastes

A solid wastes not necessary to be in a solid physical condition it might be in a semi solid, liquid or even in a gas condition. It is very difficult to determine whether the manufacturing facility generates a hazard wastes or no, if so the materials have to meet the specifications and the definition of the hazardous wastes materials. The proper definition to the solid wastes is any materials have to go through the following

- Disposed of or abandoned in lieu of disposal.
- Burned or incinerated or recycled.
- Considered inherently waste.

If the material is not solid wastes it can't be considered be a hazardous

Wastes (2).

1.2 Hazardous Wastes Materials

Hazardous waste is not acceptable no matter what due to the damage that affect the environment includes vegetation, water, air, and human health, the amount of damages based on the degree of exposure to the hazard. Hazardous wastes are mainly generated from the industries manufacturing, hospitals wastes, agricultures crops and pesticides, mining overburden returned to the mine side, fly ash waste, bottom ash waste, slag waste, flue gas emission control waste generated form combustion of coal or fossil fuels, produce crude oil, natural gas, geothermal energy, oil spills through transportation, solid wastes from the extraction, beneficiation, minerals, cement kiln dust waste, discarded wood, business activities, drilling fluids, household's activities. The hazardous wastes generally is comprised of different substances such as metal, chemical, pesticides, organics, inorganic, solid, liquid, and gaseous and sometimes combination of some of them. and there are some hazardous wastes are prohibited, which are regulated under the clean air Act, and clean water Act. The hazardous wastes materials could be very dangerous due to the physical, chemical or biological activities and its consequences. For examples, Ignitable wastes such as crude oils and its product could cause fire easily. Corrosive wastes such as steel or other metal materials could be very dangers since it reacts easily with other wastes and cause rust and contamination, added to the probability of causing injuries from the sharp edges due to the rust and

corrosions. Chemical wastes such as reactive wastes, which is very harmful on the human life and the environment, it cause explosions, or produce toxic gases. Toxic wastes could be solid or liquid or gas, the dangerous based on the degree of exposure. Explanation of the hazardous wastes characteristics in details as following (27).

1.3 Characteristics of Hazardous Waste Materials

1.3.1 Ignitability

An ignitable waste materials cause fire hazard during shipment, transportation, treatment and etc. The waste materials considered ignitable if the following characteristics exist:

- Liquid and has a flash point less than 140° F or 60° c these are moderate flammable, and less than –18 ° C is extremely flammable
- Not liquid and is able under a certain temperature and pressure cause fire through friction, absorption of moisture or, when ignited and cause very bad burn (2).

1.3.2 Corrosively

A corrosive wastes is capable of deteriorate the containers, damage human issue, dissolve toxic components of other wastes. The waste materials considered corrosively if the following characteristics exist.

- The waste materials contain pH less than or equal to 2 or greater than or equal to 12.5

- The waste materials corroding SAE 1020 steel at a rate greater than 0.25 inches per year at a temperature of 130 F (2).

1.3.3 Reactivity

A reactive waste materials are chemically unstable, it react very quickly if it expose to air or mixed with water and also have the ability of liberate toxic gases, and the ability to explode. Therefore, the reactive wastes require a special handling and storage. The reactive wastes have the following characteristics:

- Unstable and easy to change its characteristics
- Quick react with water and air
- Sometimes generate potentially explosive mixtures with water
- Generate toxic gases or vapors which could be very dangerous on the human health and have a negative impact on the environment
- If exposed to pH between 2 and 12.5, it generates toxic gases or fumes could cause a negative effect on the environment
- It has tendency of explosive reaction due to the quick react with the other wastes especially if it exposed to high temperatures or pressures

Referred to these characteristics, there is a special requirements are required during the storage or transportation or improper land disposal to avoid any problem might cause a tremendous damages to the human life and the environment as well. Therefore, awareness and a good understanding of the wastes characteristic and regulations are very essential to get involved in hazardous wastes process (2).

CHAPTER 2

Causes and Consequences of Hazardous Wastes

2.1 Causes and Consequences of Spills

- The spill result in release of flammable liquid of gases could cause fires and explosions
- Spills result In a release of toxic liquids could have a bad impact on the human health and the environment
- Spill can reach sanitary or storm sewers and cause contaminations

2.2 Causes and Consequences of Fires

- The fire probably cause release toxic vapor which have a bad impact on the environment
- Spreading of the fire could ignite other materials and spread the fire to other off site areas and increase environmental damages
- By using water or water and chemical fire could cause contaminated migration

2.3 Causes and Consequences of Explosions

- The explosions could release of toxic materials and affect the human health
- The explosions could release flying materials or shock waves could be very dangerous and cause human death

- The explosion could ignite other hazardous materials and cause more damages, which is going to be hard to control (27).

2.3.1 Storage

Environmental issues and health hazard can be generated during the storage of hazardous waste. Particularly the chemical wastes, proper storage is very important to ensure safety. The storage must be subjected to safety precaution. Storage facilities have to be guided by the federal and provincial government, the guidelines include regulations and conditions have to be followed. For example, tanks or containers must be labeled or marked clearly and show the sign of hazardous wastes words. Generators who accumulate wastes they must have the following on site

- Alarm system and internal communication on site
- Fire extinguishers
- Telephone or two way radio at the scene of operations capable of contact somebody outside the site
- Fire control equipments such as foam, inert gas, or dry chemicals or any extinguish materials
- Spill control equipment and regulations
- Water at adequate pressure to help during fires or sprinkler system
- Special protective clothing and gloves
- Decontamination equipments (2).

2.3.2 Shipping

The Transportation of Dangerous Goods legislate regulations to control hazardous waste transportation by classifying the hazardous with respect the harm of the materials, and the documents should be carried with waste shipment and the safety precautions that needed in case of emergency. The regulations are same in all Canada, even though there are some considerable changes between the provinces. The generators of hazardous wastes have too meet their obligations under the local jurisdictions regulatory of hazardous wastes in the way of shipping hazardous wastes onsite. The federal government in Canada has made a tremendous effort of enactment of the Transportation Dangerous Goods Act. This act mainly applies on the hazard wastes. The Act includes prohibition of transportation of dangerous goods by any mood of the transportation unless they meet all the requirements and the safety standard. The wastes should placed in containers has standard specification as following. First, the date should be clearly written in each container for inspection. Second, each container has to be labeled to show the text of hazardous waste. Third, generators comply with the requirements of the treatments, storages, transportations and disposals. Fourth, containers uses for holding hazardous wastes have to be in very good conditions to prevent leak especially for accumulated wastes that stay on site for long time. Fifth, the containers should be in good conditions to stand the handling and shipping and the long travel distance. Packing has to be according to the specification to avoid any leak or causing problem during the trips. There are four packing group levels used in the

Transportation Danger Goods and that based on the degree of the hazard involved in the wastes as following:

- Level I for very dangerous wastes and used a highest packing level
- Level II for dangerous and used medium packaging level
- Level III for moderate dangerous and used a lowest packing level
- Level X specific packaging level that based on the physical and chemical properties of the wastes (4).

The used containers have to be closed during the storage time it. In two cases first, if the container contains a flammable materials, the emerging vapor might cause a fire. Second, open container will be subjected to spill during movement. The only time allowed to be open is during storage or adding and removing the wastes. For waste materials such as acids and caustics require plastic drums, steel drums with liners or drums of stainless steel. Using funnels are often used to minimize losses when filling containers with liquid wastes to prevent spills.

2.3.3 Treatment

The main objective of the waste hazard treatment is reducing the volume of the wastes. Accordingly, reduce the hazard on the environmental and on health as well. Treatment could be chemical, physical, biological or thermal. The physical treatment used to separate the solid materials from the liquid through some techniques. The chemical treatment is used to reduce a vapor, solid, steam, solvents, and oxidation to reduce some component. Biological treatment used in order to disaggregate the biological objects. Thermal treatment involves heat to increase vaporization or oxidation. Furthermore, there is a potential of gas

generation and migration as a result of the chemical reaction and microbial decomposition of the waste organic materials that significantly has a negative impact on the environment. Leachate also is a significant consequence on the environment and it should be properly treated. Selection of effective treatment method for leachate is primary based on the cost, and the nature of the leachate. The optimum method used for leachate treatment is incineration through activated carbon adsorption and aerobic and anaerobic biological treatment.

CHAPTER 3

Landfill Disposal

Traditionally landfill is one of the main methods of disposal used for treated or untreated wastes. Several elements must be considered in order to choose a place for installing landfill such as: land topographic, geologic, hydrogeology, climatologically and population density and a synthetic or soil based liner has to be installed in order to prevent migration and leachate collections of hazardous waste, removal system is required. Landfill site has to meet a certain specifications to be environmentally satisfactory. For example, the groundwater surface level has to be away from the landfill to avoid contamination, also considering leachate migration. In other words, water surface run off from the site must be prevented from reaching ground water supplies. There are specific regulations and safety precautions must exist in the hazardous wastes facility to ensure adequate storage, the facility should be cool, dry and well ventilated area. Leaks is the biggest obstacles facing the below ground landfills even with all technology available, leaks leads to a accumulation of contaminated leachate with hazardous wastes and eventually penetrate the liners and reach the groundwater. To prevent leakage, the facility has to be dry and the best way of that are the aboveground landfills since the landfill contains on aboveground leachate collection landfill, a drain system consisting of stable aggregates connected with a proper system of collection pipes and the base must be overlain by a low permeability liner system. This design approved an efficiency of preventing leaks, eliminating the driving force behind the migration of

contaminants due to the immediate remove by gravitational drainage, if there is a leachate the cover is often expose to breach so, it indicates on the system integrity. The problem with the aboveground landfill is the potential of erosion of the topsoil cover due to the slope on the aboveground landfill and the run off.

3.1 Social issues related to the landfills

Installing landfill present a big issue, is very difficult people to accept the idea of constructing landfill in their community due to the nuisances such as dust, odour, noise, and visual intrusion. In addition to the landfill traffic can disturb people properties and it is not good to be close to any recreational or any community services. Therefore, the nature, the value, and extent of the community will be affected. However, increasing public opposition to the sitting of such facilities ,In both Canada and USA has brought social issues. In other words, the social aspects generate more problems than the technical ones. Therefore, the focus to solve the social issues has the priority of consideration.

There are some other methods of disposal used for special hazardous wastes such as radioactive wastes as following:

3.2 Sea Disposal

The radioactive materials is widely used in medicine and industry, and it is apparent that nuclear industry potentially produce a huge amount of contaminated radioactive materials, it is also apparent that the radioactive is the most dangerous and undesirable wastes. Researchers found that the most convenient and inexpensive way of disposal the radioactive wastes is into the

sea waster. Many studies have shown that, for a small amount of radioactive materials dissolved in a huge amount of water, the wastes will be diluted and the effect will dramatically reduced. In spite of, these good results a lot of objection and issues generated from both political and environmental aspects.

3.3 Sewer disposal

The large a mount of water carried by the sewers provides a good dilution of the hazardous wastes. Thereby, the danger will be eliminated. However, In spite of these good results this way also not widely used since once the radioactive materials entered the sewers, they lost control on it.

3.4 Transportation Modes

The federal government in Canada has made a tremendous effort of enactment of the Transportation Dangerous Goods Act. This act mainly applies on the hazard wastes. The Act includes prohibition of transportation of dangerous goods by any mood of the transportation unless they meet all the requirements and standards for safety. The main objective of the Act is to achieve the uniformity of legislation across Canada and internationally to control the transportation of hazardous wastes. The Act has a list comprised of hazard Goods includes a miscellaneous class of hazardous products, substances and some dangerous organisms. Each province applies the regulations in such a way that match with its own system. For instance, the regulations for waste disposal facilities will be left to the provinces to control it. For example, In Ontario, the Environmental Protection Act, controls the industrial wastes transportation throughout the

province. It provides forms must be filled out from shippers, carriers and receivers. However, all the regulations for the hazardous wastes transportation controlled and legislated under the federal government. There is a tremendous focus on drivers training, to increase the awareness of the environmental impact. Selecting a transportation mode essentially based on the consideration of the relative cost and risks of all alternatives transportation modes. Transportation of Dangerous Goods Act sets out requirements to control the hazardous wastes transportation, and provides remedy tools in case of any incidents occur.

3.4.1 Rail Transport

Requirements for the transportation of hazardous wastes by rail in Canada and USA have to follow the regulations known as Red Book, which established by the CTC through the Railway Transport Committee; this book includes all the safety requirements and standards, the classification of all dangerous goods and application forms for Hazard Information Emergence Response (HIER), for all cargo, shippers must fill it out, and also forms for report accidents such as incidents, leakages, etc.

3.4.2 Marine Transport

Requirements and regulations for transportation hazard waste by water are established through International Marine Organization (IMO) under the federal government. The regulations known as dangerous goods shipping regulations, which include, packages, carrying, Marking and inspections of dangerous goods

on ships, storing. Waste hazard transportation by marine shipment involve a very large quantities of hazard in a small number of trips and that due to the large capacity of the tanks used, the capacity ranged from 30,000 to 600,000 gallons. Some studies have shown that marine transportation doesn't appear to be feasible for hazardous wastes transportation because it is costly compared with other alternatives modes.

3.4.3 Air Transport

Hazard waste transported by air is very small and limited since it is very expensive compared to the other modes. In addition to the price penalty for extra handling that required for loading and unloading. Obviously, some waste hazard materials are not allowed to transport by air such flammable materials, irritants and corrosive materials, Air transportation is attractive only for some sensitive items, normally shipped in a small quantities. The hazardous wastes have to meet all the requirements and provisions of the United Nations Committee of Experts on the Transport of Dangerous Goods and the International Atomic Energy Agency's regulations for the safe Transport of Radioactive Materials. hazard waste transported materials have to meet all the requirements, regulations and standards of the International Air Transport Association. As a result of these regulations and the price, studies have shown that the air transportation mode is not considered as a good option for hazardous wastes transportation.

3.4.4 High way Transport

Requirements of hazard waste transported by highway have to meet the 49 code of Federal Motor Carrier Safety Regulations, State and local laws, the cargo tanks used to carry the hazardous materials are made of steel or aluminum alloy the capacity ranged from 4000 to 12000 gallons, usually base on the regulations of the existing road weight law. The truck mode is more likely to be the favored mode of hazardous wastes transportation.

3.4.5 Pipeline Transport

It is often used in USA to transport crude oil or other row materials, but not much for hazard waste, because simply it is not economical or practical. Studies have shown that, there is a major attraction of pipeline transportation because the lower risk of spills compared to the other mode such as truck or train.

TRANSPORT MODE	
Transport Mode	**Number**
Road	221
Rail	205
Air	14
Marine	16
Pipeline	1
Non transport	422

Figure 3.1 number of Hazardous Waste Transportation Modes (Environment Canada, 2001)

Chapter 4

Regulations and Precautions for Hazardous Wastes Transportation

The federal government provides a framework for the hazardous wastes management regulations and, proper planning in order to handle hazard wastes problems is very essential. The regulation of wastes begins from generation and covers transportation, and continues to the wastes treatment and disposal. It is required from all parties include generator, drivers, operators of the storages, treatments and disposals to have a better understanding to the regulations and safety precautions. For example, drivers have to be well prepared and knowledgeable with OSHA 29 CFR 1910.120 Hazardous Waste Operations, Health & Safety Training Program and be familiar with HazMat, D.O.T. and Security Awareness training. Drivers also have to be conversant with the requirements and regulations for handling, storing, manifesting, transporting, labeling, treating and disposing of hazardous waste. Drivers should know use the toxicity characteristics leaching procedure to identify hazardous waste. It is very vital, if the initial spill controlled and treated in the earlier stages before losing control, otherwise the effect continues as the hazardous waste enters the air or groundwater and the damage will spread to the surrounding areas and it will be very hard to control it. Chemical spill problem requires an effective plan of spill control to identify a control procedure in order to reduce the degree of the hazard. By identifying the principal cause of the chemical spill at the manufactures and transportation site is very important to control and reduce the hazard effect. Emergency report plays an important key role in the hazard waste

transportation process, Incident, spill, or leak occur must be reported in order to notify the rescue team includes the fire department, local and provincial police or RCMP detachments can provide immediate assistance. In order to facilitate emergency response measures, carriers must keep the documents that contain waybills, invoices that listed the materials involved, united nation serial number, emergency response number.

4.1 Transportation of Dangerous Goods Regulations

The Transportation of Dangerous Goods Regulations are divided into 13 parts as following (Transport of Hazardous Wastes Manual)

- Part 1 contains definitions of the specialized terms used in the regulations
- Part 2 contains information about how and when the regulations should be applied, and provide exemption to that regulations
- Part 3 contain information about the classifications of the dangerous goods, There are 9 classes of dangerous goods as following

➢ Class 1 explosives materials include substances

i. Substances with a mass explosion hazard
ii. Substances with a fragment projection hazard, but not a mass explosion hazard
iii. Substances that have a fire hazard along with either a minor blast hazard or both, but not a mass explosion hazard

iv. Substances that represent no significant hazard

v. Very insensitive substances, although with a mass explosion hazard as in i.

- Class 2 for gases include
  - i. Flammable gases
  - ii. Non flammable, non toxic, non corrosive gases
  - iii. Poisonous gases
  - iv. Corrosive gases
- Class 3 Flammable Liquids
  - i. Liquids with a closed cup flash point of less than –18° C. These are extremely flammable
  - ii. Liquids with a closed cup flash point of not less than –18° C, but less than 23° C, these are very flammable
  - iii. Liquids with a closed cup flash point not less than 23° C, but less than 37.8° C. For international air transport, the flash point is not less than 23° C, but less than 60.5° C. For waste and international marine transport, the flash point is not less than 23° C, but less than 61 ° C, these are moderate flammable
- Class 4 Flammable Solids, Substances that on contact with water emit flammable gases include
  - i. Solids which under normal circumstances are readily ignitable and burn persistently, or which cause or

contribute to fire, through friction or from heat retained from manufacturing or processing.

ii. Substances liable to spontaneous combustion under normal conditions of transport, or, when in contact with air are lizble to spontaneous heating to the point where they ignite

iii. Substances which, on contact with water, emit dangerous quantities of flammable gases, or become spontaneously combustible on contact with water or water vapor

- Class 5 Oxidizing Substances and Organic Peroxides

i. Substances that cause or contribute to the combustion of other material by yielding oxygen or oxidizing substances, whether or not the substance itself is combustible

ii. Organic compounds that contain the bivalent "O-O"

- Class 6 Poisonous Substances and Infectious Substances

i. Solids or liquids that are poisonous through vapor inhalation, by skin contact, or by ingestion.

ii. Organisms that are reasonably believed to be infectious to humans or animals, and the toxins or such organisms.

- Class 7 Radioactive Materials

i. Comprise radioactive materials with activity greater than 74 KBq/kg within the meaning of the Atomic Energy

Control Act. Radioactive materials are classified by the atomic energy control board

- Class 8 Corrosive Substances that cause visible necrosis of the skin, or that corrode steel or non clad aluminum, or are wastes that have a pH factors less than 2 or greater than 12.5
- Class 9 Miscellaneous Substances

ii. Substances or products that present sufficient danger to warrant regulation, but that cannot be assigned to another class

iii. Environmentally hazardous substances

iv. Wastes that present sufficient danger to warrant regulation, but that cannot be assigned to any other class (Transport of Hazardous Wastes Manual)

- Part 4 shows the documents that the generator and the receivers should use during the process of handling, shipping and transportation
- Part 5 describes the precaution includes safety signs and symbols that must be placed on the containers
- Part 6 and 7 describe safety standards and requirements
- Part 8 and 9 describe the government responsibilities under the Transportation Dangerous Goods Act and regulations include procedures to stop the transportation dangerous goods, and performing inspections

- There are also 12 schedules containing regulations, lists of specifications for the hazardous wastes and information about the methods should used on test the materials.

4.2 Safety Precautions & regulations

4.2.1 Toxic Solvent Spills

- In case of major spills of hazardous materials that produces toxic fumes, the area should be cleared until the ambient air changes
- Provide sufficient ventilation or breathing equipments, sand could be good since it can absorb the spill

4.2.2 Major Spill of Corrosive Liquids

- The ambient area should be flooded with water to dilute waste materials concentration
- Dilute or neutralize liquids could be absorbed by paper or solid absorbent
- Acids could be neutralized after dilution with a weak base or vise versa

Figure 4.1 Emergency Response for Hazard Spill Liquid (Transport of Hazardous Wastes Manual)

4.2.3 Mercury Spills

- Mercury should be cleaned up by suction through mercury collector, mercury sponge or vacuum flask
- Contaminated area should be powdered with sulfur or flowers and provide a good ventilation to the area
- In the following day the sulfide or the flower should be disposed of

4.2.4 Toxic Solid Spill

- In case the solid in a powder form, breathing equipment should be used and rubber gloves for the cleaning up
- The waste material from the cleaning up should be disposed of

4.3.5 Ignitable or Reactive

- Wastes should be separated from the reactive materials or the sources that might cause fire such as: smoking, cutting, welding, flames
- Storage ignitable materials should be away at least 50 ft from the facility property line
- Separate the incompatible materials and the incompatible wastes or protected from each other to avoid explosions, firs, container eruption, fumes or toxic gases.
- In case fire or explosion, the coordinator must immediately inform the local authority and identify the reasons of the accidents, materials involved, total damages and to what extend is going to be

4.3 Testing and Maintenance of Equipments

- All the equipments must be tested and maintained to ensure proper operations in the emergency time
- Testing and maintenance implies and requires a written policy and evaluations and keep track record to ensure periodically inspection

4.4 Manifest System

The transportation of hazardous wastes has to go through a certain regulations to ensure the full environmental control and safety. The purpose of the waste

manifest is to provide a very detailed record and tracking of the waste, from the beginning to the end. These regulations legislated by the government with the help of environmental experts. These regulations put it in forms called manifest. Manifest track hazardous wastes from the beginning of the process to the end to ensure safe delivery, the manifest serves both shipping documents and tracking documents and include the following information:

- Generator's name, address, phone number
- Name and the identification of the driver
- Name of the facility and the location
- Description of the types, quantities and the no of containers
- Generators have to provide documents, that the wastes are in a good condition for transportation and the appropriate method of treatment, storage and disposal

The generator complete and sign the manifest and distributed as following:

- Copy to the designated authority in the province, if the movement is in the same province, the generator should send a copy to the Environment Canada for international shipments
- Four copies should given to the transporter with the shipment
- The generator should keep a copy with him for at least two years
- The transporter fill out section B and ensure that the manifest be with him all the trip time
- The consignee should sign the four copies after receiving them and complete section C, he should keep a copy for himself, and give a

copy to the transporter and one copy to the proper authority and the last one to the consignor.

By these mandatory rules, the government will be able to control the movement of the hazardous wastes, and offences are going to be punishable by the law, the offences could be subjected to fines or imprisonment.

CHAPTER 5

Import and Export of Hazardous wastes between Canada and USA

There were many advantages resulted from the cooperation of both countries Canada and USA related to the broader authorities for the export and import of hazardous waste such as improved environmental protection regulations Act, meeting Canada's international obligations and develop Environmental Sound Management. The aim of ESM is to make sure that the hazardous wastes managed controlled in a proper way to protect the environment and human health. Canada involved in three international agreements regarding to trans boundary movements of hazardous waste materials as following:

1) Basel Convention on the Control of Trans boundary Movements of Hazardous Wastes and the disposal, 1989.

2) Canada and USA agreement concerning the Trans boundary Movements of Hazardous Wastes, 1986 and amended in 1992.

3) OECD (Organization for Economic Cooperation and Development) Decision of Council Concerning the Control of trans boundary Movements of Hazardous Wastes destined for recovery operations, 1993 and amended and replaced by C (2001)/107/Final.

The primary objective of The Basel Convention is minimizing the hazardous wastes production to enhance environmental sound management and protect the public health. The Basel Convention was comprehensive agreement includes

116 nations in 1987, Canada and USA signed this agreement in 1992. The Basel Convention produced twenty-nine articles and six annexes that include every thing related to the trans boundary movement of hazardous wastes. The agreement sets out the regulations and the conditions for the export and import of hazardous wastes. The agreement controls the trans boundary movements of hazardous wastes. Before setting down any international rules or regulations, a definition of hazardous waste materials have to be identified and classified first. Due to the difficulties to reach an exact definition of hazardous wastes materials, therefore, it was a consensus that the United Nations Environment Program will come up with the exact definition. The aim of this agreement conforms the fundamental principals and regulations to control the trans boundary movement of hazardous wastes from the origins to the destinations as following:

1) Both counties manage their wastes under its own regulations within its own jurisdiction. For example, in Canada, the federal government has the authority to manage and control her hazardous wastes under its regulations, and regulates the trans boundary movements of hazardous wastes. In other words, it controls the export and import from and into Canada as well as controls the movements between its provinces. The exporter must fill out the form which indicates the manifest reference number provided by exporter authority and that has to be prior to the transportation of the hazardous wastes.

2) Exports and imports allowed only to the countries that are parties in this agreement, the country that export wastes should notify the other country a head of time with a note include the following:

- The name of authorized career and authorized facility,
- Type of the used container for example, boxes, tanks or etc.,
- Determine the method of recycling, treatment, storage, or disposal
- The name of transporter and the mode of transportation
- The quantity in kilograms or liters of the hazardous wastes
- The port of exit through which the export will take place
- The customs office at which the hazardous wastes
- The notice has to be send in the language that are used in the import country in addition to another copy of English
- The reference number provided by the Minister
- The name, civic, mailing and electronic addresses ad telephone of the person who should be contacted in case of problem

For instance, Transport Canada and Environment Canada must receive the notification form, 60 days in advance from the generator in or out Canada for all wastes, and 30 days in advance or the first between the provinces, and 7 days in advance of subsequent shipments of PCB waste out of and into Canada (Waste Hazardous Transport Manual).

3) Exporting country must permit return of any hazardous waste that the importing country rejects it. In the case of hazardous wastes

materials not accepted for some reasons from the authorized imported facility within five business days, the importer have to notify the exporter and the authorities of that country as soon as possible. If there no respond for 90 days there are two options have to be done whether to make arrangements to dispose the hazardous wastes or to return the hazardous wastes back to the exporter where it is issued.

4) Both countries should cooperate to achieve the implementation of the Basel agreement and ensure the full control management on the hazardous wastes.

5.1 General Obligations of the Parties to the Basel Convention (31)

1. (a) Parties exercising their rights to prohibit the import of hazardous wastes or other wastes for disposal shall inform the other parties of their decision pursuant to Article13

(b) Parties shall prohibit or shall not permit the export of hazardous wastes and the other wastes to the parties, which have prohibited the import of such wastes, when notified pursuant to subparagraph above

(c) Parties shall prohibit or shall not permit the export of hazardous wastes and other wastes if the State of import does not consent in writing to the specific import, in the case where that State of import, in the case where that State of import of import not prohibited the import of such waste

2. Each party shall take the appropriate measures to:

a) Ensure that the generation of hazardous wastes and other wastes within it is reduced to a minimum, taking into account social technological and economic aspects

b) Ensure the availability of adequate disposal facilities, for the environmentally sound management of hazardous wastes and other wastes, that shall be located to the extent possible, with it whatever the place of their disposal

c) Ensure that persons involved in the management of hazardous wastes or other wastes within it take such steps as are necessary to prevent pollution due to hazardous wastes and other wastes arising form such management and, if such pollution occurs, to minimize the consequences thereof for human health and the environment

d) Ensure that the Tran boundary movement of hazardous wastes and other wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement

e) Not allow the export of hazardous wastes or other wastes to a State or group of States belonging to an economic and or political integration organization that are parties, particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will

not be managed in an environmentally sound manner according to criteria to be decided on by the parties at their first meeting

f) Require that information about a proposed trans boundary movement of hazardous wastes and other wastes be provided to the States concerned according to Annex VA, to state clearly the effects of the proposed movement on human health and the environment.

g) Prevent the import of hazardous wastes and other wastes if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner.

h) Cooperate in activities with other parties and interested organizations directly and through the secretariat, including the dissemination of information on the trans boundary movement of hazardous wastes and other wastes, in order to improve the environmentally sound management of such wastes and to achieve the prevention of illegal traffic

3) The parties consider that illegal traffic in hazardous wastes or other wastes is criminal

4) Each party shall take appropriate legal, administrative and other measures to implement and enforce the provisions of this convention, including measures to prevent and punish conduct in contravention of the convention

5) A party shall not permit hazardous wastes at other wastes to be exported to a non-party or to be imported form an non party

6) The parties agree not to allow the export of hazardous wastes or other wastes for disposal within the areas south of the 60^0 latitudes, whether or not such wastes are subject to trans boundary movement

7) Furthermore, each party shall:

a) Prohibit all persons under its national jurisdiction from transporting movement be packaged, labeled, and transported in conformity with generally accepted and recognized international rules and standards in the field of packaging labeling, and transport, and that due account is taken of relevant internationally recognized international rules and standards in the field of packaging labeling, and transport, and that due account is taken or relevant internationally recognized practices

b) Require that hazardous wastes and other wastes that are to be the subject of a trans boundary movement be packaged, labeled, and transported in conformity with generally accepted and recognized international rules and standards in the field of packaging labeling, and transport, and that due account is taken of relevant internationally recognized practices

c) Require that hazardous wastes and other wastes be accompanied by a movement document from the point at which a trans boundary movement commences to the point of disposal

8)Each party shall require those hazardous wastes or other wastes, to be exported, and managed in an environmentally sound manner in the State of import or elsewhere. The parties at their first meeting shall decide technical guidelines for the environmentally sound management of wastes subject to this convention.

9) Parties shall take the appropriate measures to ensure that the tarns boundary movement of hazardous wastes and other wastes only be allowed if

a) The state of export does not have the technical capacity and the necessary facilities, capacity or suitable disposal sites in order to dispose of the wastes in question in an environmentally sound or efficient manner

b) The wastes in question are required as a raw material for recycling or recovery industries in the State of import.

c) The trans boundary movement in question is in accordance with other criteria to be decided by the parties, provided those criteria do not differ from the objectives of this convention.

10) The obligation under this convention of States in which hazardous wastes and other wastes are generated to require that those wastes are managed in an environmentally sound manner.

11) Nothing in this convention shall prevent a party from imposing additions requirements that are consistent with the provisions of this convention, and are in

accordance with the rules of internal law, in order better to protect human health and the environment.

12) Nothing in this convention shall affect in any way the sovereignty of States over their territorial sea established in accordance with international law, and the sovereign rights and the jurisdiction, which states have in their exclusive economic zones and their continental shelves in accordance with international law and as reflected in relevant international instructions.

13) Parties shall undertake to review periodically the possibilities for the reduction of the amount and or the pollution potential of hazardous wastes and other wastes which are exported to other states in particular to developing countries. (1).

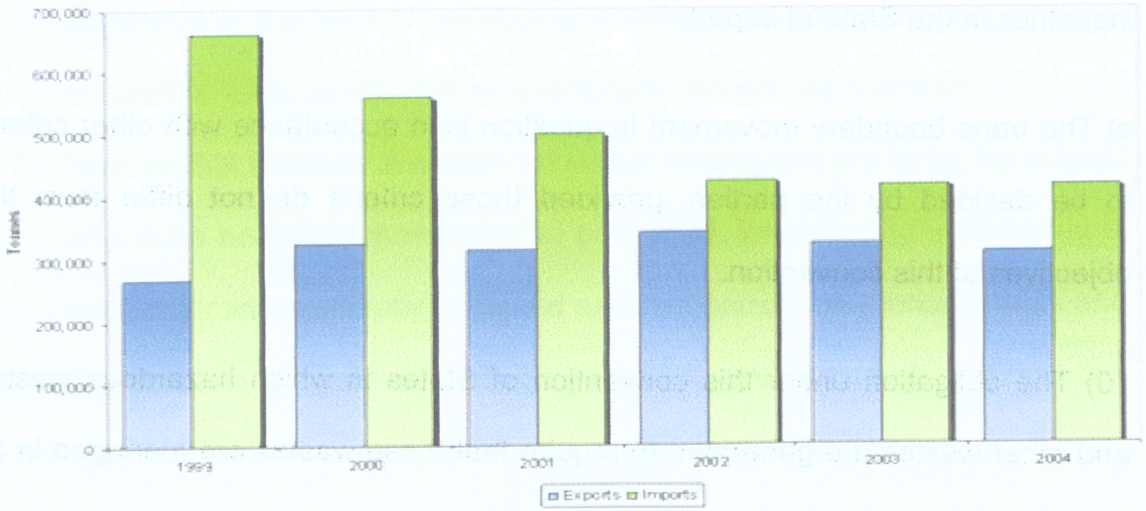

Figure 5.1 (Environment Canada 2004) Statistics on Export and Import Hazardous Waste Material 1999-2004

As shown from the graph, the 2004 Canadian's amount of hazardous waste Import and export is gradually decreasing. For example in 2002 the total quantity

of importing was almost 418,000 tons, in 2003 was almost 417,000 tones and in 2004 tones is almost 416,000 tones. Based on the statistics of 2004, 98.8% of all Canadian imports of hazardous wastes came from USA and the rest 1.2% from other countries.

5.2 Environment Sound Management

Some problems could be created from the poor management and insufficient knowledge. For example, leachate, is the mean reason of the ground waster contamination or release gases which have a negative impact on the human health and the environment. In response to the public concern to maintain adequate control over the potentially hazardous wastes and maintain environmental sound, Environmental Sound Management criteria plays a significant role to reduce the danger that imposes from the hazardous wastes, by establishing a framework or comprehensive plan. Environmental Sound Management's objective is to protect the environment and the human life through management strategies, sophisticated plans and intelligent system as following:

- Reduction of wastes are one of the most potential useful way to encourage reuse and recycle the waste materials, by exchanging the wastes from one firm to another, which can be used as an inexpensive way of raw materials which present the best way of managing the wastes with the most environmentally sound.
- Ensure that all the hazardous wastes procedures are according and conforming the Environmental Sound Management's criteria.

- Ensure compliance with the regulations and existing rules in the manifest to protect the environment
- Reduce or prevent the unexpected hazardous wastes resulted from unforeseen accidents might happens due to spill or contaminations that happened during recycling, treatment, transportation or disposal process
- Arrangements with the local emergency authorities to the fire department and to the police department for the areas that have hazardous wastes
- Arrangements to familiarize local hospitals with the hazardous waste properties in the facility and the consequences effect
- Safety and emergency response are particularly very important in the heavily urbanized area in a wide variety of different application such as planning infrastructure and transportation projects. The number of fire stations is significantly influencing the efficiency of emergency response during fire accidents. A suitable distance between fire stations and maximizing the area that can be served by these fire stations is very important issue; this could be effectively by using geographic information systems technology (GIS). The efficiency of the current fire station locations and reduce the hazard transport impact on the routes.
- Provide a list of prohibitions and conditions relating to the transportation, recycling, treatment or disposal process

Canada's first priority is to protect the environment and human health. There are a strict regulations imposed on the export and import hazardous wastes in Canada in order to protect the environment and the public health from any damage might occur through trans boundary movements of hazardous wastes. The main purpose of the proposed regulations is to enhance safety and environmental protection. Canada has issued a new manifest form shows the necessary required regulations for the trans boundary movement and the difference between the international and the domestic regulations for the hazardous wastes transportation also provides a list of the prohibited and permitted materials to export or import. The manifest shows the regulations should be followed from the very beginning of shipment to the final destination to enhance environment management sound.

In 1999, CEPA gained power to enforce some regulations on hazardous wastes materials trans boundary movements as following

1) Prohibit exports, imports of hazardous wastes movements where required by Canada's international obligations
2) Develop criteria to assess the Environmental Sound Management of Tran boundary wastes and refuse permits for exports and import
3) Prepare plan to reduce phase out exports of waste hazardous movements destined for final disposal

In 2002 there were some changes in control authorities in Canada related to the hazardous wastes trans boundary movements. For example, Transportation of

Dangerous Goods Regulations controlled the tracking requirements of hazardous wastes materials according to Transportation of Dangerous Good Act, 2001.

5.3 Environmental Legislation In Canada

Waste Hazardous Materials Process includes handling, shipping, disposal in Canada controlled by a Varity of legislations and regulations through many Acts as following:

- Transportation of Dangerous Goods Act
- Environmental Protection Act includes
  - (Waste Management General Regulations 347 Ontario)
  - (Air Pollution General Regulations 346 Ontario)
  - (Waste Management PCB Regulation 362 Ontario)
- Environmental Contamination Act
- Pest Control Products Act
- Pesticides and Regulations Act
- Nuclear Safety and Control Act includes
  - Canadian Nuclear Safety Commission (CNSC)
  - Packaging and Transport of Nuclear Substances Regulations

5.4 Hazardous Waste Management in Ontario

Ontario government has established a master plan that has achieved tremendous implementations of reducing the hazardous waste. Ontario hazardous waste is managed under the General Waste Management of Environmental Protection Act. Regulation 347. The Environmental Protection Act

enacts rules and regulation to protect the environment, and the human health. It is therefore, responsible for the approval of constructing landfills and the control of generating hazardous waste in Ontario. In addition to, the initiative of applying registrations the electronic hazardous waste information network program to coordinate all the hazardous waste activities in Ontario and provide a better service for generators, which made Ontario waste hazardous plan is the most competitive plan in North America.

5.5 Hazardous Waste Regulations in Ontario

There was amendments toke place in Ontario regulations in 2002. The modified regulations require annual renewal of the registration of the hazardous waste generators with the Environmental Protection Act, and provide detailed information about the amount of hazardous waste that being produced and disposed on and off site every year. Furthermore, these amendments on the regulations included the improving the leaching tests method and updating the classification lists of hazardous wastes. The modified regulations are legislated in a very tough way to ensure and enhance environmental sound in Ontario, and whoever breaks the law or abuse the system will expose to fines and probably to imprisonment (3).

Regulations of the hazardous waste management

- Complete a training hazardous waste course or seminar at least once every year.
- Determine the recycle materials and the waste hazardous materials

- Determine whether the waste may be legally disposed of in the sewer system or landfill.
- Treat waste as hazardous waste if it cannot be recycled, detoxified, redistributed or disposed of in the sewer or landfill.
- Follow the policies for containing, storing, labeling and inspecting accumulated hazardous waste.
- Notify the Environmental/Safety officials when hazardous waste needs to be disposed of. Indicate where the waste is, what kind and how much hazardous waste there is, as well as whom the contact person is.
- Review procedures producing hazardous waste to see if they can be minimized.
- Recognize a problem, or potential problem, with hazardous waste and take steps to correct the problem (25).

5.6 Liability requirements

Hazardous wastes have a huge potential of causing injuries, permanent disability or even death to human and damages to the environment, if such an accident occurs, the question arise, who is going to cover that damage. Financial responsibility includes insurance coverage and compensation for any injury or incidents during transportation or even during storage, treatment or disposal operation should be designated. Insurance is very important, it helps owner and the operator to be clear and have peace in mind toward any incident might face

them. The transport of hazardous waste as any transport operation could be subjected to collisions. In addition to the danger might happen from the hazardous wastes itself. It is therefore, an urgent need to cover the unforeseen losses and legislate national laws to protect anyone involves in the operation. The law should help the victim to get compensation for the harm that already happened and also provides protection rules against future harms. Reliability of staff play a very important role in the transportation operation, because experience shows that a proper training to the staff and special licenses are very essential and should be mandatory for both the carrier and handling agencies.

5.7 Inspection

Inspectors who are authorized to ensure and enhance the Transportation of Dangerous Goods Act and regulation, they appointed by the Minister and issued a certificate to practice the inspection on any wastes are ready for transportation, inspector can perform inspection on every thing related to handling, packing, documents and authority. The inspection could be at the port, places where the wastes produced or at the facility. The inspector has the right to refuse the wastes and not allowed to enter the board. The carrier also has the right to check the shipment before he transports. The Carrier he shouldn't accept to receive the shipment for these following reasons

- If there is any discrepancy and not in compliance with Transportation Danger Goods' Regulations
- Incomplete documentations

- Misinformation on the waste manifest
- Improper signs, unsafe or damaged packing
- Vehicle mechanical problem (Waste Transportation Manual)

5.8 Transportation System Attributes

Transportation System attributes could be fall into six categories

- Traffic
- Travel time
- Freight
- Operation and maintenance
- Financial perspectives
- Physical

The most important advantage of GIS in transportation is its potential for data integration. GIS application in Transportation includes land use, environmental, demographic, utility and hazardous materials databases. The hazardous materials represented by travel demand by using the origin and the destination of the trip. Utility systems, such as sewers and water, which represented as networks by using, nods and links for the appropriate attributes. Transportation includes the interaction of supply (physical attributes) and demand (Traffic attribute), the interaction between supply and demand is emphasized by travel attributes. Financial attributes cover the variety of costs such as maintenance, construction operation and vehicles operation. To classify the GIS application seven function are used as follows:

- Basic functions (editing, display, measurements). The editing function allows the user to add or delete lines, points and change the attributes. The display function generates thematic maps. The measurements function is used to determine the area and any measurements.
- Dynamic segmentation, which divides the network, links into homogenous segments. The dynamic segmentation would create new homogenous segments groups.
- Surface modeling function creates a three dimension model and create a model for the digital topographic map.
- Raster display and analysis function permits photographs to involve in GIS, this function used to add new links or new features.
- Routing based on minimum time bath available in travel distance in the software.
- Transportation modeling packages.
- Overlay function allow two or more base maps to displayed simultaneously.

CHAPTER 6

Potential application of GIS in transportation

Several application of GIS have implemented in the transportation field such as management of urban of infrastructure, traffic operation management, road safety and the assessment of road accidents and the impact on the environment many application such as the following:

- Pavement management system
- Bridge management
- Maintenance management
- Road safety management
- Transportation system management
- Travel demand forecasting
- Corridor preservation and right of way
- Construction management
- Hazardous cargo routing
- Land side economic impact
- Environmental impact
- Accident analysis
- Oversize vehicles permit routing

GIS is a powerful tool in the analysis and design of transport routing networks. Its graphical display capabilities allow not only visualization of the different routes but also the design of the network.

6.1 Risk management in Hazardous waste transport

GIS capabilities allow the risk analyst, decision makers, and general visualization of the potential transportation accident involving the release of the radioactive material into the atmosphere. There are different formulas describe the concept of hazardous wastes. The damages resulted of the uncontrolled release of the hazard wastes such as flammability, toxicity, and chemicals are based on where and when the accident occurs. Obviously, in order to reduce the risk of transportation hazardous waste is reducing the probability of transportation accidents frequency (28).

6.2 GIS to minimize Hazardous Waste

Geographic information systems (GIS) represent a technology with considerable potential for important applications in transportation engineering. One of the most important applications of the GIS is to utilize GIS to minimize the potential impact of hazardous waste transport shipment accidents. The interaction between the transportation system and the environment makes GIS technology very effective in hazardous waste. The purpose of using Arc View GIS software store roadway information to make an assessment to choose the optimal route for shipments, which minimizes the travel distance and also the exposure of the hazardous waste to population. Some studies have shown that, GIS can develop a route that minimizes the impact of hazardous waste incidents occurring along the roadway network. The ultimate goal of using GIS is to reduce the hazardous waste transportation risk, and provide the tools for reducing uncertainty in

decision making to ensure that the decision is made wisely. Developed computerized model, which local jurisdictions can manage the risks related to hazardous waste transportation. The model was developed as a part of the risk assessment. The model is used to assess the risk associated with various transportation modes. The main purpose of developing and predicting models is to assess the safety of the community through which hazardous material will be transported. The risk measurements based on many factors such as roadway design, characteristics of drivers, vehicles, and the exposure of hazardous to the population. This model developed by Chung-kuo (29). The model developed with two sub-models as following.

LOS denotes to community Level of Safety =CP/CR (6.1)

$$CR=R_L(HMV)*(P_D+P_V+N_E+N_S)*T_F \quad (6.2)$$

Where,

CR denotes to the community risk such as spillage, fire, etc. and the consequences of that such as the rate of injury, death, and property damage. In other word, it focus on the roadway transportation

CP denotes to the community preparation such as emergency response

$R_L(HMV)$ = risk level index of an incident involving a motor vehicle carrying hazardous materials

P_D = population density factor

P_V= property value factor

N_E = condition and number of hazardous materials establishments

N_S = type and numbers of the facilities which is close to the roadway (schools, hospitals, etc.)

T_F= forms of threat resulting from an incident such as spillage, explosion, fire, etc.

R_L(HMV) is separately modeled as sub-model as following

$$R_L(HMV) = R_L(MV) * (P_{EX}+P_{CG}+P_{FL}+P_{FS}+P_O+P_P+P_C+P_M) \quad (6.3)$$

Where,

P_{EX} = %explosive vehicles in ADT

P_{CG} = % compressed gas vehicles in ADT

P_{FL} = % flammable liquid vehicles in ADT

P_{Fs} =% oxidizers and organic peroxides vehicles in ADT

P_o = % poison vehicles in ADT

P_p = % radioactive vehicles in ADT

P_c = % corrosive vehicles in ADT

P_M = % miscellaneous or unknown class vehicles in ADT

$R_L(MV)$ = risk level of index of a motor vehicle incident = $T_L * (D_L+V_L+R_L)*S_L$ (6.4)

T_L = traffic volume level index

D_L = driver level index

V_L = vehicle level index

R_L = roadway geometry

S_L = average vehicle speed level index

Traffic volume T_L is rated 1 to 10

(CP) denotes to the level index for second sub-model for community preparedness, (ER) is emergency response index (0-50), and CR is regulation compliance index (0-50). Then

CP= ER+C R (28) (6.5)

6.3 Case study #1. The objective of this study is to minimize the hazardous waste that exposed to the population during the transportation trips. Based on the study of Dr. Michael Anderson (21), about the use of GIS in the Birmingham, Alabama, and metropolitan area to reduce the hazardous waste transport shipment incidents. In the U.S. statistics there are over than 500,000 shipments of hazardous materials every day. Trucks on highways transport more than 90 %

of these shipments, and 5 to 15 percent of the trucks are carrying hazardous materials. Almost 50 percent of these materials are flammable petroleum products, gasoline, and other corrosive, and 13 % are chemical materials. The remaining shipments represent any of the 2,700 chemicals considered hazardous when transported in interstate commerce. This research develops GIS application in transportation to obtain an effective ways to reduce the haulage cost and reduce hazardous waste as well. In addition to, minimizing the potential impacts of incidents resulting in the possible spill of hazardous (21).

6.3.1 Study Area: The roadways for Birmingham, Alabama (Jefferson County) are from the 1995 TIGER files. The point locations for schools are taken from a directory of Jefferson County Schools and show differences in type of school, elementary, junior high, and high school as shown in the figure below.

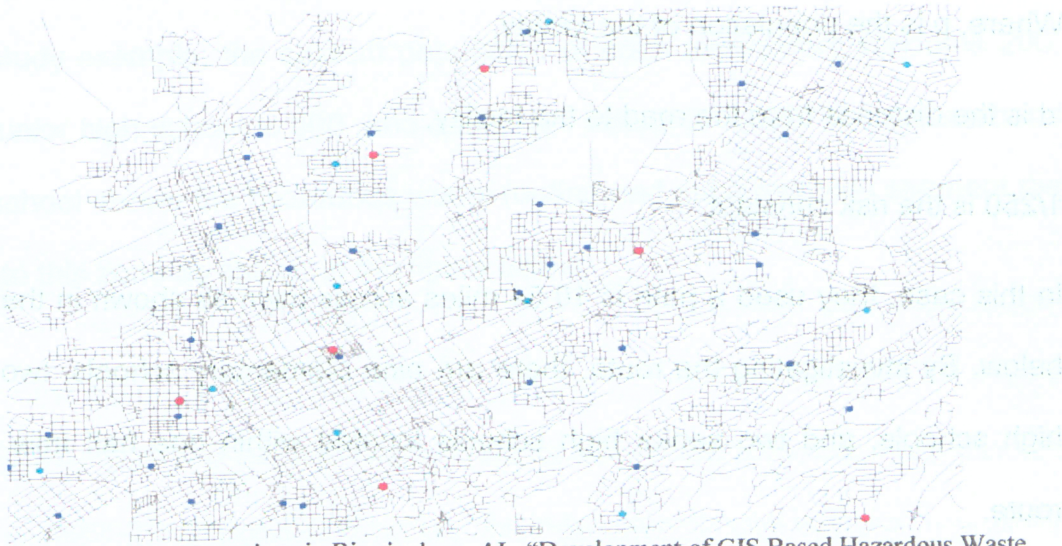

Figure 6.1 School Locations in Birmingham, AL. "Development of GIS Based Hazardous Waste Transportation System (HWTS)"

6.3.2 Methodology

The methodology that adopted for this study is, using Dykstra's Algorithm or Moore's Algorithm to developed and produces a new short routs based on the network road travel characteristics. The study based on obtaining the relationship between the population of the facility and the distance from the road segment. For instance, using schools as the facility. Accordingly, The higher the risk associated with the facility, the shorter the distance from the facility to the road segment.

The relative reciprocal function that is recommended is listed below.

$$f(p,d) = p / (250\ d) \quad (6.6)$$

$$\text{Impact} = \text{sum}\ (f(p,d)) \quad (6.7)$$

Where, p is the population of the facility,

d is the distance from the road to the facility,

1/250 is the risk constant.

In this case, they used a path is 10.54 miles across town as shown in the figure below. By investigating the route, there are nine elementary schools, two junior high schools, and two senior high schools located within one half mile of the route.

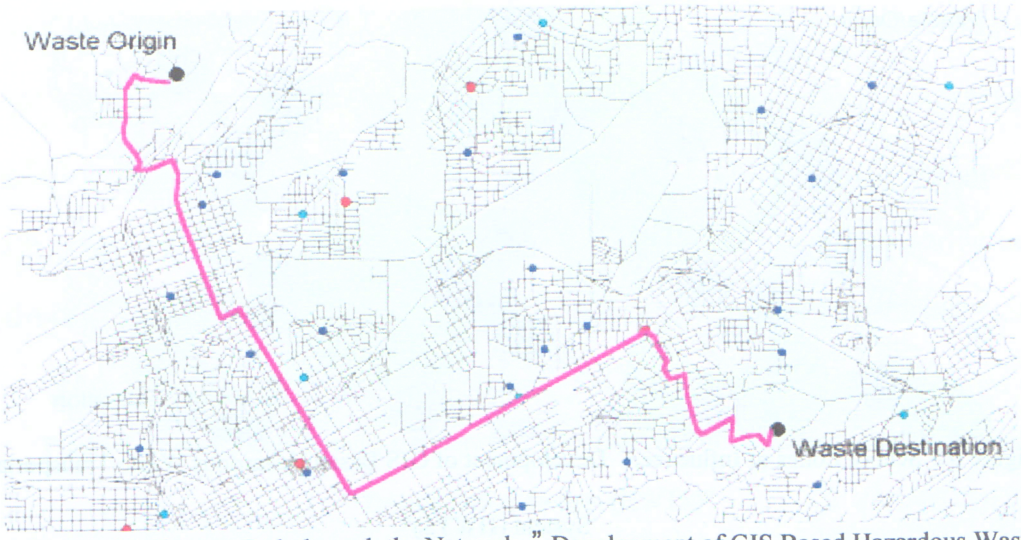

Figure 6.2 Shortest Path through the Network. " Development of GIS Based Hazardous Waste Transportation System (HWTS)"

GIS technology application in transportation is very profound. GIS is used to provide information for roadway segments within the specified distances of the study area. This information included the roadway segment distance, to develop a new potential reduction for the hazardous waste on the road segment. For the case study example, the student population of each elementary school is 200, each junior high school is 500, and each high school is 2,000. The area around each school shows the hazardous waste routing and each roadway segment the falls into this zone as shown in the figure below.

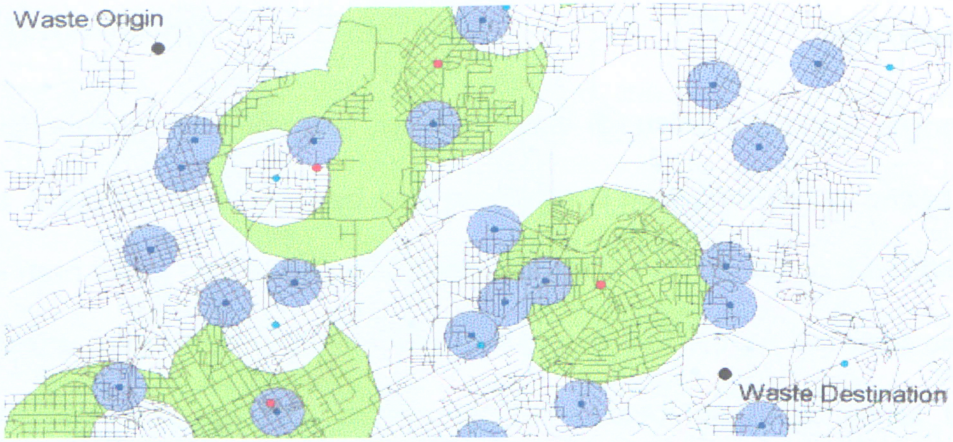

Figure 6.3 School Zones of Influence. " Development of GIS Based Hazardous Waste Transportation System (HWTS)"

The shortest route compared to the school zones of influence show that there are significant areas where this route passes close to schools as shown in the figure below.

Figure 6.4 Schools Impacted by Shortest Route. " Development of GIS Based Hazardous Waste Transportation System (HWTS)"

By using the roadway distance and impact area, a new route is developed that minimizes potential impact associated with a hazardous waste shipment.

Figure 6.5 Safest Route through the Network. "Development of GIS Based Hazardous Waste Transportation System (HWTS)"

By testing the two routes, the shortest path route has a distance of 10.54 miles compared to the minimized impact route of 11.68 miles. However, with the distance and impact level, the route that initially had the shortest path is scored as 38.91 and the route that minimizes potential impact is scored as 32.40. Therefore, providing a shortest transport route for a hazardous waste shipment that reduces the potential impact of an incident.

6.3.3 Conclusions for the case study

This study presented the development of a geographic information system based hazardous waste transport system (HWTS) that is intended to reduce the impact of potential incidents regarding hazardous waste shipments. The methodology included in the Hazardous waste transportation system provides for the determination of transportation routes that attempt to minimize the impact of potential incidents by incorporating socio-economic considerations into the routing process. The case study shown for Birmingham, Alabama is provided to

demonstrate the use of the HWTS using school locations as the socio-economic consideration. As demonstrated in the case study, the shortest route for the shipment, only 10.54 miles, passes by several city of Birmingham and Jefferson County schools. When the location of each school is considered into the routing equation, there is a small increase in total distance of travel, however, there is a larger increase in potential safety associated with the longer route". (21)

6.4 Case Study #2

This study obtained form "Transportation Safety and Risk Analysis, along Rural Southwest Roads" Douglas Filler, 2002"(22). This study aimed at developing a set of methods designed to assist road departments in rural jurisdictions (local, county, state) improve the traffic safety of the roads under their management by addressing different risk factors and assigning different weights to these factors e.g. road curvature, side slopes, intersections etc by using GIS techniques. The authors developed and tested these methods in the U.S. Southwest, where thousands of kilometers of unimproved and graded dirt roads cross Native American reservations. This generally arid region is nevertheless subject to periodic summer rainstorms and winter snow and ice, creating hazardous conditions for the region's transportation lifelines.

By using GIS, the methods can lead to less expensive means of analyzing the risks and hazards along paved and unpaved roads of the American Southwest and are also transferable to international settings, particularly in similarly arid climates (22).

6.4.1 Study Area:

The site under consideration is Hopi Reservation is located on western edge of the Colorado Plateau within the northern half of the State of Arizona, and is surrounded by the much larger Navajo Reservation as shown in the Figure below.

Figure 6.6 Maps of the Hopi Reservation "An Application of Lidar Technology to Highway Safety"

The climate is continental / temperate with hot summers and cold winters. Average daily high and low temperatures range from 5o/-6oC in winter and 32o/15o in summer. Soil scientists have recognized some 40 different soil classes on the Hopi Reservation. The soil distribution is complex and governed mainly by the extensive sedimentary parent materials (principally sandstones and shales) and topography. Three classes of roads cut across the Hopi Nation: paved highways maintained by the state of Arizona; graded dirt roads, which are maintained by the Bureau of Indian Affairs, an agency of the U.S. Department of the Interior; and a large network of informal roads, some of which receive occasional grading. Dirt roads are readily passable for much of the year although moderate to heavy rainfall in areas of clay soil greatly reduces tire traction, thus

rendering many dirt roads impassable for brief periods (usually several hours). As mentioned above, sudden downpours can also wash away road surfaces, thus cutting off important transportation lifelines on the Reservation. Other notable hazards include variations in road width due to the placement of drainage structures (culverts) and cattle guards, high curvature (i.e., sinuosity), rock-fall and slide hazards in areas of steep slope, and intersections. Each of these variables has been being treated as a risk factor in our analysis of transportation risks associated with the roads on the Reservation (22).

6.4.2 Methodology

The Hopi Nation has made significant investments in remote sensing, GIS, and GPS technologies. Further, the Nation has a federal requirement to develop a long-term plan for its road system. The data set consisted of geo-referenced data layers, including a set of digital orthohotos (1 meter spatial resolution), and a moderate resolution (10-meter) digital elevation model (DEM). Although Ikonos panchromatic and multispectral data would have been better for the first phase of this research, the relatively high cost of these data has prevented their use. Instead, the digital orthophotos of the area prepared by the U.S. Geological Survey were used. These data have the distinct advantage that they cost less than $10 per 3.75-minute quadrangle. However, the digital orthophoto quarter quads (DOQQ), as they are called, have the distinct disadvantage that because they are derived from periodic aerial surveys, they do not reflect the most recent changes in the road network. In fast growing areas like many of the U.S. suburbs

they very quickly fall out of date. Thus, for many applications, recently acquired high-resolution satellite data are preferable. Nevertheless, for research purposes, they are excellent substitutes for the more expensive satellite data. Table 1 lists the baseline data sets used in analysis thus far (22).

From the DOQQs, washes and intersections were digitized using raster-based GIS software (Idrisi32). The main advantage to using this particular software is its advanced decision-support capabilities for use in land allocation, suitability mapping, and risk assessment. Linear and point features were rasterized to a 10-meter grid, which corresponds to that of the DEM—the most spatially coarse of the data layers. The GIS software was utilized to create derived layers depicting the distance from hazardous features, namely washes, intersections, steep slopes, and culverts.

6.4.3 Evaluation of digitized features

The accuracy of features digitized from the DOQQs was evaluated with a GPS in the field during an August 2001 visit to the Reservation. Both a hand-held Garmin GPS as well as a RedHen Video Mapping System were used, which provided post-processing differential correction for position and elevation. Thus, it was possible to evaluate the accuracy of the DEM, which is one of the most important layers given the highly variable, steep topography of the Reservation.

6.6.4 Mapping areas of high risk:

Since the initial goal was to map areas of high risk along roads, a set of procedures was used to standardize and combine data layers to create composite risk maps as following:

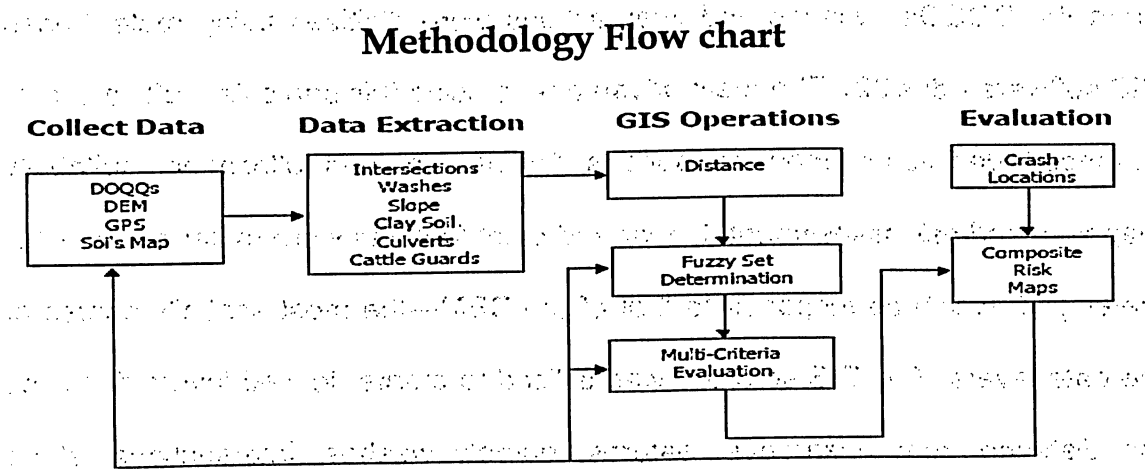

Figure 6.7 Different Steps for creating composite risk maps"An Application of Lidar Technology to Highway Safety"

Standardization of each data layer to a common set of values was performed using the Fuzzy module in the software. This module is designed to assign each pixel in an image to a fuzzy set by evaluating any of a series of fuzzy set membership functions. The main advantage to this approach for the current work is that it avoids setting hard or arbitrarily established thresholds between different levels of risk. It also facilitates subsequent integration of data layers in the generation of composite risk maps, which take into account the major risk factors for which we have data(i.e. slope, clay content, washes, culverts, intersections, and cattle guards).

Both linear fuzzy functions and J-shaped fuzzy functions were used (these can be further specified to be either monotonically increasing or decreasing functions), which are controlled by four breakpoints ordered from low to high on the measurement scale. A J-shaped function sets point a and d where the function is 0.5 and in the process, makes the J-shape function asymptotic to 0 and 1, points of absolute minimum and maximum risk. In the case of a monotonically increasing function, the first point marks the location where the membership function begins to rise above 0. The second point indicates where it reaches 1 (i.e., 100 percent probability of class membership). Output was scaled from 0 (zero probability of class membership) to 255 (100 percent probability of class membership) for each layer in our analyses. In the case of slope, for example, steepness was evaluated using a monotonically increasing function with the first breakpoint set at 10% (slopes are beginning to become "steep") and b, c and d set at 25% (slope has become a full member of the class "steep slopes").

6.4.5 Creation of composite risk maps

Integration of the data to create composite risk maps along roads was carried out using the Multi-Criteria Evaluation (MCE) module, also in Idrisi32. Like the Fuzzy module, the MCE procedure allows for the combination factors using a variety of functions. The linear-weighted function was used, which is analogous to a weighted mean, with factor weights determined arbitrarily. Factor weights are very important because they determine how individual factors will tradeoff relative

to each other. In the case of a linear weighted combination, the higher the factor weight the more influence that factor has on the final composite risk map. A factor weight sensitivity analysis was carried by varying both the factor weights and the type of fuzzy function used for each risk factor thus creating a final set of twenty or so MCE composite risk maps. Once this step was completed, each CE composite risk map was then compared to a set of accident data points from the same road networks used in the analysis. These accident points were collected by the Hopi Tribal police and converted into a GPS/GIS database at the Hopi Tribal Office. T-tests were used to assess the statistical significance of risk values at crash versus non-crash locations.

6.4.6 Results (Findings)

The MCE output ("MCE test") layers, factor weights and fuzzy functions have been shown in the figure as following.

MCE test	Layers involved	Fuzzy Functions	Factor weights
1J	1; 2; 3; 4; 5	L,L,L,L,J	0.2; 0.2; 0.2; 0.2; 0.2
1L	1; 2; 3; 4; 6	L,L,L,L,L	0.2; 0.2; 0.2; 0.2; 0.2
2J	1; 2; 3; 4; 5	L,L,L,L,J	0.25; 0.15; 0.1; 0.2; 0.3
3J	1; 2; 3; 4; 5	L,L,L,L,J	0.3; 0.2; 0.15, 0.25; 0.1
3L	1; 2; 3; 4; 6	L,L,L,L,L	0.3; 0.2; 0.15, 0.25; 0.1
4J	1; 2; 3; 4; 5	L,L,L,L,J	0.1; 0.25; 0.2; 0.3; 0.15
4L	1; 2; 3; 4; 6	L,L,L,L,L	0.1; 0.25; 0.2; 0.3; 0.15
6J	1; 2; 3; 4; 5	L,L,L,L,J	0.2; 0.1; 0.3; 0.15; 0.25
11	1; 3; 4; 5	L,L,L,J	0.25; 0.25, 0.25, 0.25
14	1; 3; 4; 5	L,L,L,J	0.2; 0.3; 0.3; 0.2
18	1; 3; 4; 5	L,L,L,J	0.1; 0.4; 0.4; 0.1

Figure 6.8 MCE composite risk maps with normally distributed scores (values from 0-255).
"An Application of Lidar Technology to Highway Safety"

Figure 11 shows the results of analysis for Route 17, which is one of three road segments that have been analyzed. As in all risk maps generated, this particular example produces data scaled from zero (no risk) to 255 (maximum risk). This composite risk map along with several others depicts good correspondence between crash locations (white dots) and areas of high risk, although in some instances crash location was displaced somewhat from the areas of highest risk, which coincide with the location of several risk features such as intersections, curves, etc. Several factors may explain this displacement including error associated with the crash site data (obtained through interviews with emergency personnel), post-collision momentum, or other hazards unaccounted for in analysis (e.g., temporary obstructions in the roadway).

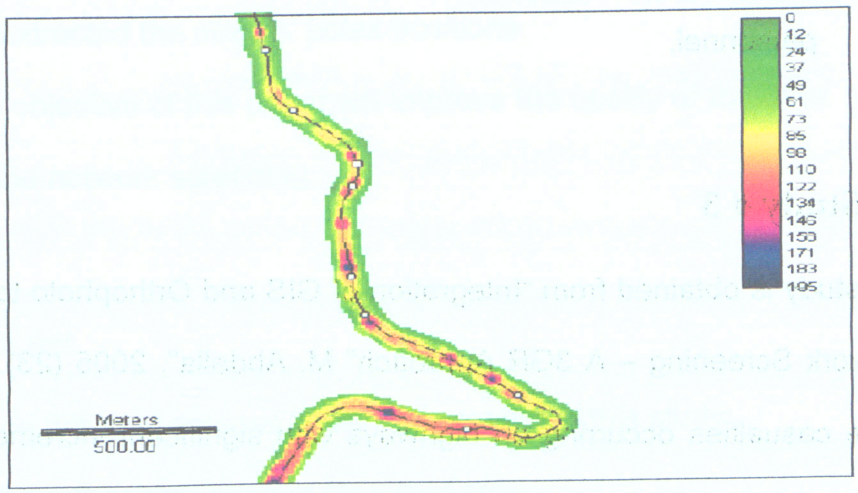

Figure 6.9 Results of MCE-based risk map (Test 4J, input parameters in table 1)
Blue to Black Tunes: Areas of high risk Green tune: Areas of low risk "An Application of Lidar Technology to Highway Safety"

Shortcomings of the study

The following shortcomings of this study have been observed:

- The digital orthophotos used have the distinct disadvantage that as they are derived from periodic aerial surveys, they do not reflect the most recent changes in the road network. These can quickly fall out of data in fast growing areas such as in U.S suburbs. Thus recently acquired high-resolution satellite data are preferable.
- Driver error is important part of collisions so it should also be taken into account while addressing different risk factors and collision history.
- There is possibility of error associated with the crash site data, which has been obtained thorough interviews with emergency personnel.

6.5 Case Study # 3

This case study is obtained from "Integration of GIS and Orthophoto to Enhance Road-Network Screening – A 3GR Approach" M. Abdalla", 2005 (23). Fatalities and severe casualties occurring on highways with significant increment due to unsafe geometric conditions and traffic controlled system. Among other factors, good visibility is essential to the safe operations of motor vehicles. Driving at nighttime can be more challenging than daytime driving, as the distance that a driver can see clearly is reduced at night. Therefore, most of the accidents occur at nighttime due to less visible environment, which is due to illuminated and un-

illuminated highways. However, there is a clear need to improve the analysis for nighttime collisions and to identify the lighting conditions accurately, but little evaluation has been done in this area because the collections process is costly and time consuming.

In this research paper, a new road-safety analysis technique is used for verifying and enhancing light database records in a road-network. Semi-Automatic method is based on the integration of data obtained from a Geographic Information System (GIS), orthophotos and a road-networks database, A semi-automatic method was developed to recognize illuminated and un-illuminated road segments by using a specific group of filters and the cross correlation technique. Validation of the procedure showed that the new technique improved the light database, and the semi-automatic method successfully identified street segment types and extracted the streets' poles positions.

The objective of this paper will improve the quality of the data, road safety analysis, and network screening.

6.5.1 Data set

Three different sources of data were used in this study:

(1) Digital orthophoto images for target area

(2) Roads database records (e.g. collisions records, traffic volume, etc)

(3) Single Line Road Network (SLRN) in GIS, ArcView Format.

The data and images used in this study were obtained from the Regional Municipality of Durham.

6.5.1.1 Methodology

The main objective is to extract the street poles (illuminated or un-illuminated) from the streets to identify its location. Since the poles are vertical objects and have very limited width in orthophoto images. Direct extraction method is not applicable; however, indirect method is developed to extract the streetlight poles. Semi-automatic method has been developed to help users to recognize the streetlight poles types and location. The method is based on observing the streetlight pole and their shadow as the shadow makes the streetlight pole easier to recognize. Filters are used to make the streetlight poles' shadow more clear. The following major steps are considered in the semi-automatic method.

6.5.2 Identifying Poles' location

- Link of orthophotos with SLRN by using ArcView
- Template windows for streetlight poles are assigned.
- To enhance the shadow of the streetlight poles, Minimum filter is used. It replaces the current brightness value of pixels. Minimum filter has the effect of spreading out black areas and shrinking while areas.
- To enhance the objects in the image, 'Find Edges' filter is applied. It makes the object image more recognizable visually and mathematically when cross correlation is applied.
- Cross correlation technique – to identify streetlight pole types and locations.

- Supervised selection is made by selecting the best results from cross correlation
- Merging of results with GIS system

6.5.3 Identifying Road Segment Types

To identify the road segment types from the aerial imagery and analyze, three different types of dataset are used: Digital orthophotos, road network records and SLNR. The Arc View GIS system was used to link the digital images, network screening database, collision database and SLRN.

The linking procedure was used to identify which road segments are illuminated (Type 1) and un-illuminated (Type 2).

6.5.3 Validation Method

In order to validate the test results from semi-automatic method, the technique was applied to the route, which consists of 62 different road segments with a total length of 39;886 meters. The site images and images taken by semi-automatic method were recorded in GIS. The results were verified on a site trip for the target route, which found that:

- Fifty-seven out of sixty-two segments (91%) verified.
- Five segments cannot be identified clearly. The reasons may be they are present in downtown core and are obstructed by the shadows of high buildings.

6.5.3.1 Findings of the study:

- The semi-automatic method successfully extracted the position of streetlight poles and identified whether road segment types were illuminated or not. The procedure resolved 90% authenticity in the results obtained for illuminated, hence, improving the data for illumination in the road database.
- The integration method presented offers a new tool to check and improve illumination data in the databases of road safety agencies.
- This method is ideal for rural and semi-urban areas as high-rise building and other factors may affect the imagery collected in urban areas.
- The integration of GIS, GPS and remote sensing can help road safety analysts to improve the quality and accuracy of their findings.

6.5.3.2 Shortcomings of the study:

- This technique could be used to check and examine intersections to identify which intersections are controlled by traffic signals. Semi-automatic technique may not be feasible if high buildings or other obstructions cover the pole's shadow.
- Orthophoto images with 0.2m spatial resolutions were used to extract the pole type/positions and to identify the segment types

and locations. However, high-resolution remote sensing images (1.0m resolution) are recommended to identify road segment types.

6.5.3.3 Conclusion remarks of the study

- The integration of GIS, orthophotos and databases can play a key role in improving the road network-screening database.
- Recent advances in Geographic Information Science and decision support have resulted in a set of new techniques for efficient integration of different GIS and remotely sensed data layers to map composite risk along certain sections of roadway.
- Airborne platforms and satellite can provide information, not possible by conventional means, at the same time, these are inexpensive and rapid.

6.5.3.4 Recommendations

- Orthophoto images can play a key role in extracting illumination data from the street network. Road agencies should give more attention to orthophoto images because the mages have considerable potential for supplying additional data about the road.
- More Efforts should be done close the gap between research and application with consideration of cost to benefit ratio and cost comparisons.
- There should be more interaction of transportation and remote sensing researchers and subsequently the technologies.

6.6 Case Study # 4

This case study is obtained from "Application of Lidar and GIS Technology to improve Highway Safety and reduce hazardous waste transportation" A.J. Khatak et al 2003 (24). The objective of this study was to utilize GIS and LiDAR elevation data to obtain information that can lead geometric safety improvements at highway intersections. Intersection safety was analyzed by working on intersection sight triangles, which are critical characteristics for safe intersection operation. Intersection sight triangles are triangular areas needed at each intersection leg for visibility. Any obstructions coming within these sight triangles will lead to unsafe travel conditions. Intersections are designed with recommended design consideration to provide sufficient sight triangles. However, subsequent changes in traffic control (e.g. all way stop controlled, 2-way stop controlled), erection of utility poles, growth of trees, shrubs and hedges, and installation of street furniture can result in obstructed sight triangles.

To improvise the safety on highway and reduce the hazardous transportation, an application of Light Detection And Ranging (LiDAR) technology is used. LiDAR elevation data were utilized in line of sight analysis to obtain information on sight line obstructions at six selected intersections located on the IA1 corridor in Iowa. The results were further verified by the field validation method of the existence of obstructions detected during the analysis.

6.6.1 Methodology and data characteristic

The basic methodology adapted for this research work is shown in the figure below. It consists of acquiring data from several sources and then combining those data in geographic information system (GIS). The acquired data constituted such as geocoded crashes, study area orthophotos, and Lidar elevation data, which were combined in ArcView (ESRI) GIS software. Utilizing the combined data, sight lines were evaluated to obtain information on obstructions located within sight triangles at selected intersections. Results of the analysis were then field-validated by visiting the analyzed intersections. The study area and various data acquired for this research along with the processing procedures are described next.

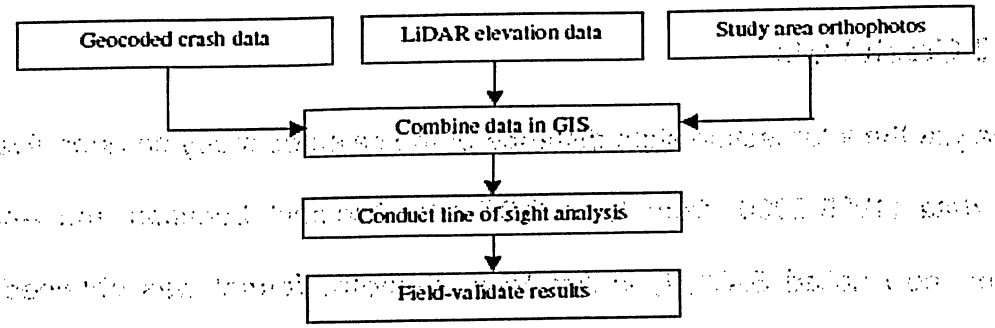

Figure 6.10 Schematic Diagram of Methodology of Research "An Application of Lidar Technology to Highway Safety"

6.6.1.1 Study Area

The study corridor selected for this research passing through Linn and Johnson Counties, IA, consisted of the Northern section of IA 1 Solon Bypass as shown in Figure below. The study corridor has 72 intersections (include 43 highways). It

receives significant traffic during morning and evening because of its proximity to the University of Iowa.

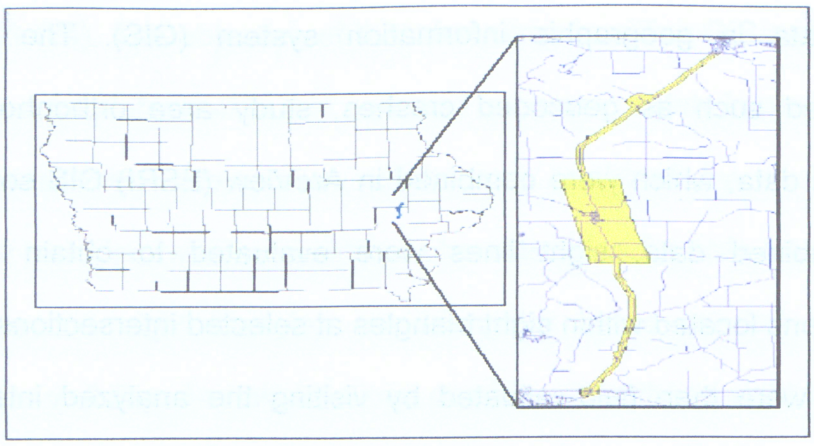

Figure 6.11 Study area corridor, IA 1Solon Bypass, IOWA "An Application of Lidar Technology to Highway Safety"

6.6.1.2 Crash Data

To analyze the intersection sight distance of the selected study corridor, five year crash data (1996-2000) from Iowa DOT GIS Accident Location and Analysis System (now called SAVER) in Arc View shapefile format was obtained. The crash data of intersection with three or more crashes involving persons and vehicles were extracted. This can narrows the research to the most critical intersections, which has more accidents.

6.6.1.3 Data analysis

Out of the 72 intersections selected in the corridor, six intersections in the City of Solon were selected for the line of sight analysis. The selection based on

intersection crash frequency (three or more during the study period), older driver involvement, Lidar data coverage. The crashes at these selected six intersections appear to be off-the road but this is due to minor discrepancies in overlaying the crash layer on the aerial imagery. All six selected intersections had stop control on the minor intersecting road. IA 1 running North-South through the City of Solon is named Market St. and it is the major road through the six intersections. Its intersections with East Third St. and East Rock St. are 3-legged while the other four intersections are 4-legged as shown in Figure below. Line of sight analysis was carried out utilizing both the LiDAR first return and last-return elevation data.

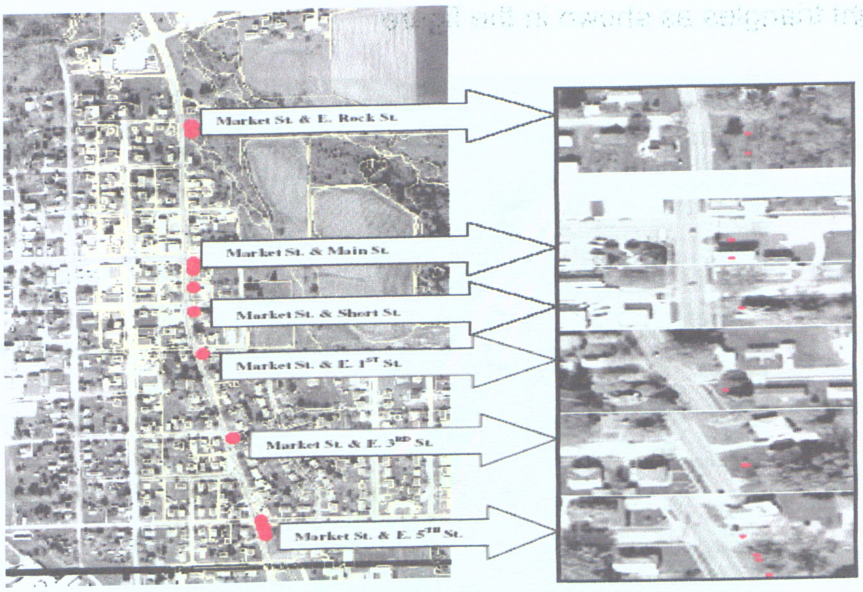

Figure 6.12 Selected Six Intersections and Crash locations "An Application of Lidar Technology to Highway Safety"

6.6.1.4 Line of Sight Analysis

Line of sight of an observer is determined by a 3-D Analyst extension using a TIN. An analyst specifies the location of an observer, the observer's eye height,

the location of a target, and the height of the target. Utilizing this input, ArcView calculates if the observer has a clear line of sight to the target. If not, ArcView identifies the location where the sight line is blocked. Line of sight analysis capabilities of ArcView were utilized to locate obstructions within sight triangles using TINs created from the first-return and last-return data. Multiple sight lines were drawn in ArcView to identify obstructions within sight triangles at the six selected intersections. A distance of 100 ft along the major road was maintained between successive sight lines. Sight lines were drawn over TIN themes starting at the stopped driver's position and ending at the marked target position at 445 ft, and then at every 100 ft intervals along major road of the sight triangles as shown in the figure

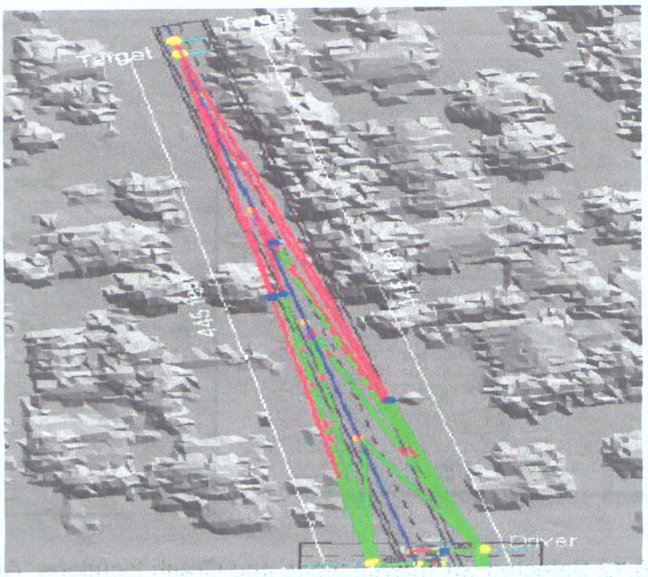

Figure6.13 Multiple lines of sight at 100-ft interval along the major road"An Application of Lidar Technology to Highway Safety"

The light gray and dark gray portions of a sight line indicate the visible and non-visible portions of the driver's field of view. A dark gray point marks blockages of

sight lines. The distances between the dark gray points and the location of the driver stopped on the minor road were measured. The results of line of sight analysis indicated 66 points where sight line was blocked while sight lines through three intersection sight triangles were not blocked. Since it is possible that a single object will result in the blocking of multiple sight lines therefore, the 66 points do not necessarily indicate the presence of 66 individual obstructions. To validate blocking of sight lines, the City of Solon, IA was visited and intersection sight triangles verified using video equipment.

6.6.1.5 Field Validation

A digital video camera mounted 3.5 ft on a tripod and a passenger car with 3.5 ft marked on both sides was used to verify sight line obstructions within intersection sight triangles. The camera was placed at the location of the stopped driver on the minor road and its height (3.5 ft) represented the driver's eye level. The passenger car was driven at a constant speed of 25 mph in each direction on the main road and its motion recorded by the video camera. The 3.5 ft high marked sides of the car represented a target of that height. Driving the car at a constant 25 mph speed ensured that distances could be calculated during video analysis by noting travel time of the passenger car. After video capture, it was transferred to a desktop computer for a frame-by-frame analysis. MGI's Video Wave 3 (Roxio, Inc.) video editing software was used to keep an accurate account of time elapsed during the video capture.

Objects located within 445 ft of the camera that blocked the passenger car were noted and their distance from the camera calculated. This calculation was based on the time it took the passenger car to travel between the object and the camera. If the blocking object was found to be in the approximate vicinity of the dark gray points in the line of sight analysis, then it was assumed that the line of sight analysis had correctly identified an obstruction in the intersection sight triangle.

Most of the sight line blockings identified by the line of sight analysis were validated either as obstructions or as potential obstructions. Some of the actual obstructions validated included tree trunks, utility poles, and utility appurtenances. Potential obstructions primarily consisted of overhanging tree branches as shown in Figure below

		Video validation	
		Confirmed	Unconfirmed
Line of sight analysis	Identified	62	4
	Not identified	3	0

Figure 6.14 confirmed and Non-confirmed sight line obstructions "An Application of Lidar Technology to Highway Safety"

6.6.1.6 Findings of the study

The objective of this study was to illustrate the use of Lidar elevation data to obtain highway safety-related information by taking into consideration intersection safety. Using Lidar data on potential sight distance obstructions at six selected intersections and then validating the results by videotaping in the field conducted line of sight analysis. Results verified that about 90% of the

potential and actual obstructions were correctly identified by the line of sight analysis.

Line of sight analysis is useful for detecting intersections where drivers might have trouble due to potential sight obstruction (overhanging tree branches) in the intersection sight triangles.

Lidar is beneficial finding in safety analysis and other applications like flooding mapping, vehicle-collision prevention systems, speed enforcement, and area wide vehicle emission estimation and railroading route location. It can also create a false color imagery to identify features of varying degree of quality.

6.6.1.7 Shortcoming of the study

- Cost-benefit analysis could be a significant factor while evaluating the benefits of Lidar technology, in the presence of other alternative methods like video/photo log analysis, safety audits.
- Obtaining Lidar data and aerial images simultaneously would enable analysts to detect obstructions such as on-road vehicles in the analysis thereby reducing the detection of false obstructions.
- The impact of positional inaccuracies of Lidar (up to one meter, horizontally) is important on the identification of sight triangle intersection. The effect such inaccuracy has on the triangle depends greatly on the overall size, density and location of the obstruction with respect to the driver's eye. The closer the object to

the driver, the more field of view potentially obstructed and the more difference a positional inaccuracy will create.

CHAPTER 7

Conclusions

Hazardous waste is a real threat to human life. It has negative impact on the environment and the human health if it is not properly controlled and managed. The effects of hazardous wastes have a different dangerous effect. The hazardous waste generally contains different substances such as metal, chemical, pesticides, organics, inorganic, solid, liquid, and gaseous and sometimes combination of some of them, but the biggest threat comes from the chemical wastes evolved from the contaminated ground water. Hazardous wastes have the most important potential environmental impact. In the past few decades, throughout the country, the concern for hazardous waste has grown tremendously due to the danger that threatens public health and the environment. In response to this concern, many legislatives and potentials have designated to control the wastes hazard problems. Generators, transporters, and handlers of the hazardous waste are playing the most important roles of reducing the hazardous wastes problems. Generator, are the institutions which produce the wastes whether manufactures or non manufacturing, which known as on-site wastes hazardous waste management which present 80 - 95 percent of hazardous waste volume, about 5-20 percent of hazardous waste are transported to off site waste hazardous facilities. There are different modes of hazardous waste transportion (highway, railway, air, water) and each mode has its own regulation and specifications.

There are 25% of people in the emergency response have adequate training to meet a hazardous materials emergency (30).

Geographic information systems (GIS) represent a technology with considerable potential for important applications in transportation engineering. One of the most important applications of the GIS is to utilize GIS to minimize the potential impact of hazardous waste transport shipment accidents. GIS is a powerful tool in the analysis and design of transport routing networks. Its graphical display capabilities allow not only visualization of the different routes but also the design of the road network.

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