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Optimal route risk-based algorithm for hazardous material transport in Kuwait

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ABSTRACT

Risk analysis of dangerous goods' routing indemnifies the safety of surrounding environment and population. For such a purpose, a risk/cost based algorithm was adopted to fit the available data of the State of Kuwait. Such algorithm identified the available alternative routes with their rankings for dangerous goods' transportation. Regulations of dangerous goods' transport that were set by various Kuwait's ministries were reviewed. Each aspect of the risk/cost based algorithm examined and reshaped in accordance to the available data and regulations. Incident probability, incident consequence, and risk assessment were used as the algorithm's main criteria. Gasoline transport by Kuwaiti National Petroleum Company (KNPC) was selected as a case study. The risk associated with a number of proposed routes was investigated. Consequently, an incident simulation scenario was developed by ALOHA toolset (a dispersion model software). This was based on the collected data that include climate properties, type of dangerous materials, topography, and type of release. The developed model was embedded in a GIS environment to generate impact zones based on both the dispersion model and the emergency response guide recommendations. The resulted impact zones had assisted in analyzing the population exposure estimations as well as in the sensitive and emergency facilities' proximity considerations. The results showed the best route choice for the studied case.

1. Introduction

Transport of dangerous goods and hazardous materials throughout Kuwait is a daily activity between factories, fuel stations, and warehouses. Those materials whether in gas or liquid form could be explosive, corrosive, poisonous, flammable, or infectious. Such dangerous materials transported on Kuwait's road networks are crossing residential and industrial areas. For this reason, it is important to analyze the risk associated with the transportation process and establish safe routing criteria. In a previous study conducted by Sayed et al. (2008), a dangerous good decision support system (DSS) was developed that is specific to the needs, conditions, and data availability within British Colombia. The DSS investigated potential risks and found an optimal route based on the least cost objectives as to finally estimate the safety of a route. As a follow up, the risk/cost-based dangerous goods' routing algorithm developed by Sayed et al. (2008) was modified in the current study to fit Kuwaiti data. Throughout the process, data was gathered from various institutions to reconstruct the different aspects of the Kuwaiti-version of the algorithm. Kuwait governmental regulations regarding the transport of dangerous goods were reviewed to help in the implementation of the algorithm. Kuwait's road network was represented in a GIS database with a dispersion plume, simulating a specific accident under local weather conditions, to create an impact zone. The impact zone was constructed based on the guidelines of the Emergency Response Guide (ERG) that was developed by the United States Department of Transportation, Transport Canada, and the Secretariat of Communications and Transportation (Mexico). By incorporating different data within GIS, a comparison between various scenarios was possible. Furthermore, the capabilities of the Dangerous Goods Routing Algorithm (DGRA) were demonstrated through a locally selected case study to identify the optimal safe route.

1.1. Statement of the problem

When deciding on the best dangerous goods routing strategy, various issues arise such as cost, risk, and social consequences. Therefore, intensive study is necessary to insure the safety of the transportation process. The dangerous goods routing algorithm adopted from Sayed et al. (2008) quantifies the risk factors associated with the transportation of hazardous materials. This is crucial in the case of Kuwait City in order to investigate

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the safety of process logistics regarding dangerous goods and to offer means for analyzing the routing strategies for such materials by governmental ministries. According to Kuwait customs department for the year 2012, the total weight of hazardous materials that entered the country and transported on the road system was 66.9 million kilograms at a total cost of 14.28 million dollars. The total amount of fuel transported to gas stations by Kuwait's national petroleum company was 211 billion liters of fuel for the years 2012/2013. These large figures do not include the massive amounts being transported by many other local companies. Such large amounts of hazardous materials need to be studied and heavily regulated for the safety of the public. For this reason, implementing the DGRA algorithm would provide the much-needed perspective on the best strategies to control the process of transporting DG.

1.2. Study objectives

In general, the main goal of this work was to fit the literature methodology related to risk/cost-based dangerous goods' routing algorithm to the Kuwait data. Maximizing the benefits of DGRA algorithm was accomplished through demonstrating how it can be implemented on Kuwait's road network and environment based on the local regulations for dangerous goods' transportation. The final form of DGRA was then demonstrated using a case study for transporting a shipment of gasoline. By a further analysis of the algorithm and its associated variables, it was possible to create a dispersion model and a buffer zone in compliance with the guidelines of the ERG. Both methods provided an impact zone that was infused in GIS database to extract the values necessary to estimate the risk by DGRA. This will highlight the risk associated with each route, provide a better planning scheme of hazardous materials transportation and optimize the routing process. Current laws controlling the transportation of hazardous matter in Kuwait were also revised in the light of research findings. It is important to specify the shortcomings of current Kuwait laws controlling the dangerous goods, thereby clarify how the findings for this paper can contribute to enhancing the current regulations. According to UN (2009) and Law of Environment Public Authority in Kuwait, these shortcomings can be summarized as follow:

- The appropriate classification of wastes considering their hazards and the controlling criteria need to be better defined in the law for a better strategies development regarding DG transportation.
- The law need to clearly include regulations on how to protect workers who may be exposed unknowingly during opening and transporting of DG.
- It is important also that the law offer certain measures to ensure that the potential risks of the dangerous goods are adequately communicated to all who may be exposed to the goods in the course of transport.
- An important issue that need to be added as a major modification is that Kuwait laws should establish provisions for the reporting of accidents and incidents involving DG in transport. All relevant information to DG transport need to be provided. This is important to build a historical database for planning emergency response.
- DGTA should be related adequately to the traffic control rooms for a proper recirculation of traffic and warnings sending in the case of an accident for traffic to avoid the affected area. VMS/monitoring techniques can be an asset in such case.

1.3. Scope of the study

This study first implemented the dangerous goods' routing algorithm (Traffic Department, MOI, Kuwait, 2014) that identified dangerous goods' routing criteria based on the available datasets. Data was gathered from different ministries and governmental institutions that are related to various aspects of dangerous goods' routing. Regulations controlling the process of transporting dangerous goods were also investigated. Then, the definition of traditional risk was compared to the dangerous goods' routing algorithm.

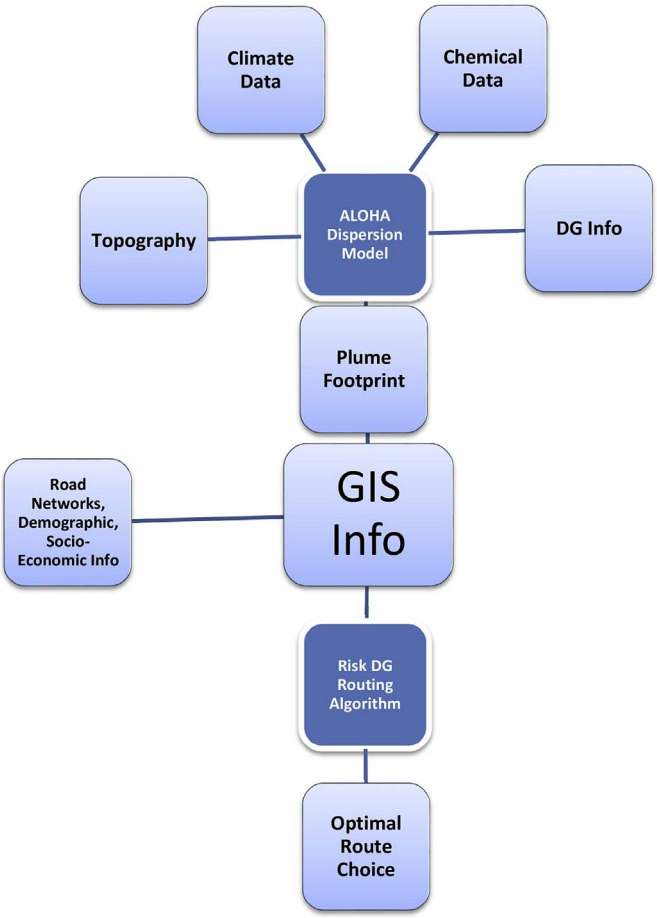

Fig. 1. Flow chart outlining the overall process of this research.

All collected information were then integrated into a GIS environment that incorporated other factors such as population centers and topography. This was done to finally present results in a way that will help in reaching a better decision for the optimal routing strategy. A case study that involved the main producer and transporter of gasoline in Kuwait was investigated with the aid of a dispersion model. The guidelines specified by the Emergency Response Guide were implemented. By comparing different factors such as travel distance, travel time, casualties, and costs along each route; a tradeoff was necessary to choose the best route.

All of the above data make up the components of cost-based risk criteria that when integrated into GIS; an optimal routing strategy is to be obtained. When incorporating the impact zone in a geographic information system that fits Kuwait's datasets, all DGRA risk criteria values are then available to be compared with the same risk values of alternative routes. To improve the understanding and readability, the overall process of this research is outlined using a flowchart (Fig. 1), highlighting what are new or different approaches from the past literature. Fig. 1 shows a conceptual framework for the proposed risk/cost-based DGRA. The model contains two major components: a Dispersion Model and a GIS. The dispersion model uses site data, chemical, atmosphere and source information to generate a plume footprint. Afterwards, the footprint and a number of datasets are integrated together in a GIS environment to perform the analysis. Based on the study objectives, the proposed methodology involves a set of dangerous goods routing criteria pertaining to safety, efficiency, security, and cost. These are chosen to include incident probabilities, incident consequence, operating costs, and human health impacts.