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A Methodology to Design a Composite Accident Index and Assess the Links in a Network Carrying Hazardous Waste: A Case Study of Kolkata Metropolitan Area

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Abstract

Hazardous waste management (HWM) involves transportation, storage, handling, treatment and disposal of these wastes. Transportation of the wastes is the only practice in HWM which is carried out in an unregulated offsite domain. These wastes are transported from their generating units (i.e. factories) and transferred to treatment, storage and disposal facilities (TSDF) for treatment and disposal so as to cause minimum damage to the environment. The transportation activity of hazardous waste imposes huge risk on the network it uses for routing of such wastes. The risk of accident involved during routing activity of hazardous wastes occurs in a totally uncontrolled domain making it ominous. Such accidents can result in explosions, fires, toxic fumes or spills contaminating the air, water or the earth. The adjoining population exposed to such catastrophes is unaware of the procedures to handle such waste and possible consequences they pose on human health due to exposure. Thus routing operations of these wastes have created concerns among researchers across the globe regarding the possible repercussions it may have on the human life, property and the environment at large. The possibility of accidents is on the rise due to expanding urban areas and increasing population density. However, the magnitude of the outcomes is increased manifolds due to involvement of hazardous waste. Risk assessments of networks through which such hazardous wastes are transported have been carried out in the past. The traditional definition of risk, which defines risk as a product of probability of occurrence of an event and the impact of a given event on the vulnerable population has been conventionally used by researchers across the world for quantitative risk assessment. However, this method requires database regarding the probability of occurrence of an event. Lack of such a database can jeopardize the above mentioned risk assessment methodology.
The present research aims at designing a methodology for assessing the accident index (AI) of links in a network based on its physical, traffic and landuse characteristics. These characteristics would incorporate attributes like carriageway width, surface

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condition of the links, congestion, night time visibility, pedestrians and non-motorized traffic on the link, type of adjoining landuse, etc. This index is designed based on the principles of aggregation used for designing environmental indices. AI act as a complementary tool in the assessment of risk in a network. Thus, unavailability of accident database would not deter researchers or industrial practitioners from assessing the risk posed due to hazardous waste transportation through a network. This can also be used to identify causal relationship between the attributes of AI and probability of occurrence of an event where such datasets are available. A regional network can be further analyzed based on the AI values of its constituent links and vulnerable links with high propensity of an accident can be identified. The proposed methodology has been demonstrated using the case study of the road network of Kolkata Metropolitan Area (KMA). Spatial analyses of the distribution of AI values over the network revealed concentration of AI values in few links of the network. The analyses of the network of KMA revealed that 4% links had AI values 3.5 to 5 times the mean AI value of the network. This analysis can be used for designing appropriate policy interventions for specific links of a network to reduce accident propensity of in a regional network.

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Keywords: Hazardous waste; Risk assessment; Routing; Aggregation; Composite Index

1. Introduction

Urbanization and the urban way of living has made human race captive to many manufactured products and this trend has had caught up with the rural areas as well. The dependence of modern lifestyle on manufactured products be it packaged food, detergents, electronic goods, building materials, modern textiles, etc has triggered the proliferation of the manufacturing sector. However, with every unit of manufactured product there involves an environmental cost which involves environmental pollution, depletion of natural resources and finally generation of unwanted waste (GEO-2000). These wastes have the potency to degrade environmental standards beyond repair and can pose serious threats to human health (Horton, Berkowitz, Haugh, Orr and Kaye, 2003).The disposal of such waste generated by different manufacturing sectors has become a burning issue for policy makers, environmentalists and manufacturers as well (Kumar, Mukherjee, Chakrabarti and Devotta, 2008).

Hazardous wastes thus generated are being disposed off in specialized disposal facilities to contain their negative impacts. This involves transportation of such wastes from their respective generating units to the centralized disposal facilities. Such transportation of hazardous wastes from the industrial units to these centralized Treatment, Storage and Disposal Facilities (TSDFs) receive hazardous waste from a number of generating units located in a region and usually have a catchment radius of 200 km (Chakrabarti, Patil and Devotta, 2003). Transportation of hazardous waste, though carried out by specialized vehicles can encounter an accident which may result in a devastating outcome, e.g. explosion fireballs, emission of toxic fumes, contamination of soil and surface water, etc (Rice et al., 2008). Thus an element of risk is involved during transportation of such hazardous waste. The route through which they are transported expose the entire population living adjoining these links of the road network to fatal risks. Moreover, the physical properties along these links are also exposed to risk of complete demolition (Alonso et al., 2008).

A lot of research activity has been carried out in past in this regard. The focus of these researches has been on impact of hazardous wastes on human health and environment at large (Kales, Polyhronopolous, Castro, Goldman, Christiani, 1997. Misra and Pandey, 2004), improvement of collection efficiency and disposal techniques of hazardous wastes (Yang, 1996), risk assessment during transportation of hazardous waste (Das, Gupta, Mazumder, 2012a), routing methodology to transport such wastes (Das, Gupta, Mazumder, 2012b), exercises to optimize routing and siting of TSDF (Alumur and Kara, 2007), etc. It is evident from the list that for carrying out most of these studies database of accidents during transportation of hazardous waste would be needed. The lack of a proper database can completely jeopardize the entire methodology of most of such studies. This is a bottleneck in most of the developing economies where such specialized database does not exist or is not updated regularly. Many a time accidents go unreported and hence make the database unreliable. This study intends to look into this problem and attempts at finding an alternative methodology to predict accident propensity in a road network using network specific physical and traffic characteristics.