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A Bayesian Network for the Transportation Accidents of Hazardous Materials Handling Time Assessment

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Abstract

To improve the efficiency of emergency rescue in transportation accidents of hazardous materials(HAZMAT), a Bayesian network(BN) was developed in this paper to estimate the accident handling time. Also, based on this BN, the difficulty of handling every types of accidents can be quantified. According to theoretical analysis and literature review, 7 nodes (season, time, type of road, type of HAZMAT, the former accident, the secondary accident and handling time) are used to set up the BN. The value of mutual information was calculated to refine the BN. A database of 902 transportation accident of HAZMAT cases was built up for Bayesian parameter learning. Based on the parameter learning of BN, the results were summarized as follow: (1) The BN could be used to estimate the probabilities of handling time in different periods which include '0 to 2 hours', '2 to 4 hours', '4 hours and more'. (2) The difficulty of each type of accident can be ordered as follow: rollover> rear-end> internal fault≈ impact> falling> tire fault> vehicle body fire. Leakage>combustion explosion.

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Keywords: hazardous materials transportation accidents, Bayesian network, accident handling time, emergency rescue

1. Introduction

In recent years,the road transportation volume of HAZMAT ranges from 0.1 billion tons to 0.2 billion tons annually in China [1]. With the increase of the HAZMAT freight amount, there were the hazmat road transportation accidents frequently, which caused great damage to the national economy, peoples' life property and the environment resources. Because of the physic-chemical characters of HAZMAT (such as explosion, combustion, poison, corrosion, combustion supporting), a more serious secondary accident is often derived from the former accident which poses a great threat to pedestrians, residents, ecological environment, buildings and vehicles. It is significant to seek a mathematic model for estimating the accident handling time. Only in this way, can the traffic situation be controlled timely. Also, according to the estimate of the accidents handling time, once an accident happened, an emergency response plan can be formulated appropriately.

The following scholars have studied the causes and the consequences of the accident. A. Ronza [2] used transportation accident databases to investigate ignition and explosion probabilities of flammable spills by event trees; C. Samuel [3] presented a temporal trend study of HAZMAT incidents occurring through the transportation of flammable liquids; Bahareh Inanloo [4] weighed exposure health risks, proximity to vulnerable areas, delay costs and trucking expenses of HAZMAT cargo routing by Python programming. Although there has been many studies on road transportation accidents of HAZMAT, the disposal of these accidents was always neglected.

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Moreover, with the advantage of causal analysis, Bayesian network is widely used in the case study of accidents in transporting hazardous meterials. L.J. Zhao [5], developed a Bayesian network of 8 nodes(road condition, weather, management, human, HAZMAT packing and loading, transportation vehicle) which based on a database of 94 cases transportation accidents of HAZMAT. T. Zhu et al [1]. studied 162 accidents that occurred during the transportation of HAZMAT and concluded that the following major factors were responsible for the accidents: such as road condition, weather, management, human, HAZMAT packing and loading, transportation vehicle, the number of deaths and the number of injured. X. Wang [6] concluded the following factors: human, type of tank, weather, road condition. However, the related research was mainly to analyze the cause of the accident, the vital factors such as handling time, type of the former accident and the secondary accident were always neglected.

In this respect, 902 transportation accidents of HAZMAT were studied from the beginning of 2013 to 2016 in this paper. A new BN was developed for estimating accident handling time and assessing the difficulty of each types of accidents.

2. Bayesian network and NETICA

Bayesian network is a graph model for describing the probabilistic correlation between variables. It is one of the most effective theoretical models in uncertain knowledge representation and reasoning field [7]. With the development of Bayesian statistics, it has been widely used. Also, BN is gaining more and more experts and scholars' recognition.

2.1. Directed acyclic graph

Based on literatures material, risk analysis methods such as fault tree [7] and bow tie [8] are applied to construct BN. By using these methods, the structure of BN is simplified. However, the directed edges in levels can only be neglected. BN constructed by directed acyclic graph can avoid the above-mentioned problems. The directed edge between two nodes (from the parent node to its offspring nodes) represent the causal relationship of them, each node corresponds to a conditional probability [9]. A typical DAG was shown in Fig. 1.

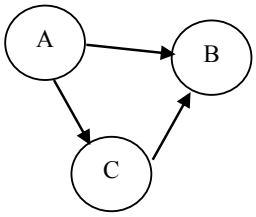

Fig. 1. Directed acyclic graph

2.2. A brief introduction of NETICA

At present, many software platforms are available to construct BN, such as BN Toolkit, BayesBuider, JavaBayes, Hugin expert. Compared with other software, NETICA is such popular for its GUI and practicability. It is a powerful, easy-to-use, complete program for working with belief networks and influence diagrams. It has an intuitive and smooth user interface for drawing the networks, and the relationships between variables may be entered as individual probabilities, in the form of equations.

3. Develop a Bayesian network for transportation accidents of HAZMAT assessment

3.1. Define the variables and develop preliminary Bayesian network

According to theoretical analysis and literature review, the following factors were concluded: Weather condition, Management, Type of road, Road condition, Skill, Health, Safety awareness of driver, HAZMAT packing and loading, Transportation vehicle. However, once a transportation accident of HAZMAT occurred, the accident investigation has not yet been carried out, so after answered the emergency call, only 6 nodes (season, time, the type of road, the type of HAZMAT, the former accident, the secondary accident) can be obtained. Therefore, the 7 nodes (season, time, the type of road, the type of HAZMAT, the former accident, the secondary accident and handling time) are used to construct the BN and they can be divided into 3 levels: