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Alternative method of highway traffic safety analysis for developing countries using delphi technique and Bayesian network

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ABSTRACT

Highway traffic accidents all over the world result in more than 1.3 million fatalities annually. An alarming number of these fatalities occurs in developing countries. There are many risk factors that are associated with frequent accidents, heavy loss of lives, and property damage in developing countries. Unfortunately, poor record keeping practices are very difficult obstacle to overcome in striving to obtain a near accurate casualty and safety data. In light of the fact that there are numerous accident causes, any attempts to curb the escalating death and injury rates in developing countries must include the identification of the primary accident causes.

This paper, therefore, seeks to show that the Delphi Technique is a suitable alternative method that can be exploited in generating highway traffic accident data through which the major accident causes can be identified. In order to authenticate the technique used, Korea, a country that underwent similar problems when it was in its early stages of development in addition to the availability of excellent highway safety records in its database, is chosen and utilized for this purpose. Validation of the methodology confirms the technique is suitable for application in developing countries. Furthermore, the Delphi Technique, in combination with the Bayesian Network Model, is utilized in modeling highway traffic accidents and forecasting accident rates in the countries of research.

1. Introduction

The issue of traffic safety is a global problem which seriously affects developing countries as well as developed countries. The magnitude of the negative effects of traffic safety problems is more devastating in developing countries than in industrialized ones for many obvious reasons. One of such reasons is that little or nothing is done to guarantee the safety of road users in developing countries including drivers of motorized and non-motorized vehicles, passengers, and even pedestrians (WHO, 2004). Very little is known about the primary contributing factors of these highway traffic accidents in developing countries simply because most of these countries either do not keep any good records or have no records at all. A majority of the developing countries have the tendency to blame most highway crashes on speed alone. By implication, these countries have no reliable highway traffic accident data kept on various incidences of accidents. Additionally, a majority of the countries are poorly trained in accident investigations and accident data collection, record keeping, and data maintenance. In most instances, many accident scenes are unintentionally greatly contaminated by witnesses and well meaning individuals (good Samaritans) who simply stop by the accident scenes to help the crash victims. Additionally, many researchers have faced different levels of frustration owing to lack of transportation safety data to advance their research work and a good number simply abandoned the effort altogether because of lack of data.

In order to start tackling the safety issues on the highways of these developing countries, a logical approach is to first identify the primary causes of the accidents. This is a very challenging undertaking as no reasonable, meaningful, or useable data exist in most of the developing countries. Besides, the diverse nature of these countries politically, culturally, and level of development creates another level of problems. This also means that they are diverse in their driving cultures, policy enforcement techniques, and traffic safety education methods. Since there is no positive evidence

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of good policy or good plan in place, a reasonable plan of action is to develop a method by which reliable and useable highway traffic accident data can be obtained. Such alternative will prove very valuable in identifying the primary highway traffic accident causes. To that effect, the Delphi Technique, employed in this paper, is utilized and the data obtained in the process, along with Bayesian Network Model, is eventually used in forecasting highway traffic accidents of the developing countries.

With the preceding in perspective, the primary goal of this paper, therefore, is to develop a method to obtain the primary causes of highway traffic accidents in developing countries. Once the major causes are obtained, they are used to determine their individual impacts as accident causes and finally generate their individual level of contributions in any accident situation. By utilizing the Bayesian Network, these contributions are eventually modeled to generate the highway traffic safety standards of developing countries and forecast the probability of occurrence of highway traffic accidents in them. This eventually produces the highway traffic collision rates. The results obtained are in turn employed to test the validity of the Delphi method itself. This validation process is achieved by using the data from Korea, a country that experienced similar problems when it was developing. The data that are generated from the Delphi Technique are authenticated by utilizing the data stored in the Korean National database already established to have been properly collected, kept, and maintained.

2. Literature review

2.1. The Delphi technique

The Delphi Technique is essentially a technique that is based on the guess work of experts whose independent guesses over a number of times produce trustworthy information or data that can be used for an intended purpose. This is a prediction approach that originated from the Rand Corporation in the 1960's (Cline, 2000). The technique is a methodical interactive procedure that completely relies on the knowledge of a panel of experts whose duty it is to predict an outcome, which is normally achieved through the goal of consensus building without bringing the experts face to face. It is essential when a group of individuals wants to take a stance on an important subject in a setting, or when the issue being considered centers on strong groups with differing opinions and ideas. If the strengths of participating experts in the survey are numerically high, the outcome of their combined predictions will be more precise. It is universally understood that Delphi technique employs group interaction (Rowe et al., 1991; Häder and Häder, 1995) and in effect uses questionnaire as a method of interaction (Martino, 1993). Because expert opinions are the sole source of information available, this technique is particularly useful for forecasting events that would take place in distant future (Cuhls, 2000). The conclusions arrived at simply replicate the views of the experts, their knowledge, as well as their professional opinions.

In all cases, the selection process is usually knowledge-based and specific, and is done by contacting only those who are very familiar with the specific subject of research. Those that are believed would provide extremely reliable results are invited to participate (Washington et al., 2009). This includes experts in the field of transportation and highway traffic safety, hospital staff (doctors, nurses, paramedics, etc.) that are familiar with, and/or directly involved in the treatment of those that sustain injuries in highway critical events, transportation planning professionals and officials, policy makers, law enforcement personnel, and professional drivers.

The Delphi Technique has several advantages including its application to varying size groups. It can be used in official settings or in relaxed situations (Green et al., 2007). According to Brooks (1979), the technique prevents a few dominant individuals from imposing their ideologies and will on others. Its flexibility also accords those who may be constrained by geographic location and time the opportunity to respond at their convenient time. It produces the same type of results as in a group converged in one place. It allows experts with differing views to come to an agreement in a short time frame (Green et al., 2007). Helmer (1983) also agreed that the technique is regularly used to obtain agreement within a group of experts that has relevance in dependability. Helmer (1983) also supported the research conclusion by Linstone and Turoff (1975) and Dalkey (1967) that the use of Delphi in group response generates a singular opinion that conveys the experts' view. It is very inexpensive to run because it eliminates time and cost of travel (Green et al., 2007). A few of the obstacles associated with unwillingness to proffer unpopular opinions, the rejection of the opinions of associates, as well as modification of previously accepted positions are overcome. The anonymity of participants is guaranteed and this allows them the freedom to express their opinions without undue pressures to conform from others in the group (Green et al., 2007). Barnes (1987) in his own study concluded that the technique is simple to use, adding that superior level mathematical expertise is not required in its application. Martorella (1991) states that the use of questionnaires eliminates some of the general problems associated with group interviews. For these reasons, all decisions are evaluated on their value or merit, as opposed to who originated the idea.

Because the use of iterations is involved, participants have ample opportunities to reevaluate their initial responses. Finally, the conclusion arrived directly reflects the professional opinions, knowledge, and viewpoints of all participating experts (Rowe and Wright, 2001). With the above advantages come some drawbacks, which include, that an ample amount of time is invested in assembling the right Delphi Panel. The opinion of a select few may not be representative of the general consensus or the opinion of a larger group. Middle ground solutions or results may not always be right. Maintaining active participation by all in the panel may be extremely difficult and the facilitator may easily influence the outcome of the entire process since it is less transparent than face-to-face alternatives (Roberts and Roberts, 2011).

Based on the preceding discussion, the data from the Delphi panelists are worthless if there is no meaningful method of bringing them together. There are several modeling techniques available, but the use of the Bayesian Network Model is employed due to the advantages it presents, which are discussed next.

2.2. The Bayesian network model

An effective approach in maintaining traffic safety hinges on determining and analyzing the major causes of traffic accidents. Once all the data are obtained from the Delphi panelists, the next task is to find a way to tie them together to determine how they influence the occurrence of accidents. One of the ways to do so is by using the Bayesian Network Model. A Bayesian network is a precisely meticulous way to replicate a world, one which is flexible and adaptable to the measure of knowledge an individual has, and one which is mathematically proficient, (Norsys, 2000; Pearl, 1988). This network is also a graphical model for interpretation under ambiguity, where the nodes represent variables and curve represents direct link between the nodes (Heckerman et al., 1995; Grossman and Domingos, 2004). In addition, Bayesian network models the quantitative potency of the connections between variables, thereby allowing likely beliefs about them to be updated routinely as new information is added (Neapolitan, 1990; Pearl,