A SYSTEMATIC GROUPING/NETWORK MODELLING APPROACH

FOR FINDING LESS RISKY HIGHWAY TRAFFIC ROUTES

Civil Engineering

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ABSTRACT

This thesis presents an approach that uses a systematic grouping Fall-Tree method to analyze limited highway traffic accident data to find risk weight factors that are attributed to road segments of highway networks. The routes of less risky travel are then determined using a network modelling software that minimizes the risk weight factors of the paths between two points.

In the transportation industry, increasing concern has been devoted to finding the less risky route (or risky route) for shipping goods from production sites to the market areas. In addition to cost and length, the decision maker also considers the possibility of accidents when transporting dangerous and hazardous materials. This thesis provides a methodology based on a systematic grouping method for estimating the significant and insignificant factors that can contribute to accidents with F-ratios under limited data available on each subroute, and for evaluating risk weight factors. The less risky routes can be found using shortest path network modelling with minimum risk weight factors on each proposed travelling route.

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Chapter 1

INTRODUCTION

There has always been a need for some form of analysis of transportation safety since the advent of the appearance era of transportation tools.

From the statistics of National Safety Council (1982), the death rate of all accidents is 40.2% in which motor-vehicle accidents take up 49.5%, and this data has been stable around 50% for many years. Dangerous and hazardous materials transportation is a large and growing segment of the transportation industry. As public concern grows over the safety of dangerous and hazardous materials transport, public officials are placing greater emphasis on the ability to conduct analyses of present practices and future policy initiatives. The capability to do this effectively is directly dependent on the quality and availability of information on previous transport accidents and incidents. Because of the potential for fires, explosions, ground water contamination, and toxic effects on human health in the event that materials are inadvertently released, a very important problem has been proposed to find the less risky route from an origin to a point of destination. Especially to find the less risky routes under limited highway accident data available.

1.1 Background

Previous research evaluations in this area have formulated risk estimation methodologies that neglect important factors affecting Highway Traffic Accidents (HTA) in the face of limited data availability. Traditional approaches to the transportation system analysis have focused on economic analysis and, consequently, much is known about operating costs and costing methodology. However, transport risk estimation is only now reaching adolescence. At the heart of this problem is the subject of risk estimation. Emphasis is placed on assessing the risk weight factors which is defined as the ratio of number of HTA on a subroute divided by the total HTA on the concerned routes or the selection of less risky traffic routes. The conventional way of assessing the risk is using Fault-Tree analysis [2,15]. In this type of analysis, the probability of accident occurrence along a travelling route is determined and the less risky route is given by the route with the smallest probability of an accident. The advantage of this method is that many possibilities of accidents and several factors which affect the accident data can be considered. But the obvious disadvantage is that, because of the difficulty of carrying out the calculations, few factors are considered, and it is quite possible that significant factors be ignored. Another disadvantage is the difficulty of calculating these

probabilities when several factors are present, because they have to consider the individual probability density functions of all factors and the joint probability density functions of all combinations of factors.

After the determination of risk weight factors or the probabilities of accident occurrence, two major approaches for solving for the path of travel currently exist. One approach is the labelling approach (or the dynamic programming approach), and the other is the shortest path network approach.

Usually, the researchers consider factors separately for different goals, for instance, two factors are considered when transporting nuclear fuel, travelling length and the population along the route. The conclusion is that the less risky route is different when considering these two factors separately and two separate highway routes can be used depending on the trade-off between these two goals. The dynamic programming approach is normally used when two or three goals are considered at the same time. The shortest path is mainly used when considering a single factor. For solving the proposed problem, the shortest path approach will be used because the author only considers the minimum risk weight factor on the travelling routes and the length is considered by the program automatically.

1.2 New Approach - Systematic Grouping Approach

Systematic grouping method[16,24,27]

There are many factors affecting highway traffic accidents (HTA) which exist independently and interact with each other dependently. Usually, the relations between any two factors and among all factors are not obvious. With the increase on the number of factors, it is very difficult and, sometimes, even impossible to get the solution (finding risky route) using conventional approaches. The more factors that are to be considered, the more accurate the results are, but the more difficult to analyze them to find the solution of the problem. So the question is how to group and analyze the data regardless of the number of factors considered.

The beauty of systematic grouping method is that interactions among factors can be considered automatically when grouping, we can use as many factors as possible as long as the data of these factors are available. Another advantage of the systematic grouping approach is that it can find out the significant and insignificant factors which influence HTA. Because of the complexity of these random factors in different places, the property of its extensive application appears very advantageous and superior to some traditional approaches.

The systematic grouping approach is not a fresh concept, but its use in the analysis of HTA, and the determination of

less risky route is original.

Another difference of this approach from other conventional approaches is that instead of calculating the probability of accidents due to the factors and probability of accidents due to interaction of factors, systematic grouping approach uses risk weight factors on the subroutes. Because each individual subroute has different risk weight factors due to different road situations, the shortest route network modelling can be used to minimize the risk weight factors on the travelling routes.

1.3 Objective and Scope of This Work

The objective of this study is to formulate a systematic grouping approach to analyze limited highway traffic accident data for the determination of risk weight factors and the evaluation of significant factors that contribute to accidents.

Because of the lack of real accidents data, the scope of this study is only based on assumed data. The author can only use several fixed factors like average daily traffic data, road design conditions, etc. which have been proven significant in most cases [17,25]. The software QSB (Quantitative System Business), which contains the calculation of shortest route modelling problem, will be used for selecting the path of travel which minimizes the risk of an

accident according to the weight factors of the individual subroutes.

1.4 Organization of Thesis

In Chapter 2, the author presents the basic theories, mathematical models and derivations of systematic grouping method and shortest path approach.

For completion, APPENDIX C includes over 40 factors influencing HTA as references. Chapter 3 is the core part of this thesis and includes the case studies of proposed method considering Texas highway maps of District 24 (EL PASO) and District 6 (ODESSA). This chapter also includes the use of F-ratios for finding the significant factors, the calculation of risk weight factors and the use of shortest path network modelling for the routes with less risk.

The summary and conclusions of the research presented in this thesis are discussed in Chapter 4. Recommendations for future enhancement and improvement of the methods are also covered in this chapter.

Appendix A outlines the procedures for finding less risky routes. Appendix B contains 9 maps which show corresponding less risky routes that was determined using the proposed method.

Chapter 2

BASIC THEORY OF SYSTEMATIC GROUPING

Highway traffic accidents (HTA) are affected by many factors or elements. It is very important to know how significant each factor influences HTA. Here, highway traffic accident data is defined as a count or a list of accidents in a given segment of a road or street with the corresponding conditions and factors that might have caused the accident to occur. The systematic grouping method consists of categorizing HTA data into different classes and put the data into corresponding combinations of categories to find the significance of the factors. The advantage of grouping methods is that the methods analyze the significance of the factors which affect the solution, regardless of the number of factors considered. For example, average daily traffic data, road design conditions and the number of lanes are three factors affecting HTA, which maybe significant or not. Grouping methods analyze whether or not these three factors are significant, then choose the significant factors to determine the risk weight factors which are used in shortest path network modelling to evaluate the risky and less risky routes.

There are two basic theories which are implemented: (1) grouping methods [16,24,27] and (2) shortest route network

modelling [18,19,20,21,22,23,38,39,41]. The mathematical models and introduction of these two theories will be described in the following sections.

2.1 Systematic Grouping Method

The elements A,B,C... affecting an event are defined as factors A, B, C,...; each individual factor has different data hierarchy [26] which can be expressed as A_1, A_2, A_3...A_i, B_1, B_2, B_3, B_4,...B_j, C_1, C_2,...C_k etc. The divisionS of these groups of data are called levels. For instance, factor A can be defined as the average daily traffic (ADT) and can be grouped into levels A_1 (ADT<600), A_2 (600<ADT<2000), A_3 (2000<ADT<4000) and A_4 (ADT>4000). The influence of the level to the experiment results is defined as an effect. We group factor A in P groups or levels (P=4 for the above-mentioned example), factor B in Q groups (Q levels), factor C in M groups (M levels) and similarly for the rests of the factors. Figure 2.1 shows a graphical fall-tree representation of the systematic grouping. Factor A is represented with P main branches. The level of factor B cause Q subbranches underneath each level of factor A. Likewise, the levels of C produce M branches under each level B. There are M*Q*P different branches that consider all possible configurations of factors.

For the illustration purposes, consider the case of highway traffic accident reports collected for a period of

time. Each report contains the location of the accident, the time of the accident, and the driving conditions of the road. These accident reports can be analyzed by defining possible factors. The number of accidents that occur at each road location under the possible influence of the defined factors can be counted. Then, with a large data available, the number of accidents provide records that can be interpreted as risks of accidents.

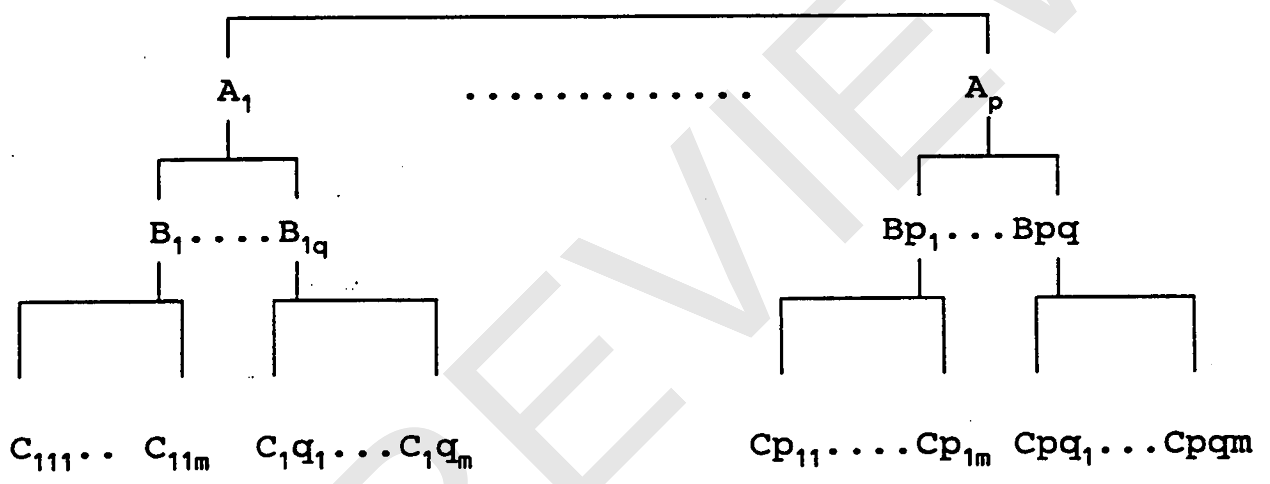

Figure 2.1 Systematic Grouping

The convenience and advantage of systematic grouping is that it is not needed to consider the interaction among the factors.

2.2 Mathematical Model of Grouping Method

The generalized mathematical model of grouping methods for two factors A and B will be shown in this section. For