

INFORMATION TO USERS

This dissertation copy was prepared from a negative microfilm created and inspected by the school granting the degree. We are using this film without further inspection or change. If there are any questions about the content, please write directly to the school. The quality of this reproduction is heavily dependent upon the quality of the original material.

The following explanation of techniques is provided to help clarify notations which may appear on this reproduction.

1. Manuscripts may not always be complete. When it is not possible to obtain missing pages, a note appears to indicate this.
2. When copyrighted materials are removed from the manuscript, a note appears to indicate this.
3. Oversize materials (maps, drawings and charts are photographed by sectioning the original, beginning at the upper left hand corner and continuing from left to right in equal sections with small overlaps.

UMI[®]

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

PREVIEW

PREVIEW

**A SYSTEMATIC GROUPING/NETWORK MODELLING APPROACH
FOR FINDING LESS RISKY HIGHWAY TRAFFIC ROUTES
Civil Engineering**

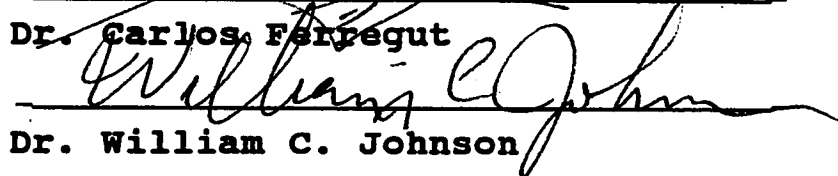
APPROVED:



Dr. Roberto A. Osegueda, Chairman



Dr. Carlos Ferregut



Dr. William C. Johnson



Dean of the Graduate School

**A SYSTEMATIC GROUPING/NETWORK MODELLING APPROACH
FOR FINDING LESS RISKY HIGHWAY TRAFFIC ROUTES**

by

DAWEI WANG, B.S.

THESIS

**Presented to the Faculty of the Graduate School of
The University of Texas at El Paso
in Partial Fulfillment
of the Requirements
for the Degree of
MASTER OF SCIENCE**

**Civil Engineering Department
THE UNIVERSITY OF TEXAS AT EL PASO**

May 1992

ACKNOWLEDGMENTS

Many people have contributed to this thesis directly and indirectly. I really wish to use this chance to express my sincere appreciation and gratitude for their help and support.

First of all, unending thanks should go to Dr. Roberto A. Osegueda who has provided invaluable support during my graduate program at UTEP and patient guidance to this research work and thesis. He is also one of the best teachers I have met while attending American universities.

Secondly, special appreciation has to be tendered to Dr. Carlos Ferregut for his constant guidance and support to this thesis. He has provided many valuable mathematical ideas and useful information which contributed to the accomplishment of this thesis work.

Particular thanks should go to Dr. William C. Johnson for his advisory committee participation and comments on the thesis.

I would also like to express my appreciation to Dr. H.S. Oey for his advise and for providing for software.

Similarly, gratitude is given to Dr. David Rozendal for his advise and support during my graduate program at UTEP.

Special appreciation goes to Mr. Alfredo Candelaria for his review and critique of this thesis.

I also want to take this chance to express my

appreciation to Mr. Chang Cheng, Mr. Qiang Yiejie and Mr. Lin Yingjie for their help at UTEP.

The moral support from my wife, my parents, parents-in-law and all the members of my family are always the most encouraging source. I would like to thank them all, especially my lovely wife, Hua, for her constant understanding, support and patience.

Very special thanks should be given to my relatives, Fan Yan and Mei Ping at the University of Pennsylvania who have my unending gratitude.

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.

CONTENTS

	PAGE
LIST OF TABLES	viii
LIST OF FIGURES	ix
Chapter	
1. INTRODUCTION	1
1.1 Background	2
1.2 New Approach - Systematic Grouping Approach	4
1.3 Objective and Scope of This Work	5
1.4 Organization of Thesis	6
2. BASIC THEORY OF SYSTEMATIC GROUPING	7
2.1 Systematic Grouping Method	8
2.2 Mathematical Model of Grouping Method	9
2.3 Shortest Path Network Modelling	19
3. APPLICATION OF SYSTEMATIC GROUPING-SHORTEST	
ROUTE APPROACH	23
3.1 Analysis of Factors	23
3.2 Risky Weight Factors	35
3.3 Finding of Less Risky Routes and Analysis of Results	42
3.4 Discussion of Route Selection	49
3.5 Effectiveness of Significant Factors	50
3.6 HTA Data and Factors for Study Cases	51
3.7 Overview of Study Cases	63

3.8 Discussion of Results	68
4. SUMMARY, CONCLUSIONS AND RECOMMENDATION	
4.1 Summary	70
4.2 Conclusions and Recommendation	71
REFERENCES	73
APPENDIX A	77
Algorithm of Finding Less Risky Routes in Daytime .	77
APPENDIX B	82
Maps of Less Risky and Risky Routes in Odessa and El Paso	82
APPENDIX C	92
Generalized Factors Affecting Highway Traffic Accidents	92
CURRICULUM VITAE	133

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Analysis of Variance Table	19
3.1	Addition of Relevant Group Data of Odessa District	28
3.2	Analysis of Variance of HTA Data for District 6	30
3.3	Addition of Relevant Data	33
3.4	Analysis of Variance of HTA Data for District 6	34
3.5	Arrangement of Node and Link Numbers, RWF and OWF	38
3.6	Addition of Relevant Data of El Paso District	56
3.7	Risky Weight Factors for Case Study 1	64
3.8	Risky Weight Factors for Case Study 2	65
3.9	Risky Weight Factors for Case Study 3	66
3.10	Differences of NOL in Three Case Studies ...	67

LIST OF FIGURES

Figure	Title	Page
2.1	Systematic Grouping	9
2.2	Illustration of Calculation in Systematic Grouping	10
3.1	Systematic Grouping Data for Odessa	27
3.2	Systematic Grouping Data for Odessa	32
3.3	Risk and Optimal Weight Factors for Odessa	37
3.4	Less Risky Routes in Daytime (Odessa)	45
3.5	Risky Routes in Daytime (Odessa)	46
3.6	Less Risky Routes at Night (Odessa)	47
3.7	Risky Routes at Night (Odessa)	48
3.8a	Systematic Grouping Data of HTA Under A_1 ..	52
3.8b	Systematic Grouping Data of HTA Under A_2 ..	53
3.8c	Systematic Grouping Data of HTA Under A_3 ..	54
3.8d	Systematic Grouping Data of HTA Under A_4 ..	55
3.9a	Risky Weight Factors Under A_1	59
3.9b	Risky Weight Factors Under A_2	60
3.9c	Risky Weight Factors Under A_3	61
3.9d	Risky Weight Factors Under A_4	62
3.10	Less Risky Routes in Daytime for Case Study 1	68
3.11	Less Risky Routes in Daytime for Case Study 2	68

3.12	Less Risky Routes in Daytime for Case Study 3	68
C-1	Truck Accident Rates for Different Truck Type and Working Conditions	93
C-2	Distribution of Truck Accidents Percentage by Truck Configuration	94
C-3	APM by location (Daytime, East and West) ..	95
C-4	Accidents on Dry and Wet Pavements	96
C-5	Relative Accident Involvement by Driver Age for Total and Injury Accidents	97
C-6	Accidents Affected by Improvements of Road Conditions	98
C-7	Accidents for Approach/Departure Distance of Bridge	99
C-8	Accidents Due To Driver Errors at Cross Section of Highway and Railway	100
C-9	Relation Between Pedestrian Volume and Pedestrian Accident Experience for Three Levels of Vehicle Volume	101
C-10	Accidents Affected by Signal at Intersection	102
C-11	School Trip Pedestrian Accidents	103
C-12	Accidents at Different Time of Day for Automobiles and Bicycle	104
C-13	Average Accidents in Different Months of	

	a Year	105
C-14	Average Accidents in Different Days of a Week	106
C-15	Fixed-Object Accident Type by Road System	107
C-16	Accidents Attributable to Inattention	108
C-17	Accidents Involvements for Straight Trucks	109
C-18	Relations Between Accident Rate per 100 Million Vehicle Miles and Weight of Vehicle	110
C-19	Road Accident Involvement of Various Weight Groups of Trucks	111
C-20	Types of Police Vehicle Accidents	112
C-21	Weighted Means of Wet-to-Dry Truck Accident Involvement Ratios	113
C-22	Relationship Between Lane Width and Accident Rate on Rural, Two-Lane Roads ...	114
C-23	Accident Rates Caused by Different Accident Types Downgrade Direction	115
C-24	Relationship Between Single-Vehicle Accidents With Different Lane Width and ADT	116
C-25	Fatal Accident Involvement Rates for Combination Vehicles by Type of Road and Area	117
C-26	Fatal Accident Involvement Rates by Vehicle Configuration, Type of Road, Area,	

		xii
	and Time of Day	118
C-27	Accidents Due To Improper Driving	119
C-28	Accidents Affected by Vehicle Defect	120
C-29	Percentage of Deaths Due to Accidents in Different Times and Places	121
C-30	Sex of Driver Involved in Accidents in Different Years	122
C-31	Death and Injuries of Pedestrians by Action	123
C-32	Driver Drinking Conditions Involved in Accident	124
C-33	Types of Motor Vehicles Involved in Accidents	125
C-34	Motor-Vehicle Deaths on Major Holidays ...	126
C-35	Normalized Relationship Between Accidents and Lane and Shoulder Conditions	127
C-36	Normalized Relationship Between Accidents and Width of Clear Recovery Area	128
C-37	Normalized Relationship Between Accidents and Bridge Width	129
C-38	Accidents Affected by The Degree of Curvature of Road	130
C-39	Accidents Affected by Light Conditions ...	131
C-40	Accidents Affected by Road Surface Conditions	132

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 $A_1, A_2, A_3 \dots A_i$, $B_1, B_2, B_3, B_4, \dots B_j$, $C_1, C_2, \dots C_k$ 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.

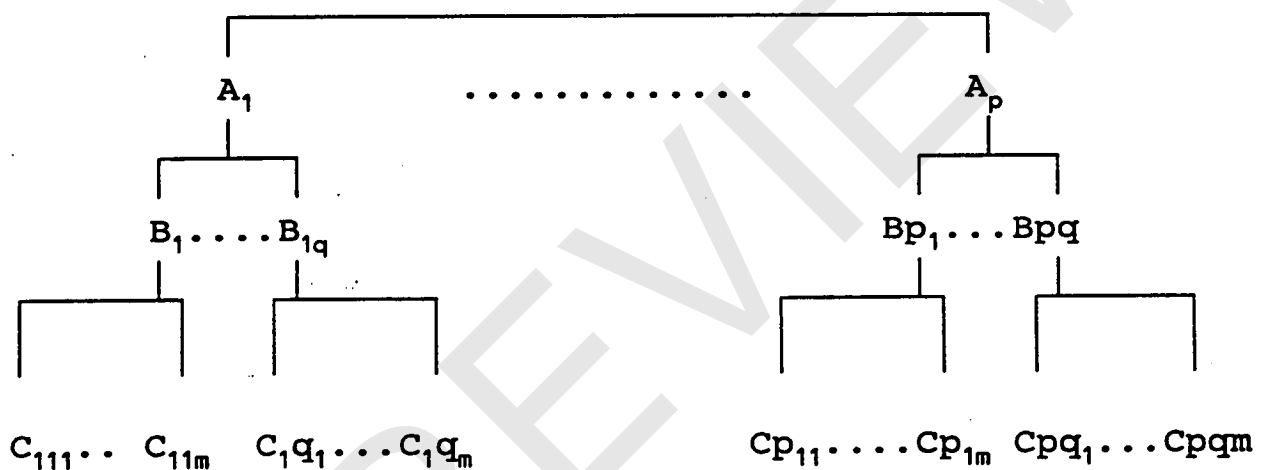


Figure 2.1 Systematic Grouping

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