

摘要

由於巨大的地震災害發生時，造成道路系統遭受毀滅性的破壞，致使災區緊急救援與工程搶修等車輛無法通行，嚴重影響救災計畫之進行，尤其於災害發生期間，道路交通系統嚴重受損導致部分路段無法通行。因此，如何維持災區運輸系統功能，以有效提升緊急救援效率，並減少人民生命財產損失，成為災害發生期間最基本且重要工作。

本研究目的即在構建交通管制決策工具，祈能建立不同救援需求目的之交通管制策略，而能有效控制私人車輛及管理緊急救援車輛，並充分發揮震後受損道路系統應有之功能。由於交通管制決策過程中『決策者』與『用路者』之間係相互影響之互動決策過程，本研究乃應用二階數學規劃方法及路網最佳化理論，建構多目標「交通管制策略模式」。基本模式架構決策目標，乃以緊急救援車輛為最高優先考量，並在道路容量許可前提下，使進入管制區車輛最大化為目標之管制策略，另為因應災區瞬間產生擁擠車流及平衡災區交通需求與供給，乃尋求最短路徑旅行時間方式用以分析旅運行為，以符合災區緊急救援需求。

修正模式架構則同時考量滿足『救災需求』與『民眾需求』為目標之管制策略，並於模式下階考量結合路網均衡指派與旅次分布之整合模式（Combined Trips Distribution/Assignment Model, CDA）探求問題之本質，以同時考量地震發生後旅次重分布行為，並藉由旅運行為分析尋求最短旅行時間路徑。為實證分析所建構交通管制決策模式之可行性及合理性，以及求解模式之效率性，分別應用模糊互動規劃法及基因演算法分析；最後經由情境假設分析結果顯示，本研究因應地震災區所建構之交通管制決策模式，能充分發揮都市地震災區道路網系統功能，並有效提昇緊急救援工作之效率。

關鍵字：交通管制、二階規劃、緊急車輛、基因演算法、模糊互動規劃、CDA 模式

ABSTRACT

When a severe earthquake takes place, the road network system often suffers serious destruction and results in malfunctioning of network systems. In particular, impassable roads and streets block transportation in the periods of evacuation, rescue and restoration. How to maintain traffic functions to facilitate rescue missions and save more lives will turn out to be an essential task during the post-quake period.

This thesis aims at developing a decision-making tool that can potentially be used in managing the traffic flows of emergency vehicles and controlling those for private use in earthquake disasters. Methodologically, it addresses a multi-objective, two-modal network flow problem based on the concept of bi-level programming and network optimization theory. The objective of the Basic Model is to allow as many non-rescue vehicles to enter the disaster areas as possible with two requirements: not to disturb necessary rescue vehicles entering the disaster areas and not to exceed the left available roadway capacity.

In order to balance travel demand and traffic supply and to find the minimum travel time path for emergency rescue, the Revised Model sets two levels of objectives and takes both the needs of rescue and non-rescue vehicles into consideration. Given the route choice behavior and the most likely OD trip distribution pattern, the lower level objective will meet the above two levels objectives and integrate the CDA (Combined Distribution/Assignment) concept into the minimum link travel times. To prove the feasibility of the model and make it more efficient, the fuzzy interactive algorithm and genetic algorithm (GA) will be applied. Lastly, a hypothetical scenarios analysis shows that this study can create an effective way to implement traffic regulation during earthquake disaster.

Keywords: traffic regulation, bi-level programming, emergency vehicles, genetic algorithm, fuzzy interactive programming, CDA (combined distribution/assignment model)

CONTENTS

ABSTRACT	I
CONTENTS.....	III
TABLE CONTENTS	VI
FIGURE CONTENTS	VII

CHAPTER 1 INTRODUCTION..... 1

1.1 Research Background	1
1.2 Research Motivations and Objectives.....	2
1.3 Research Scope	2
1.4 Research Method	3
1.5 Dissertation Framework.....	6

CHAPTER 2 LITERATURE REVIEW 8

2.1 Damages of Road Network System in Earthquake Disaster	9
2.1.1 Road Network Conditions after Chi-Chi Earthquake	9
2.1.2 Road Network Conditions after Hansin-Awaji Earthquake	11
2.1.3 Road Network Conditions after Northridge Earthquake	12
2.2 Post Earthquake Traffic Regulation Issues.....	13
2.2.1 The Characteristics of Travel Behavior.....	14
2.2.2 Priority of Trip Purpose in Different Post-Earthquake States	16
2.2.3 Development of ITS Technology Against Major Earthquake	16
2.3 Past Researches on Traffic Regulation Strategy in Disaster Area	19

2.3.1	Comparison of Emergency Response Operations	19
2.3.2	Traffic Regulation Strategies in Disaster Area	23
CHAPTER 3 RESEARCH METHODOLOGY		26
3.1	Bi-Level Programming	27
3.2	Fuzzy Interactive Algorithm	29
3.3	Genetic Algorithm.....	33
3.4	Hypothetical Scenario Analysis	40
CHAPTER 4 BASIC MODEL AND BI-LEVEL PROGRAMMING		42
4.1	Traffic Regulation Problems and Strategies	42
4.1.1	Traffic Regulation Problems	43
4.1.2	Traffic Regulation Strategies.....	44
4.2	Traffic Regulation Decision-Making Systems Framework	46
4.3	Formulation of Basic Model	56
4.3.1	Model Assumption	56
4.3.2	Model Formulation.....	57
4.4	Properties of Basic Model.....	62
4.5	Numerical Example of a Simple Case: Fuzzy Interactive Algorithm.	62
4.5.1	Applying Fuzzy Approach to Solving the Model	63
4.5.2	Numerical Examples	67
CHAPTER 5 DEVELOPMENT OF REVISED MODEL		71
5.1	Weaknesses of Basic Model.....	71
5.2	Properties of Revised Model.....	73
5.3	Formulation of the Revised Model	73
5.4	Key Features of the Revised Model.....	80

5.5	Numerical Example of a Simple Case: Genetic Algorithm	81
CHAPTER 6	CASE STUDY	91
6.1	Problem Descriptions.....	91
6.2	Solution by Genetic Algorithm	96
6.3	Analysis of Results	103
6.4	Discussions and Summary	109
CHAPTER 7	CONCLUSIONS AND SUGGESTIONS	112
7.1	Conclusions.....	112
7.2	Suggestions	114
REFERENCES.....		116
APPENDIX.....		122

TABLE CONTENTS

Table 2.1	Priority of Trip Purposes Post-Earthquake	16
Table 2.2	Comparison of Emergency Response Operation and Loss in Major Earthquake	22
Table 4.1	Conceptual Framework of Basic Model.....	59
Table 4.2	Notation of the Basic Model.....	60
Table 4.3	Parameter for Fuzzy Traffic Regulation Problems	68
Table 5.1	Notation of the Revised Model.....	78
Table 5.2	Link Data for the Example Road Network.....	83
Table 6.1	Production and Attraction Trips.....	94
Table 6.2	Parameters for Traffic Regulation Problems	94
Table 6.3	Comparisons of Performance Measures in Revised Model	109

FIGURE CONTENTS

Figure 1.2	Flow-Chart of Dissertation	7
Figure 2.1	Distributions of Major Disaster Areas	8
Figure 2.2	Changing LOS Before/After Chi-Chi Earthquake.....	9
Figure 2.3	Changing Travel Speed Before/After Chi-Chi Earthquake	10
Figure 2.4	Basic Framework of Road Traffic Regulation Management System Post-Earthquake	19
Figure 2.5	Example of Regulated Areas	23
Figure 2.6	Traffic State on Earthquake Disaster Areas	24
Figure 3.1	Bi-level Interactive Decision Processes.....	28
Figure 3.2	Chromosome Coding	34
Figure 3.3	Example of One-Point Crossover	36
Figure 3.4	Bit Mutation on the Fifth Bit	36
Figure 3.5	Conventional Genetic Algorithm Cycle	37
Figure 3.6	The Process of Genetic Algorithm Approach	38
Figure 4.1	Traffic Regulation Decision-Making Systems	48
Figure 4.2	Traffic Regulation Frameworks in Earthquake-Raided Area	54
Figure 4.3	Traffic Regulation Decision-Making Concept and Model Formulation.....	55
Figure 4.4	Fuzzy Interactive Decision-Making Process	65
Figure 4.5	Test Road Network	67
Figure 5.1	Test Road Network. All Links Are Two-Directional	82
Figure 5.2	Solution Algorithms by Visual Basic.NET Code.....	84
Figure 5.3	Numerical Results by Genetic Algorithm.....	85
Figure 5.4	Determination of Allowable Vehicle Flows under Degraded Road Network Capacity	85
Figure 5.5	Some Emergency Vehicles Exceed Degraded Road Network	

Capacity	86
Figure 5.6 Test Result of Traffic Flow by Genetic Algorithm	87
Figure 5.7 The Maximum Traffic Volume in Each Generation	88
Figure 5.8 Parameters Change in Each Generation by GA.....	88
Figure 5.9 The Shortest Path Travel Time of Every Population in Each Generation.....	89
 Figure 5.10 The Convergence of Genetic Algorithm Iteration	90
Figure 6.1 Emergency Rescue Road Network of Taipei City	93
Figure 6.2 Test Road Network of Taipei City	93
Figure 6.3 Flow-chart of Cumulative Genetic Algorithm Approach	96
Figure 6.4 Chromosome Coding	97
Figure 6.5 Roulette Wheel Selections	101
Figure 6.6 Visual Basic.NET Program Execute by Genetic Algorithm.....	104
Figure 6.7 Road Network Capacities and Traffic Volumes.....	105
Figure 6.8 Process of Genetic Algorithm Iteration	105
Figure 6.9 The Shortest Path Travel Time of Every Population in Each	106
Generation	
Figure 6.10 The Convergence of Genetic Algorithm Iteration	107
Figure 6.11 Effect of the Different Crossover Probability for Medium-size	107
Network	
Figure 6.12 Effect of the Different Mutation Probability for Medium-size Network.....	108