UNIVERSITI TEKNOLOGI MARA

A NEW NON-RECURRENT CONGESTION DETECTION AND TRAFFIC RE-ROUTING MODEL WITH ANT CONSENSUS BEHAVIOUR IN HOUSE HUNTING ALGORITHM

NORULHIDAYAH BINTI ISA

Thesis submitted in fulfilment
of the requirements for the degree of
Doctor of Philosophy
(Computer Science)

College of Computing, Informatics and Mathematics

June 2024

ABSTRACT

The increasing traffic congestion has led to the development of various traffic routing strategies to improve the network's performance. However, most of these strategies have focused on recurrent congestion (RC), which refers to the regular and predictable congestion during peak hours. On the other hand, non-recurrent congestion (NRC) is unpredictable and occurs due to accidents, road closures, or other unforeseen events. NRC affects road users and traffic monitoring authorities in various ways. Hence, it is essential to address this issue with practical solutions to alleviate its impact on transportation systems and communities. The challenge in solving NRC, which involves distinguishing between RC and NRC, is further compounded by the need to establish clear standards for usual and unusual traffic indicator measurements, which are essential for accurate identification. NRC must be timely and precisely identified to enable prompt management to minimize the wastage of resources and the potential for another NRC event. Various approaches aimed to alleviate congestion by improving traffic flow, increasing capacity, and optimising traffic demand have been proposed. However, existing solutions often prioritise individual drivers' convenience and minimise travel disruptions without considering the overall network performance, which is crucial during NRC. To be effective, NRC management needs near real-time traffic monitoring and strategies for re-routing. This study proposes a new model for detecting NRC and formulating a traffic re-routing strategy called Non-Recurrent Congestion Detection (NRC-D) and Non-Recurrent Congestion Re-Routing (NRC-R). Various parameters and indicators are identified by collecting traffic data from a traffic simulator under normal and NRC traffic conditions. Analyses were first conducted by monitoring parameters such as edge mean speed, travel time, vehicle number, and occupancy in the traffic data obtained from different traffic scenarios. Secondly, NRC was induced by stopping a car in the SuMO simulation software. Clustering algorithms were then applied to identify the threshold for distinguishing between recurrent and non-recurrent congestion. A new parameter called NRCSpeed, which comprised of Mean Speed Relative difference (MSR) and stationary time, were introduced to better present the edge condition during NRC. Thirdly, the consensus behaviour in the ant house hunting algorithm was adopted in the NRC-R, a re-routing model to handle traffic re-routing to improve network performance by reducing the edge stationary time. NRC-R performs the re-routing whenever NRC-D; a NRC detection model detects the NRC edge in the traffic network, and it happens on a near real-time basis. Fourthly, the NRC-D and NRC-R models were tested and evaluated using ten different accident traffic datasets. The models' performances were evaluated by comparing the improvement in edge stationary time before and after the model implementation. The parameter used, called Edge Improvement, measures the stationary time improvement by edges, while Total Stationary Time Improvement measures the overall network reduction in total stationary time. The results showed a more than 80% reduction in total stationary time across all datasets. Then, the performance of the model was validated using a dependent paired t-test to determine if the reduction in stationary time was significant. The proposed models can benefit traffic managers and transportation planners in making informed decisions to improve network performance during NRC events.

ACKNOWLEDGEMENT

I want to express my deepest gratitude to my supervisor, Associate Professor Dr. Marina Yusoff, and Professor Dr. Azlinah Haji Mohamed, for their unwavering guidance, encouragement, and support throughout my ten-year PhD journey. Their expertise and insight have been invaluable, and their constructive feedback has profoundly shaped the direction of this research.

I am also deeply grateful to my thesis committee members for their time, effort, and invaluable feedback. Their suggestions and comments have significantly contributed to the enhancement of this work.

My heartfelt thanks go to my colleagues and friends in the KPPIM at UiTM Shah Alam and UiTM Cawangan Terengganu. Your support, encouragement, and engaging discussions have been a constant source of motivation. Your diverse perspectives and expertise have greatly enriched my understanding of the research topic and kept me inspired through the toughest times.

A special mention goes to my friend Dr. Mohd Razif Shamsudin, who patiently listened to my concerns, assisted me during my journey, and provided crucial help in the design of my algorithms. Your support and patience have been a cornerstone of my success.

I also wish to extend my sincere appreciation to my postgrad lab members, especially to my Datins group, Dr. Shakila, Dr. Zazaleena, and Dr. Nadiah, whose camaraderie and encouragement have been a tremendous source of motivation. Your continuous support has made this journey much more manageable and enjoyable. Finally, our dreams have come true.

To my Note group, who are more than sisters to me, Hana and Iza, who cried and laughed together along this journey, your emotional support and companionship have been invaluable.

Finally, I would like to thank my family members, especially my mother, Dr. Rohana Yusoff, whose endless prayers and meticulous proofreading of my thesis have been invaluable. My husband, Muhammad Atif Ramlan, who has patiently cared for our children, Yusuf Abqary Muhammad Atif and Umar Fawaz Muhammad Atif, and provided unwavering support, love, and encouragement. Your understanding, patience, and sacrifices have been instrumental in enabling me to pursue and complete this degree. To my dear sons, Yusuf Abqary and Umar Fawaz, your innocent smiles, boundless energy, and unconditional love have been my greatest source of strength.

Lastly, to those who have contributed directly and indirectly to this journey, special thanks to you. May God reward you for your kindness and support.

I am honored and humbled to have had the opportunity to undertake this research, and I hope that it will make a positive contribution to the field.

TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	**ii**
AUTHOR'S DECLARATION	**iii**
ABSTRACT	**iv**
ACKNOWLEDGEMENT	**v**
TABLE OF CONTENTS	**vi**
LIST OF TABLES	**x**
LIST OF FIGURES	**xiii**
LIST OF ABBREVIATIONS	**xvii**
CHAPTER 1 INTRODUCTION	**1**
1.1 Research Background	1
1.2 Problem Statement	5
1.3 Research Question	7
1.4 Research Objective	7
1.5 Research Scope	8
1.6 Research Significance	9
1.7 Research Contribution	10
1.8 Thesis Outline	12
CHAPTER 2 LITERATURE REVIEW	**13**
2.1 Introduction	13
2.2 Traffic Congestion	13
2.2.1 Recurrent and Non-recurrent Traffic Congestion	15
2.2.2 Traffic Congestion Characteristics	16
2.2.3 Non Recurrent Traffic Congestion detection	18
2.3 Traffic Congestion Relief Approaches	19
2.4 Traffic Routing	23
2.4.1 Dynamic Traffic Routing	24
2.4.2 Deterministic and Stochastic Environment	25

CHAPTER 1
INTRODUCTION

This chapter gives an overview of the research conducted. The background of the study and the problem covered are highlighted. It provides an overview of what is covered in this research.

1.1 Research Background

Traffic congestion is a growing problem, causing significant disruptions in transportation networks globally. It is a complex issue influenced by various factors, including urban growth, road user behaviour, structural defects in network infrastructure, incidents, and imbalanced traffic flow during peak hours. Urban areas like Kuala Lumpur, Malaysia, are particularly susceptible to this issue, which is caused by a consistent increase in vehicular ownership (Azhar & Zahari, 2022; 2024). This problem affects the daily lives of residents and commuters and poses severe implications for the economy and public health (Vallati & Chrpa, 2020). The resulting travel delays, increased transportation costs, and inconvenience to road users have far-reaching effects on developed and developing countries. In the United States, drivers spend an average of 14.5 million hours per week on traffic (Guo et al., 2020). In addition, traffic congestion ranked as the top frustration factor and main stress factor for ages (Afrin & Yodo, 2020; Ali et al., 2018).

Consequently, traffic congestion has become a burden for road users and traffic monitoring authorities. Despite ongoing discussions for over two decades, traffic congestion remains a persistent problem, particularly in urban areas, due to rapid population growth (Cheng et al., 2020). Therefore, it is crucial to address this issue with practical solutions to mitigate its impact on transportation systems and communities. Although many cities worldwide have implemented traffic management systems, existing approaches often address recurrent congestion (RC), such as rush hour traffic or recurring bottlenecks, rather than non-recurrent congestion (NRC). The difference between these two types of congestion lies in their predictability and cause. RC occurs daily due to increased demand over the network capacity, particularly during peak hours, and road users are generally aware of this situation and have certain expectations