EFFECTIVE VECTOR VARIANCE IN MODELING MALAYSIA HIGHWAY TRAFFIC NETWORK

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DEDICATION

This thesis is dedicated to my beloved family, thank you for the prayer, never ending support and encouragement for my success. To my friends who always be there when I need them.

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ABSTRACT

Highway traffic networks consist of in-coming vehicles to a toll plaza and out-coming vehicles from a toll plaza. The current practice to analyse a network is by using social network analysis (SNA) with the following three steps: (i) the network is considered as an undirected weighted complete graph (UWCG), (ii) the important information in the network is filtered using minimal spanning tree (MST), and (iii) the topological properties of each node is investigated using certain centrality measures. However, highway networks are complex and need a better method to analyse it. In this thesis, the Projek Lebuhraya Usahasama Berhad (PLUS) highway network is represented as a weighted directed network (WDN). The PLUS highway traffic network from 63 toll plazas in Peninsular Malaysia is studied to understand the in-coming and out-coming weights of traffic burden. Here, the weights of traffic burden refer to the in-coming and out-coming vehicles between two toll plazas. This study represents the complex PLUS highway traffic network as a non-symmetric matrix with positive finite element. The important information contain in the network are extracted using a unique and more robust method known as Forest. It is found that PLUS highway network produces only one MST in a network. This differs from other complex networks such as stock markets which typically produce more than one MST in a network. This study also investigates the dynamicity amongst PLUS highway toll plazas, which has not been discussed in other highway network studies. Using regression analysis on log return of traffic burden, it is found that Bukit Tambun Utara and Bukit Tambun Selatan are the two most dynamic toll plazas. In addition, the topological properties of network in this study use four types of centrality measures which are degree, betweenness, closeness and eigenvector. The performance of the toll plazas in the network can also be summarized based on an overall centrality measure using Principle Component Analysis. This approach is able to identify the most important toll plaza in the network. For instance, Sungei Besi toll plaza is found to be the most important toll plaza from the years 2009 until 2013 for in-coming traffic burden. However, this method could not identify the performance of the toll plazas based on the importance of their centrality measures. This is because it does not take into account, the multivariate dispersion of the centrality measures and thus cannot identify the most important centrality measure. An existing measure of multivariate dispersion is using effective variance (EV) based on the geometric mean of all eigenvalues. In this study, a new approach called effective vector variance (EVV) based on the arithmetic mean of all eigenvalues is used together with EV to identify the most important centrality measure. It is found that the most important centrality measure containing only one type of centrality measure is betweenness, the important centrality measure containing two types of centrality measures is betweenness and eigenvector, and the most important centrality measure containing three types of centrality measures is degree, betweenness and eigenvector. The results from this study can be used by the management of PLUS highway to improve its current system and operation.

ABSTRAK

Rangkaian trafik lebuhraya terdiri daripada kenderaan yang masuk ke plaza tol dan kenderaan yang keluar dari plaza tol. Kaedah semasa yang digunapakai untuk menganalisis rangkaian ialah dengan menggunakan analisis rangkaian sosial (SNA) dengan tiga langkah berikut: (i) rangkaian dianggap sebagai graf wajaran lengkap tak berarah (UWCG), (ii) maklumat penting dalam rangkaian ditapis dengan menggunakan pokok perentangan minimum (MST), dan (iii) sifat-sifat topologi setiap nod disiasat dengan menggunakan pengukuran pemusatan tertentu. Walau bagaimanapun, rangkaian lebuhraya adalah lebih rumit dan memerlukan kaedah yang lebih baik untuk menganalisisnya. Dalam tesis ini, rangkaian lebuhraya Projek Lebuhraya Usahasama Berhad (PLUS) telah diwakili sebagai rangkaian wajaran berarah (WDN). Rangkaian trafik lebuhraya PLUS daripada 63 buah plaza tol di Semenanjung Malaysia telah dikaji untuk memahami pemberat beban trafik yang masuk dan keluar. Di sini, pemberat kepada beban trafik merujuk kepada jumlah bilangan kenderaan yang masuk dan keluar di antara dua plaza tol. Kajian ini merujuk kepada rangkaian trafik PLUS yang kompleks sebagai matrik bukan simetrik dengan unsur terhingga yang positif. Maklumat penting yang terkandung dalam rangkaian ini diekstrak dengan menggunakan kaedah yang unik dan lebih teguh dikenali sebagai Forest. Didapati bahawa rangkaian lebuhraya PLUS menghasilkan hanya satu MST dalam rangkaiannya. Ini berbeza daripada rangkaian kompleks lain seperti pasaran saham yang biasanya menghasilkan lebih daripada satu MST dalam rangkaiannya. Kajian ini juga menyiasat dinamik di antara plaza-plaza tol di lebuhraya PLUS, yang belum pernah dibincangkan dalam kajian rangkaian lebuhraya yang lain sebelum ini. Dengan menggunakan analisis regresi pada log hasil pulangan bagi bebanan trafik, ia menunjukkan bahawa Bukit Tambun Utara dan Bukit Tambun Selatan adalah plaza tol yang paling dinamik. Tambahan lagi, sifat topologi dalam rangkaian kajian ini menggunakan empat jenis pengukuran pemusatan iaitu darjah, antara, kedekatan dan vektor eigen. Prestasi plaza tol dalam rangkaian juga boleh dirumuskan berdasarkan keseluruhan ukuran pemusatan menggunakan Analisis Komponen Utama. Pendekatan ini dapat mengenal pasti plaza tol yang paling penting dalam rangkaian. Sebagai contoh, plaza tol Sungei Besi adalah plaza tol yang paling penting daripada tahun 2009 hingga 2013 untuk beban lalu lintas yang masuk. Walau bagaimanapun, kaedah ini tidak dapat mengenal pasti prestasi plaza tol berdasarkan kepada kepentingan ukuran pemusatan. Ini kerana ia tidak mengambilkira penyebaran variasi berbilang bagi ukuran pemusatan dan seterusnya tidak dapat mengenal pasti ukuran pemusatan yang paling penting. Ukuran sedia ada bagi penyebaran variasi berbilang adalah dengan menggunakan varians yang berkesan (EV) berdasarkan pada purata geometrik untuk semua nilai eigen. Dalam kajian ini, satu pendekatan baru yang disebut sebagai varian vektor yang berkesan (EVV) yang berdasarkan pada nilai aritmetik untuk semua nilai eigen telah digunakan bersama dengan EV untuk mengenal pasti ukuran pemusatan yang paling penting. Kajian ini mendapati bahawa ukuran pemusatan yang paling penting yang mengandungi satu jenis ukuran pemusatan ialah antara, ukuran pemusatan yang paling penting yang mengandungi dua jenis ukuran pemusatan ialah antara dan vektor eigen, dan ukuran pemusatan yang paling penting yang mengandungi tiga jenis ukuran pemusatan ialah darjah, antara dan vektor eigen. Hasil daripada kajian ini boleh digunakan oleh pengurusan lebuhraya PLUS untuk memperbaiki sistem dan operasi mereka yang sedia ada.

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LIST OF ABBREVIATIONS

EV	-	Effective Variance
EVV	-	Effective Vector Variance
GV	-	Generalized Variance
MST	-	Minimum Spanning Tree
PLUS	-	Projek Lebuhraya Usahasama Berhad
SDU	-	Subdominant Ultrametric
SNA	-	Social Network Analysis
VV	-	Vector Variance
WDG	-	Weighted Directed Graph
JRU	-	Juru
BTU	-	Bukit Tambun (U)
BTS	-	Bukit Tambun (S)
JWI	-	Jawi
BBR	-	Bandar Baru
BKM	-	Bukit Merah
TPU	-	Taiping (U)
CKJ	-	Changkat Jering
KKS	-	Kuala Kangsar
IPU	-	Ipoh (U)
IPS	-	Ipoh (S)
SPP	-	Simpang Pulai
GPG	-	Gopeng
TPH	-	Tapah
BDR	-	Bidor
SKI	-	Sungkai
PSR	-	Persimpangan Slim River
BRG	-	Behrang
TGM	-	Tanjung Malim
LBB	-	Lembah Beringin
BTR	-	Bukit Tagar

BKB	-	Bukit Beruntung
RAW	-	Rawang
RWS	-	Rawang Selatan
HSB	-	Sungai Buloh (U)
SGB	-	Sungai Buloh
JLD	-	Jalan Duta
KDR	-	Kota Damansara
DMR	-	Damansara
SBG	-	Subang
STA	-	Setia Alam
BKR	-	Bukit Raja
SBI	-	Sungei Besi
UPM	-	UPM
KJG	-	Kajang
BGS	-	Bangi
PPM	-	Persimpangan Putra Mahkota
NLI	-	Nilai
SHA	-	Shah Alam
EBN	-	Ebor (N)
EBS	-	Ebor (S)
SEA	-	Seafield
USJ	-	USJ
PHT	-	Putra Height
KLA	-	KLIA
SBN	-	Seremban
PDU	-	Port Dickson (U)
PDS	-	Port Dickson (S)
SWG	-	Senawang
PLI	-	Pedas Linggi
SAT	-	Simpang Ampat
AKH	-	Ayer Keroh
JSN	-	Jasin
TGK	-	Tangkak

PGH	-	Pagoh
YPU	-	Yong Peng (U)
YPS	-	Yong Peng (S)
AHT	-	Ayer Hitam
MAC	-	Machap
SPR	-	Simpang Renggam
SDK	-	Sedenak
KLI	-	Kulai
SNU	-	Senai (U)
SKD	-	Skudai

LIST OF SYMBOLS

λ	-	Eigenvalues
D, d	-	Distance matrix, the elements of D
Tr	-	Trace
R^2	-	Correlation
$\mathbf{A}$	-	Adjacency matrix
Σ	-	Covariance matrix

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Network analysis can be found in many fields such as medical, organizations, economics, ecologies, technologies, transportations and many more. The relationships in the network explain the systems which contain each element that is connected among them. These connections are the topics of interest and the network topology is investigated. The information contains in the network can be filtered and interpret with the application of social network analysis (SNA). The visualization of each network can be presented by using the theoretical graph approach while the important information in the network can be extracted by using MST and *Forest*. The behavior of each centrality measures is one of the topic interests. The most important centrality measures can be defined by looking at each dispersion measure.

1.2 Background of the Problem

The highway is one of the most important facilities to transfer passengers as well as consumer goods. Therefore, the highway has the potential to support economic growth. It contributes directly to socio-economic development and thus improves the quality of life. Industrialization and economic growth have been rapidly increasing once Projek Lebuhraya Usahasama Berhad (PLUS) highway network in Malaysia was built. Hence, the patterns of transportation also changed following the economic development. The growth of the Malaysian highway network is the result and the cause of this positive progress of industrialization. The demand for traveling increases as the need for people mobility increases. It is also related and associated with the demands and supplies in manufacturing sectors, rapid urban development, and population growth.

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1. **Asrah, N. M.,** Djauhari, M. A., & Mohamad, I. (2016). PLUS Traffic Highway: An Analysis Based on Time Series Similarity Approach. The Social Sciences (Pakistan). 11(11), 2753-2759. doi:10.3923/sscience.2016.2753.2759. **(Indexed by SCOPUS)**

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