The Most Important Centrality Measures of PLUS Highway Traffic Network: Introducing Effective Vector Variance

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Introduction

- The development of highway network in a country is crucial. This facility is one of the most important part in transportation to transport passengers and goods.
- Transport infrastructure is important to generate connections between geographically separated locations for both commercial and individual needs. When an industrial is rapidly developing in a country, it need a good connection between road and highway network so it easy to move from a place to another.
- Transportation can be considered as a key prerequisite of social and economic development of any country since it is the most widely used mode of travel. The economic performance and competitive enhancement are depend on the better road network.

- Several advantages of road transport are passengers and goods can be transferred regardless of distance with high speed and no time restrictions. Road network and highway also are enable to carry peoples, materials, raw materials, semi-finished and finished products intended for trading.
- The higher technology in development of road network can promised the instance of the development for tourism, influx of foreign investments, regional development, etc.
- These indicators such as employment, wages, consumption, savings, investment, benefits of tourism – will have an impact on the volume of gross domestic product (GDP) and also the key macroeconomic indicator, which measures the economic output of the state (Ivanova and Masarova, 2013)

- In this study, we are interested to analyze the highways network in Peninsular Malaysia.
- Highway in Malaysia become vital since the road mileage in Malaysia is increasing from 135,226 km in year 2009 to 180,882 km in year 2012. The number of registered motor vehicles also increases from 20,188,565 in year 2010 to 22,702,221 in year 2012 (DOSM, 2013).
- The highest number of registered motor vehicles is motorcycles, followed by motorcar, taxi and hired car, bus, goods vehicles and other vehicles.
- The rising of road mileage and registered vehicles shows that Malaysia really need good road networks as these statistics will increase year by year (DOSM, 2013).
- The growth of Malaysian highway network can reviewed as the cause of positive progresses of industrialization.

- The demand of traveling is keep increases as the need of mobility in manufacturing sectors for demands and supplies continue. Other factors that influence the demand of traveling are the rapid urban development and also the population growth.
- This study is focused on PLUS highway traffic network. All toll plazas along PLUS highway are connected to each other and they represent a dynamic network.
- Accordingly, it is very important to determine the most crucial toll plazas for in-coming traffic burden.

Methodology

a) Data Collection

- Data collected from Toll Department of PLUS Malaysia Sdn.Bhd.

- Penang (3), Kedah (1), Perak (14), Selangor (23), Wilayah Persekutuan (3), Negeri Sembilan (4), Melaka (3) and Johor (11). Total toll plazas = 63.
- Time range is from 1st January 2013 until December 2013.
- Traffic burden referred to the number of vehicles with their loads such as passengers and goods.

b) Information Filtering

- The distance matrix is used to determine the minimum spanning tree (MST). The data matrix for number of vehicles are transformed into distance matrix D using formula

  $D = Maximum\ value - a_{ij}$ for all $ij = 1,2, \ldots\ldots, n$.

  a_{ij} refers to the element (i, j) in the distance matrix and n refer to the number of toll plazas studied (63).

- MST is concept in graph theory to filter the information contained in a weighted connected graph of n objects (nodes). It is a tree with $(n-1)$ edges (links) that minimizes the sum of the weights (distances in our case).
- MST is constructed to visualized the important information contained in the network in *D* in terms of topological properties.

- MST is built by linking every element in a set of *n* together in a graph characterized by a minimal distance between the nodes.
- Kruskal algorithm is used to construct MST using Matlab.
- Use *Pajek* software to visualize the network topology of the entire toll plazas.

c) Centrality Measures

- To understand the importance of each node relative to the others.
- **Degree centrality** measures the connectivity of each toll plazas and provided information of how many toll plazas are connected with a particular toll plaza. It also measured the involvement of the node in the network (Opsahl *et al*., 2010).
- **Betweenness centrality** explains how a toll plaza influences other toll plazas without any connection between them (Park & Yilmaz, 2010).
- **Closeness centrality** indicates how a toll plaza is close to the other toll plazas (Newman, 2008).

- **Eigenvector centrality** measures the strength and the importance of a toll plaza with its connections. The toll plazas with high scores represents that they are connected to the other important toll plazas.
- **Overall centrality** measure will help to find the overall role of each node (Yusoff *et al.*, 2012).

d) The most important centrality measure

- To determine the most important centrality measure since every centrality measure has it own meaning.
- **Effective variance (EV)** is used and it is based on generalized variance (GV) (Serfling, 1980). GV is the determinant of covariance matrix *C* and is the product of all eigenvalues of C.
- EV is the geometric mean of all those eigenvalues. $EV = \sqrt[4]{GV}$
- Djauhari (2007) introduced vector variance (VV) as an alternative since GV has serious limitations. VV is the sum of square of all eigenvalues of *C*.
- **Effective vector variance (EVV)** is introduced as an alternative to EV.

$EVV = \frac{VV}{4}$ Thus, EVV is the arithmetic mean of all squared eigenvalues.

- According to EV, the centrality measure *k* is said the most important one if, $\frac{\sigma_k^2}{\sqrt[4]{GV}} = \max_{1 \le j \le 4} \frac{\sigma_j^2}{\sqrt[4]{GV}}$

  where σ_j^2 is the variance of the score of centrality measure *j*.
  Thus, the score of centrality measure *k* has the largest variance.

- According to EVV, the centrality measure *k* is said the most important one if, $\frac{\sigma_k^2}{\frac{VV}{4}} = \max_{1 \le j \le 4} \frac{\sigma_j^2}{\frac{VV}{4}}$

  Similarly, the score of centrality measure *k* has the largest variance.

Results: MST

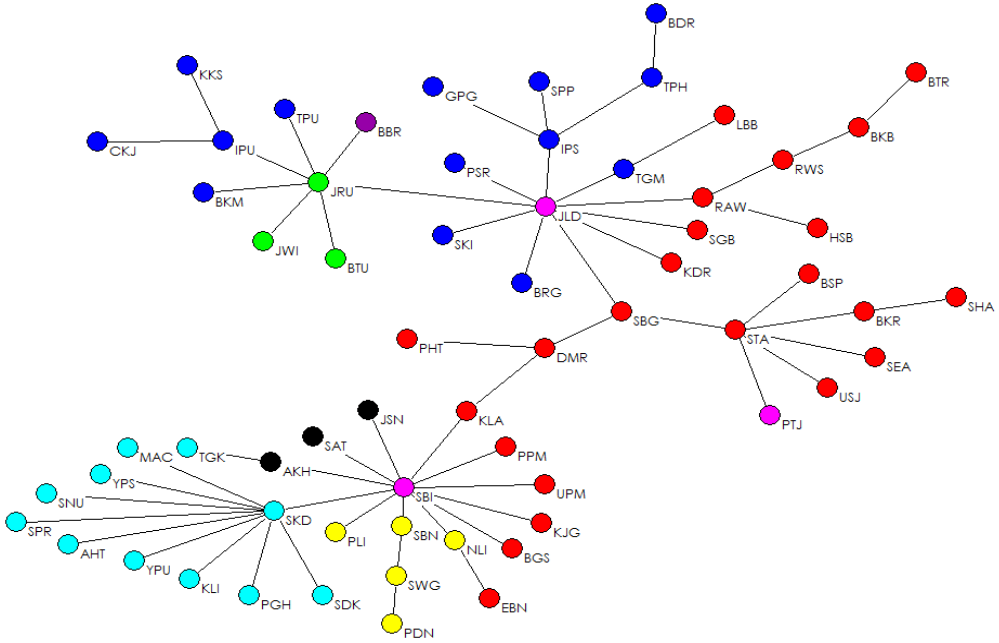


Figure 3.1: Forest for in-coming traffic burden in 2013

Results: Centrality Measures

Centrality Measures	In-coming
Degree (Crowded traffic, more connections & most important toll plaza)	1. SBI (0.1904) 2. JLD & SKD (0.1587) 3. JRU (0.1111)
Betweenness (High potential to control the traffic flow)	1. JLD (0.6367) 2. SBG (0.6034) 3. SBI (0.6018)
Closeness (Close to the other toll plazas, could reach other toll plazas quickly, not need a shortcut)	1. SBG (0.2981) 2. DMR (0.2884) 3. JLD (0.2857)
Eigenvector (Connected to other important toll plaza)	1. SBI (0.5932) 2. SKD (0.4356) 3. KLA (0.1771)
Overall (most important toll plaza)	1. SBI (0.0101) 2. JLD (0.0094) 3. SKD (0.0067)

Results: EV & EVV

	Degree	Between	Closeness	Eigenvector
EV	0.50764 (3)	9.88860 (1)	0.40147 (4)	4.42034 (2)
EVV	22.86770 (3)	445.45143 (1)	18.08498 (4)	199.12308 (2)

The most important centrality measures for in-coming traffic burden according to EV and EVV

(i) betweenness, (ii) eigenvector, (iii) degree and (iv) closeness centrality measures.

Based on the betweenness centrality measure, JLD, SBG and SBI are the toll plazas with higher scores.

Results: EV & EVV in terms of relative importance

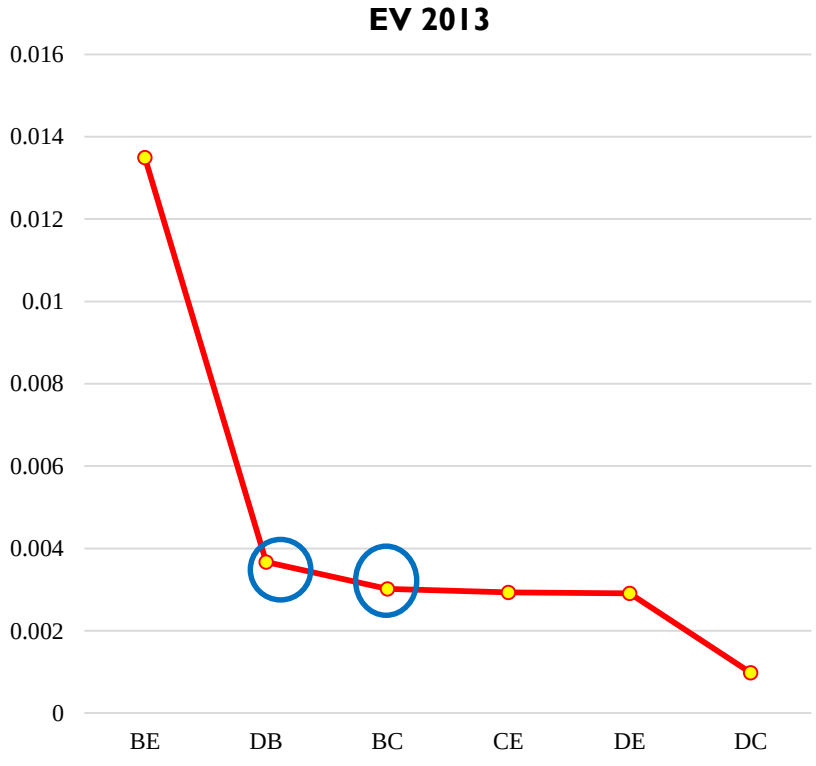
EV

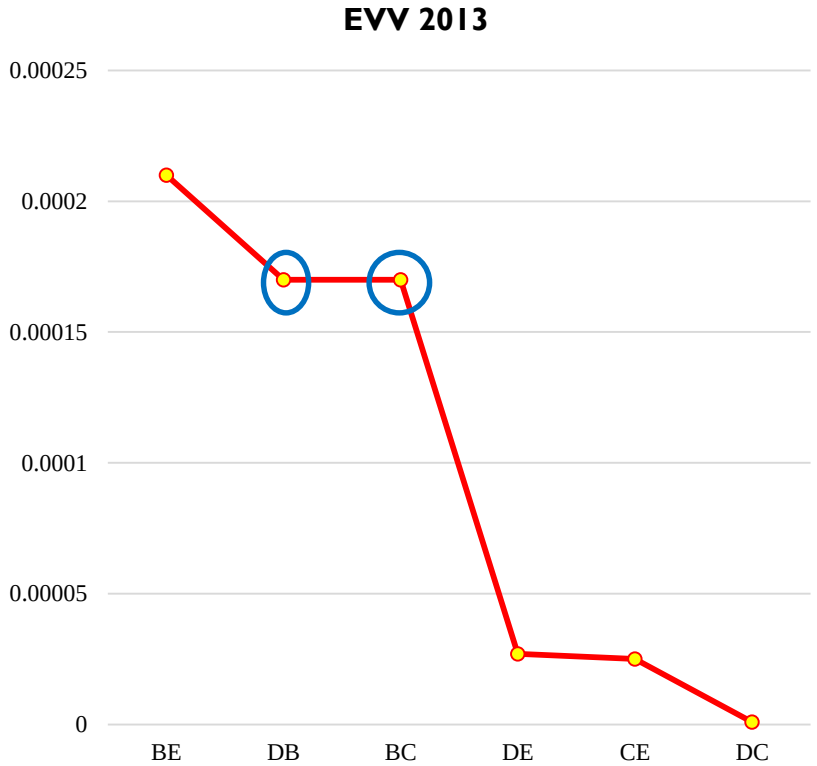
Pairs	2013
BE	0.01402
DB	0.00387
DE	0.00303
CE	0.00298
BC	0.00292
DC	0.00098

EVV

Pairs	2013
BE	0.00021
DB	0.00017
BC	0.00017
DE	2.75E-05
CE	2.5E-05
DC	9.9E-07

Results: EV & EVV in terms of relative importance





Conclusions & Recommendations

- SBI is found to be the most important toll plaza for in-coming traffic burden in 2013. This toll plaza is scored the highest in degree centrality, eigenvector centrality and overall centrality measures.
- Meanwhile, JLD scored the highest in betweenness centrality measure and second highest for degree and overall centrality measures.
- SBI and JLD have many connections with other toll plazas. They have very high potential to control the traffic flow in the PLUS highway, and are the most important toll plazas in the PLUS highway. They also receive the highest number of vehicles that enter from both the southern and the northern destinations.
- Both toll plazas also scored the highest ranking in betweenness centrality measure. These toll plazas have to be given the most attention by PLUS highway management in their policy and future planning.

- From EV and EVV results, it tell us that the most important centrality measures for in-coming traffic burden is betweenness, follow by eigenvector, degree and closeness centrality measures.
- According to betweenness centrality measure, JLD, SBG and SBI are the toll plazas with higher scores. PLUS highway management have to paid more attention to these toll plaza since they produce the highest results for both EV and EVV.

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Thank you

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