A Quantity Estimated Method to Measure Flow of Nodes in a Freight Transport Network

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Abstract ***-*** *This study focuses on estimating flows of nodes in a courier transportation network. Literature has quantified exiting flow of nodes by analyzing real data for quantities transported and travel time. Due to difficulties in accessing real data, a method for estimating data especially on quantity transported among nodes is required. The purpose of this study is to develop a quantity estimated method for measuring the exiting flows of nodes in a freight transport network. The level of significance of each node in the network is estimated through a proposed 'criticality factor'. Nodes are equally categorized as high, medium, and low based on the descending order of the criticality factor. A weighting scale is developed for these three categories. Google map is used to derive travel time. The exiting flow of nodes is derived as the ratio between quantity exited and the time taken. This method is applied to peak, off peak, highway, and expressway operations. The study recommends using proper amount of equipment at nodes, consolidation of vehicles and relocation of warehouses. This study contributes to the domain of cost reduction in freight network by estimating the exiting flows of all the nodes in a freight network.*

Keywords: ***Exiting Flow, Freight Network Flow, Criticality Factor, Quantity Estimated, Maximum Vehicle Capacity***

I. INTRODUCTION

Monitoring network statistics is crucial for lowering the total operation cost, especially for courier service providers in the freight transportation industry. Estimating the exiting freight flow of each node in a courier transport network is vital for identifying strategies to lower the total operation cost of the network. Statistical information on quantity of freight transported between nodes and time taken for freight movement between those nodes are required to estimate the freight flow of each node in the network. However, these statistical information on exiting freight quantity and time taken are not properly maintained by the courier service providers due to many reasons such as high freight volume, high speed data, requisition of advanced hardware for collection of data etc. This situation leads to no or improper estimation of freight flow of nodes in the network. Simulation methods have been developed in the existing literature to estimate exiting freight flow of nodes using partially collected statistical information on vehicle capacity, freight quantity, frequency of vehicles, speed of vehicle, travel time etc. No method has been developed to estimate the exiting freight flow of nodes in a network where only the information on maximum capacity of vehicles is available. Lack of proper methods to estimate the freight flow of nodes in transport network when the information only on the vehicle capacity is available leads to improper location of nodes (warehouses), improper vehicle routing, unnecessary allocation of material handling equipment and staff at nodes (warehouses). All these result in increased total operation cost of freight transport network. Increased total operation costs affect both the courier service provider and the customer. Therefore, the objective of this study is to develop a quantity estimated method to estimate the exiting freight flow of nodes in a transport network and the sub objective is to examine how the flow of traffic varies based on both the time of day and the type of the route.

II. LITERATURE REVIEW

In order to compute the exiting flow of each node in the freight transport network, it is necessary to know the quantity of freight transported from each node to all the other nodes and the time taken for those movements of freight among nodes.

A. Measuring the Travel Time for Goods Movement Among Nodes

Several approaches for measuring travel time for goods movement/ traffic among nodes or in routes in the transport network have been proposed in previous studies. One of them is the vehicle sensing method. This approach employs 5-minute traffic volume and dwell periods acquired from vehicle sensors, as well as vehicle length, to determine the speed of cars directly beneath the sensors. The travel time for that road segment is determined using the predicted speeds and lengths of the road section (Sano et al., 2000). However, this strategy can only be employed if a specific density of car sensors is deployed.

Another approach for calculating travel time is the Automated Vehicle Identifier method (AVI). In this approach, upstream and downstream data from car plates saved with AVI are considered, and the downstream (arriving vehicle) end is compared to the upstream end (departing vehicle). The journeys time is computed by subtracting the departure and arrival times. When the vehicle count reaches the given limit for a defined time (5 minutes), the vehicle travel times are averaged, and the AVI measured travel time is determined. In this manner, travel time may be directly determined using the AVI method (Van Der Zijpp, 1997). However, there are several issues with the approach, such as the fact that it does not provide a good interpretation when a vehicle takes a path other than the predicted one, when the measuring section is long, and when there are significant changes in traffic conditions.

The most trustworthy location and movement trajectory data have been found to be incorporated by major mobile operating system developers such as Google Android and Apple iOS. Google map data advantages include potentially comprehensive geographical and temporal coverage, high positioning accuracy, low maintenance costs, and the ability to monitor travel time when weather and traffic conditions change (Dumbliauskas et al., 2017).

B. Measuring Quantity Transported

Existing research used genuine data from its original sources to calculate the amount of quantity transported (Purboyo & Ibad, 2017). Aside from that, other technologies for measuring precise amounts, such as Radio Frequency Identification Devices (RFID) and Global Positioning System (GPS), may be recognized. RFIDs are inexpensive tags that aid in the tracking of products and vehicles. These devices are attached to particular products and can be either active (constantly sending a radio frequency signal) or passive (only emitting a signal when queried by an outside source (Ollivier 2005).

GPS tracking uses satellites to monitor fleets of vehicles or cargo containers, ensuring that there are no unscheduled pauses and that a preplanned path is followed. The primary disadvantages of the methodologies are the data requirements and the computational complexity of the solution procedure. Aside from that, each sector's cost function necessitates a massive quantity of data, which is frequently confidential and not published owing to its possible strategic influence (Ollivier, 2005). Estimating freight flow is crucial when genuine data is limited, enabling informed decisions in transportation planning and logistics optimization despite constraints.

C. Criticality of Nodes

Criticality is vital for assigning a certain weight factor to a node, which finally reflects the trip attractiveness of that particular node. When measuring exiting flow of nodes, it is discovered that evaluating the criticality of each node in a network is necessary since it provides accurate interpretations of the degree of flow in a specific node. When measuring criticality, node degree and betweenness centrality in the transport network have been used. Past research has measured the criticality of a network using functionality and operational characteristics of each node (Xie, F., & Levinson, D.,2011). Functionality and operational characteristics are highly propositional to a particular node's criticality (Psaltoglou & Calle, 2018).

III. METHODOLOGY

This methodology estimates freight flow and quantity transported between nodes using a nine-step approach based on known vehicle capacity. It improves transportation planning, logistics management, and supply chain efficiency.

Consider a network that consists of n nodes where nA denotes the central hub. (n includes nA as well). In this case study, a trip between any nodes occurs from the particular origin node to destination node through a Central node.

Step 01- Travel time from central node (n_A) to all the other nodes ($n_1, n_2, n_3 \ldots n_{(n-1)}$) in the network is found. Then the travel time from all the other nodes ($n_1, n_2, n_3 \ldots n_{(n-1)}$) to the central node ($n_A$) is found.

Step 02- Travel time between any pair of nodes (except central node) n_i to n_j is calculated by taking the summation of travel time ($T_{ni,nj}$) from n_i to n_k ($T_{ni,nk}$)and n_k to n_j ($T_{nk,nj}$).

$$T_{ni,nj} = T_{ni,nk} + T_{nk,nj} \tag{1}$$

If any movement from n_i to n_j is passing a traffic zone, in addition to the normal time, time taken to pass that traffic zone is calculated by the ratio of distance and the traffic jam speed. To calculate traffic jam speed, measure the distance between two points and record the time it takes for a vehicle to travel that distance. Divide the distance by the time to obtain the average speed.

Step 03- The distance from any node to the nearest larger trip attractor is found. This distance is denoted as x_i.

Step 04- The criticality factor for each node is found as shown below.

$$C_i = \{1- [\frac{x_i - x_{(least)}}{x_{(highest)} - x_{(least)}}]\} x100\% \quad (2)$$

C_i = criticality factor for node i in terms of percentage
$x_{(highest)}$ = maximum x_i out of all observed
$x_{(least)}$ = minimum x_i out of all observed

Step 05- This ‘c_i’ value is multiplied by the maximum capacity in kilograms of the truck (V) to find the quantity of goods transported (q) from central node to other nodes.

Step 06- The criticality factor for all nodes is ordered from highest to lowest. Nodes are categorized based on the criticality factors. Each category consists of approximately equal number of nodes.

Step 07- Weights for each category is found by the following formula.

$$w_k = [\frac{(q(k)}{q(all)}] \text{ x } 100\% \quad (3)$$

w_k= weight of the k^{th} node category
$q_{(k)}$= total quantity of goods received by all the nodes in k^{th} category from the central hub
$q_{(all)}$ = total quantity of goods received by all nodes in the network (include the central node) from the central hub
n = number of nodes in the network

Step 08- The amount of quantity transported between any node ni and nj ($q_{(ni-nj)}$), is calculated by the following equation.

$$q_{(ni-nj)} = \frac{C_{(ni)\%} \text{ X } C_{(nj)\%} \text{ X } V}{Ni \text{ X } Nj} \quad (4)$$

V- maximum capacity of the truck in kilograms
c(ni) – Criticality percentage of origin node
c(nj) – Criticality percentage of destination node
N_i - number of nodes in the node category that include node ni
N_j - number of nodes in the node category that include node nj

Step 09- The Quantity Estimated Existing Flow (QEEF) for each node is calculated as follows.

$$\text{QEEF}_k = \frac{\sum_{i=1}^{n}\left(a \times q_{n_k n_i}\right)}{\left(\Sigma_{l=1}^{n}\left(a \times t_{n_k n_i}\right)\right)n} \quad (5)$$

$QEEF_k$ = flow of node k
a = existence of a link (either 1 or 0)
$q_{n_k n_i}$ = amount of quantity transported from n_k to n_i
$t_{n_k n_i}$ = time taken to travel from node n_k to any node n_i
n = number of nodes in the network

IV. DATA PRESENTATION AND ANALYZING

A. Introduction

A courier firm was selected to demonstrate the method of estimating the network flow. The central node of the network is Colombo, and the other 27 nodes of the network are Colombo (1), Biyagama (2), Katunayake (3), Yakkala (4), Awissawella (5), Kaluthara (6), Horana (7), Kurunegala (8), Kandy (9), Galle (10), Mathara (11), Dambulla (12), Nuwaraeliya (13), Kegalle (14), Rathnapura (15), Hambanthota (16), Polonnaruwa (17), Anuradhapura (18), Ampara (19), Batticaloa (20), Mahiyanganaya (21), Maravila (22), Balangoda (23), Embilipitiya (24), Bandarawela (25), Trincomalee (26), Jaffna (27) and Vavuniya (28). The goods collected at each node are sent to central node (Colombo). A vehicle for each node is allocated to transport the goods to Colombo. Then the goods are delivered to the destination nodes from Colombo during off peak hours (probably at midnight). The proposed steps to estimate the network flow are demonstrated.

Step 01- First, travel time from Colombo to all the other 27 nodes was found using google maps. Then this method was applied to find the travel time from all the other nodes (except Colombo) to Colombo as well.

Table 1. Travel time matrix in hrs. (without using expressway – peak time)

	1	2	3	…	28
1	0.00	1.14	1.89	…	5.28
2	0.73	0.00	2.62	…	6.02
3	0.72	1.85	0.00	…	6.00
…	…	…	…	…	…
28	5.33	6.47	7.22	…	0.00

Source: Survey Data (2023)

Step 02 - Travel time between any pair of nodes (except Colombo) was calculated as follows.

As an example, the travel time from Biyagama (2) to Katunayake (3) (TBK) was calculated by taking the summation of travel time from Biyagama to Colombo (1) (TBC) and Colombo to Katunayake (TCK).

$$T_{n2,3} = T_{n2,n1} + T_{n1,n3} \quad (6)$$

TBK = TBC + TCK
=0.73 h + 1.89 h
=2.62 h

Step 03 - All the network's traffic zones were taken into account, and when a vehicle passed through a traffic zone, time taken to pass that traffic zone is calculated by the ratio of distance and the traffic jam speed. When determining the travel time between Biyagama and

Katunayake, for example, the Colombo traffic zone must be taken into account. Traffic zones can be identified from google maps by selecting "traffic" from the menu button. On the map, there are four colored lines which are green, orange, yellow and red. Routes having green lines show that traffic is moving quickly, while those with red lines suggest that traffic is moving slowly. As a result, the distance of the Colombo traffic zone (13.7 km) must be divided by the speed at jam density in Colombo which is 17 kmh-1 (Sandaruwan et al., 2019).

Step 04 - To measure the criticality of each node, the distance from each node to the nearest trip attractor was taken into account. Export Processing Zones were considered as the nearest trip attractors. They were Mawathagama, Polgahawela, Mirigama, Katunayake, Biyagama, Colombo, Horana, Seethawaka, Koggala, Kandy, Malwatta, Wathupitiwela and Mirijjawela.

Table 2. Distance to the nearest EPZ from each node

Sub Node	Nearest EPZ	Distance to the Nearest EPZ (km)
Katunayake	Biyagama	1.4
Awissawella	Seethawaka	0.8
Biyagama	Biyagama	6.0
Hambanthota	Mirijjawila	9.6
Horana	Horana	10.5
…	…	…
Jaffna	Mavathagama	305.7

Source: Survey Data (2023)

Step 05 - After finding the distance to the nearest EPZ, all the values were ordered from highest to lowest in order to measure the criticality. First 9 nodes were taken as high critical nodes, next 9 nodes were taken as medium critical nodes and last 10 nodes were taken as least critical nodes. (Even though Colombo was taken as a medium critical node, an assumption was made that Colombo should be considered as a high critical node because it is the central hub of this network).

Step 06- Using the below formula, the percentage of criticality of all 28 nodes were calculated. As an example, when considering Biyagama node,

$$C_B = \{1- [\frac{x_B - x_{(least)}}{x_{(highest)} - x_{(least)}}]\} x100\% \quad (7)$$

$$C_B = \{1- [\frac{6km - 1km}{306km - 1km}]\} x100\%$$

$$C_B = 98.3607\%$$

Table 3. Percentage of quantity transported for each node from the central hub

Sub Node	% Of Quantity Transported
Katunayake	100
Awissawella	100
Biyagama	98.3607
Hambanthota	97.0492
…	…
Jaffna	0

Source: Survey Data (2023)

Sub Node	Quantity Transported (kg)
Katunayake	4000
Awissawella	4000
Biyagama	3934.43
Hambanthota	3881.97
…	…
Jaffna	0

After finding the percentage of criticality, it should be multiplied by the maximum capacity which is 4000 kg.

Table 4. Quantity transported for each node from the central hub

Source: Survey Data (2023)

Step 07- Ratio for high critical nodes (MH) is shown below,

$$M_H = [\frac{q(H)}{q(all)}] \text{ x } 100\% \quad (7)$$

$$M_H = [\frac{38.7016}{85.6787}] \text{ x } 100\%$$

$$M_H = 45.1707\% \approx 45\%$$

(Here *q(H)* refers to all the quantities that are transported to high critical nodes from the central hub and *q(all)* refers to total quantity that is transported to all nodes from the central hub)

Ratio for medium critical nodes (MM) is shown below,

$$M_M = [\frac{q(M)}{q(all)}] \text{ x } 100\% \quad (8)$$

$$M_M = [\frac{27.8557}{85.6787}] \text{ x } 100\%$$

$$M_M = 32.5119\% \approx 33\%$$

Ratio for low critical nodes (ML) is shown below,

$$M_L = [\frac{q(L)}{q(all)}] \text{ x } 100\% \quad (9)$$

$$M_L = [\frac{19.1213}{85.6787}] \text{ x } 100\%$$

$$M_L = 22.3175\% \approx 22\%$$

Step 08 - The amount of quantity transported between two nodes is estimated as below. As an example, the quantity transfer between a high critical node (Biyagama) and a medium critical node (Kandy) is taken into account,

$$q_{(H-M)} = \frac{C_{B(H)\%} \ X \ C_{K(M)\%} \ X \ 4}{Number \ of \ H \ X \ M \ nodes} \quad (10)$$

$$q_{(H-M)} = \frac{45\% \ X \ 33\% \ X \ 4}{10 \ X \ 8}$$

$$q_{(H-M)} = 0.007425 \text{ t}$$

$$= 0.007425 \text{ t}$$

Table 5. Quantity transported between nodes in kg
Source: Survey Data (2023)

Step 09- The total amount of quantity transferred from that particular node to all the other nodes (27) and the sum of travel time from that node to all of the other nodes (27) were used to compute network flow for a node.

For an example, network flow for Biyagama is (12) calculated as below,

$$QEEF_B = \frac{\sum_{i=0}^{n} (a \times q_{n_B n_{n-1}})}{\left(\Sigma_{l=0}^{n} (a \times t_{n_B n_{n-1}} \ )\right) n} \quad (11)$$

$(q_{n_B n_{n-1}}$= 0.000+8.1+8.1+………+3.96=171.9 kg
$t_{n_B n_{n-1}}$= 0.00+1.14+1.89+…….5.28=122.33h)

$$QEEF_B = \frac{1 \ \times 171.9 \ kg}{(1 \ \times 122.33h \ )x \ 1}$$

$$QETNF_B = 1.4052 \ kgh^{-1}$$

Condition 02- QEEF when using expressways during peak hours
All the calculations were done according to the above methodology. Here the travel time has been reduced due to the usage of expressways.

Table 6. Travel time matrix in hrs. (using expressways - peak time)

	1	**2**	**3**	**…**	**28**
1	0.00	1.14	0.53	**…**	5.28
2	0.73	0.00	1.27	**…**	6.02
3	0.72	1.85	0.00	**…**	6.00
…	**…**	**…**	**…**	**…**	**…**
28	5.33	6.47	5.87	**…**	0.00

Source: Survey Data (2023)

Condition 03- QEEF when using expressways during off-peak hours
All the calculations were done according to the above methodology. Here the travel time has been reduced due to the usage of expressways and off-peak hours.

Table 7. Travel time matrix in hrs.(using expressways – off-peak time)

		1	**2**	**3**	**…**	**28**
1		0.00	0.55	0.53	**…**	4.82
2		0.73	0.00	1.27	**…**	5.55
3		0.72	1.27	0.00	**…**	5.53
…		**…**	**…**	**…**	**…**	**…**
28		5.33	5.88	5.87	**…**	0.00

	1	**2**	**3**	**…**	**28**
1	0.000	8.1	8.1	**…**	3.96
2	8.1	0.000	8.1	**…**	3.96
3	8.1	8.1	0.000	**…**	3.96
…	**…**	**…**	**…**	**…**	**…**
28	3.96	3.96	3.96	**…**	0.000

Source: Survey Data (2023)

Condition 04 - QEEF when using normal routes without expressways during off-peak hours

Table 8. Travel time matrix in hrs. (without using expressway- off-peak time)

	1	**2**	**3**	**…**	**28**
1	0.00	0.55	0.53	**…**	4.82
2	0.73	0.00	1.27	**…**	5.55
3	0.72	1.27	0.00	**…**	5.53
…	**…**	**…**	**…**	**…**	**…**
28	5.33	5.88	5.87	**…**	0.00

Source: Survey Data (2023)

V. ANALYZING

After calculating the QEEF for the above mentioned four scenarios, the descending order of the QEEF values can be listed as condition 3 (with expressways, off-peak), condition 4 (no expressways, offpeak), condition 2 (with expressways, peak time) and condition 1 (no expressways, peak time). So, the highest flow is in the third condition which is the QEEF values during off-peak time in expressways and least QEEF values are obtained in the first condition which is the QEEF values during peak time in normal routes without expressways. When ranking all 28 nodes according to the QEEF values, the order of the nodes is almost the same in all four situations. It is identified that, Colombo, Biyagama, Katunayake, Yakkala, Horana, Awissawella, Kaluthara, Galle, Maravila, Kegalle and Kurunegala have higher flow under all these conditions whereas Mathara, Rathnapura, Hambanthota, Kandy, Embilipitiya, Dambulla, Mahiyanganaya, and Balangoda have medium flow under all these conditions and Anuradhapura, Nuwaraeliya, Polonnaruwa, Bandarawela, Vavuniya, Trincomalee, Ampara, Batticaloa, and Jaffna have lower flow under all these conditions. Hence, there are slight differences in condition 2 and 4. When considering the QEEF values of condition 2 (with expressways, peak time) Biyagama has been ranked as two and Katunayake as three which is ranked vice versa in all other conditions (Biyagama ranked as three and Katunayake ranked as two). When considering the QEEF values of condition 4 (no expressways, off-peak time) Kandy has been ranked as 16 and Embilipitiya as 15 which is ranked vice versa in all other conditions (Kandy ranked as 15 and Embilipitiya ranked as 16).

Table 9. Rankings of nodes according to their flow (Rank num 01= highest flow)

City	Condition - 01	Condition - 02	Condition - 03	Condition - 04
Colombo	1	1	1	1
Biyagama	3	2	3	3
Katunayake	2	3	2	2
…	…	…	…	…
Vavuniya	24	24	24	24

Source: Survey Data (2023)

VI. DISCUSSION

As stated in the study, not many studies have been done using estimated values for quantities (where real data is not available), and the findings of this newly developed study can be used to measure freight network flow when data is unavailable. Aside from that, the developed index values can be used to improve freight network flow in low-flow areas.

According to the QEEF values, certain nodes have less flow than others. As a result, the warehouses in less flow areas (Vavuniya – 0.8489 kg/h/Jaffna – 0.2940 kg/h) can be relocated, which lowering the organization's total expenditures. Because maintaining an extra warehouse is expensive, this strategy can be utilized for sub nodes with less flow. Because of the high revenues, it is suggested that instead of maintaining a warehouse for regions with low flow, a 3PL service can be adopted.

A consolidated vehicle can be used to transport goods from nodes whose summated flows are equal or less than equal to the vehicle capacity. When the total weight exceeds 4000 kg, a larger capacity vehicle might be employed to transport the products. This will assist in boosting the flow of the courier service network by transporting more products in a shorter period of time.

More equipment can be used at high flow nodes (Biyagama – 1.4052 kg/h/Katunayake – 1.4191 kg/h) to boost the flow of goods, whereas fewer linked nodes can use less equipment because their flow is lower. Nodes with less flow (Trincomalee – 0.3461 kg/h, Bandarawela – 0.3666 kg/h) can be boosted by lowering trip time by delivering items during off-peak hours, which avoids traffic congestion. To travel during off-peak hours, warehouse processing time should be reduced by deploying more equipment that requires less labor. As a result, using an automated system in warehouses can improve network flow.

The best route with ideal conditions should be utilized to optimize the profit factor. It has been observed that not using expressways during peak hours greatly lowers flow, but that some specific scenarios reduce/enhance the flow of certain nodes. As a result, taking expressways during peak and offpeak hours is both cost economical and time efficient. It is also suggested that dispersing the whole amount during offpeak hours reduces costs due to reduced congestion. While the QEEF data are examined, it is usually revealed that nodes have high flow (Galle – 1.0876 kg/h/Yakkala – 1.39078 kg/h) when supplying commodities during off-peak hours.

In this expressway with peak hour situation, lengthening the waiting time allows for a higher flow than previously. So, when there is a full load to be carried, commodities transfer from less flow nodes (Polonnaruwa – 0.3687 kg/h /Bandarewala – 0.3666 kg/h) may be completed in two days. This method will improve the flow of the courier service network while also lowering costs.

VI. CONCLUSION

The method used in this research study can be applied to a variety of commercial and non-commercial domains, such as port networks, supermarket networks, and so on, to improve the freight network flow of their particular transport network and, as a consequence, to increase the profit factor as well as the efficiency and productivity.

D. Limitations

The main limitation of this research is the unavailability of data as this study has chosen a very competitive commercial industry. The lack of information in this study led to a lot of assumptions. It was assumed that the amount of goods transported to each node was assumed to be proportional to the criticality of that node since functionality and operational characteristics are highly propositional to a particular node's criticality (Psaltoglou & Calle, 2018).Even Colombo is a medium critical node according to the results obtained, it was assumed as a high critical node because it acts as the central hub of this network. As the next assumption, when there is a traffic zone between two nodes, extra time was added to the total time taken to travel (When calculating the travel time between Colombo and Kandy, extra time was added to the total time since there is a traffic zone in between).

E. Future Research

In future research, it is suggested that accessibility and mobility, as well as the population and consumer behavior of each location, be considered as key influences on the network flow of a node. Furthermore, the index's accuracy can be improved by using real values for quantities to measure the flow of goods.

REFERENCES

Dumbliauskas, V., Grigonis, V., & Barauskas, A. (2017). Application of Google-based Data for Travel Time Analysis: Kaunas City Case Study. *PROMET - Traffic&Transportation*,29(6),613–621. https://doi.org/10.7307/ptt.v29i6.2369

G. Ollivier, "Global Faciliation Partnership for Transport and Trade," GFP, June 2005. [Online]. Available: https://assets.publishing.service.gov.uk/media/57a08c6aed91 5d622c00132b/C21-trackingnote.pdf. [Accessed 10 April 2022].

Psaltoglou, A., & Calle, E. (2018). Enhanced connectivity index – A new measure for identifying critical points in urban public transportation networks. *International Journal of Critical Infrastructure Protection*, *21*, 22–32. https://doi.org/10.1016/j.ijcip.2018.02.003

Purboyo, H., & Ibad, M. Z. (2017). East Java Maritime Connectivity and Its Regional Development Support. *IOP Conference Series: Earth and Environmental Science*, *79*(1). https://doi.org/10.1088/1755-1315/79/1/012006

Sano, Y., Furukawa, S., Takamura, F., & Yamane, K. (2000). Travel-time measuring system for efficient traffic information service. *Hitachi Review*, *49*(3), 135–139.

Van Der Zijpp, N. J. (1997). Dynamic origin-destination matrix estimation from traffic counts and automated vehicle identification data. *Transportation Research Record*, *1607*, 87–94. https://doi.org/10.3141/1607-13

Xie, F., & Levinson, D. (2011). Evaluating the effects of the I-35W bridge collapse on road-users in the twin cities metropolitan region. Transportation planning and technology, 34(7), 691-703.

Beuthe, M., Jourquin, B., Geerts, J. F., & à Ndjang'Ha, C. K. (2001). Freight transportation demand elasticities: a geographic multimodal transportation network analysis. Transportation Research Part E: Logistics and Transportation Review, 37(4), 253-266.
Ashrafi, Z., Shahraki, H. S., Bachmann, C., Gingerich, K., & Maoh, H. (2017). Quantifying the criticality of highway infrastructure for freight transportation. Transportation Research Record, 2610(1),10-18

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