A Predictive Model on Throughput Performance of Malaysian Ports Post Kra Canal

Nur Zakri S.A.* and Ahmad M.Z.

School of Mechanical Engineering, Faculty of Engineering,
Universiti Teknologi Malaysia,
81310 UTM Johor Bahru,
Johor, Malaysia

*Corresponding email: salaaminz@yahoo.com

Article history
Received
15 August 2019
Revised
3 October 2019
Accepted
2 December 2019
Published
15 December 2019

ABSTRACT

Potential development of the Kra Canal is a contentious issue especially amongst the maritime nations along the Strait of Malacca. By allowing direct access from the South China Sea to the Indian Ocean and bypassing the Strait of Malacca, the container ports located south of the canal is expected to be adversely affected. The objective of this paper is to study the impact of the development of the Kra Canal on the Malaysian container ports and also to compare their predicted performance against their current conditions. The intermodal solution method will be used together with the shipper preference to develop a predictive model of the throughput market share for the Malaysian container ports post construction of the hypothetical Kra Canal.

Keywords: *Kra Canal, intermodal network, shipper preference, container ports*

1.0 INTRODUCTION

China unveiled a strategic initiative that focuses on the connectivity between the Eurasian countries and People Republic of China aptly named One Belt, One Road in 2013 [1, 2]. One of the proposals to realize this initiative is to construct a canal through the Isthmus of Kra to connect the Gulf of Thailand to the Indian Ocean, bypassing the Strait of Malacca.

The development of the Kra Canal would provide an alternative route from the congested Strait of Malacca, reduce the voyage distance by about 1200 km and voyage time between two to five days [1]. By the end of 2016, three of the top 20 world container terminals by throughput is located along the Strait of Malacca[3]. The construction of Kra Canal may adversely affect the competitiveness of these terminal ports.It is pertinent for Malaysian maritime industry to adapt to this possible eventuality of the canal development. As such, its effect on the Malaysian ports intermodal network needs to be well understood. The proposed Kra Canal is illustrated in Figure 1.

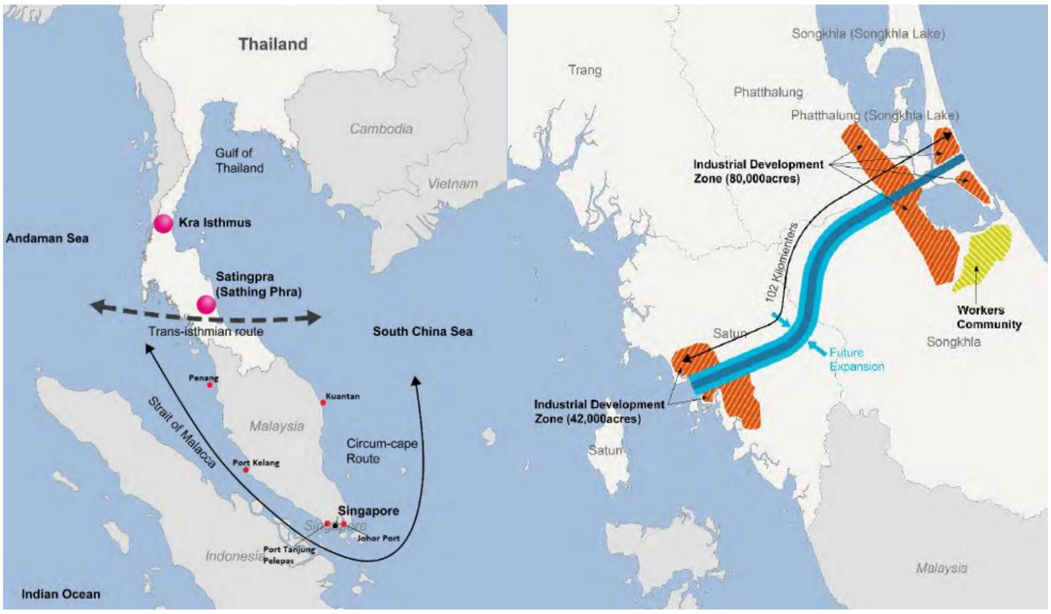

Figure 1: Proposed Kra Canal [1]

2.0 LITERATURE REVIEW

The case for Kra Canal has been discussed by Abdul Rahman *et al*. (2016) in that it would provide cost savings to shippers, in addition to increase in security from the risk of piracy of Strait of Malacca and the reduction in travel distance of approximately two to five days [4]. Their findings predicted that that Port Kelang, Johor Port and Port Tanjung Pelepas would be adversely affected by the Kra Canal but Penang is expected to thrive due to its proximity to the canal. Yang *et al*. (2011) surmised in their analysis of the intermodal network optimization that the travel distance is less critical to the overall transport cost as opposed to the transit time and they concluded that the construction of the KraCanal would indeed pose a significant threat to the Strait of Malacca intermodal transport [5]. On the other hand, Zeng *et al*. (2017) through their gravity model of spatial interaction between ports, predicted that although the port in Strait of Malacca would experience market share decline, the impact would only be slight [2].The study on the relative efficiency of the ASEAN ports by Kutin *et al*. (2017) identified that the Malaysian ports along the Strait of Malacca have a high relative efficiency to its neighbor and are already approaching its efficiency frontier [6]. This is represented in terms of constant and variable return to scale. By introducing an alternative port or ports with the construction of the KraCanal into the sample, the result would have skewed the efficiency of the Malaysian ports into inefficiency. This would concur with the findings in both [5] and [2]. Alternatively, in their research,Chen *et al*. (2017) suggested a different conclusion in that the competitiveness of the transshipment hub would not be reduced with the introduction of other nearby ports, even if they provide a shorter transport distance [7]. Preference by shippers and freight forwarders are also factored in by the custom regulations and government policies. The effectiveness of the seaports is dependent on its intermodal networks. One of the key findings by Jeevan *et al*. (2015) is that the enhancement of the seaports and dry ports connectivity would improve the efficiency of both [8]. The reliability of seaports is one of the selection criteria by shippers to utilize a route.

The criteria are explored in more detail by [9] where the utilization of intermodal network between origin and destination pair (O-D pair) are primarily based on transport cost and transport time. The shortest path is considered between trade-off of the two competing objectives. This is supported by works in [10] where the authors argued that the selection of route by shippers is highly dependent on its utility. In their probabilistic model of O-D pair, the variables are demand at destination, total cost of the route, shippers value of time, transit time to destination and an unobservable utility factor to shippers.

Cho *et al*. (2012) introduced an algorithm on an intermodal network that concurred with both [2] and [9] regarding the determinants of the route selection of shippers [11]. However, instead of utilizing all nodes in an O-D pair as with the case of [9] and [10] models, they would eliminate the nodes by the order of cost, voyage time and its arrival date with respect to the next shipment departure. This method known as pruning rules, allows for better performance and efficacy when seeking the optimal route when there is numerous path available. Several intermodal network models proposed in the literature reviewed such as in [5] and [9] offered fixed demand between O-D pairs. This is also the assumption used in works by [12]though they recommended the demand elasticity be addressed in future works as demand is related to the total shipping charge. This is indeed a matter that requires relevant attention when considering the introduction of an alternative route such as via the Kra Canal.

In addition to competing objectives as the main problem of modeling intermodal networks, Chang (2008) proposed an algorithm that accounts for the scheduled transportation modes and demanded the delivery time and transportation economies of scale [13]. However, by introducing the time constraint and larger scale analysis, the algorithm application did not reflect the overall feasibility of the intermodal network, only revealing its relation to a specific product delivery. The problem of homogenous product may be overcome using a thing algorithm by assigning the weighted sample to better approximate the overall intermodal network feasibility. An alternative to representing the intermodal networks solutions is by providing clustering networks. This is demonstrated by [14] in their logistic suite which allows for the reduction in the size of the networks and improving the calculation time to obtain solutions. Applying the clustering of networks on the hinterland of a transshipment hub in an intermodal network could simplify the transportation economies of scale component offered in[13].

It is thus evident that from the literature that the selection of route by shipper is based on the most optimum solution in an intermodal network [9-11]. This is identified through the lowest cost model of intermodal solutions. In addition, research by [7] and [8] implied that the shipper preference of a route would also be governed by factors not directly offered in the cost model of an intermodal solution.To the best of the author’s knowledge, none of the literature reviewed provides the intermodal solution model incorporating shipper preference to its cost model.

3.0 METHODOLOGY

Intermodal solution is a method to address the issue of non-dominating solution between competing objectives when selecting route of shipment. The common competing objectives are cost and time.

Intermodal solution model in this paper consists of two main components: a cost model and shipper preference as illustrated in Figure 2. The cost model establishes the total cost, Y_N for each origin-destination pair. This includes total transportation costs, K_N and consolidated port fees, C_N. The shipper preference is based on the actual origin-destination pair throughput in relation to its total cost. The component of the total cost is summarized as follows:

$$Y_N = K_N + C_N \tag{1}$$

Ideally, when there is a dominated solution of a cost model, all will result in the throughput single origin-destination pair. Under actual circumstances, throughput also passes through pairs with less optimal solution. The number of throughputs passing through each pair is inversely proportional to its total cost. The relationship between the throughput, R_N and total cost, Y_N of each pair can be expressed by a unique constant pair of the shipper preference, d_N as follows:

$$R_N \propto \frac{1}{Y_N} \tag{2}$$

$$d_N = \text{constant} = R_N X Y_N \tag{3}$$

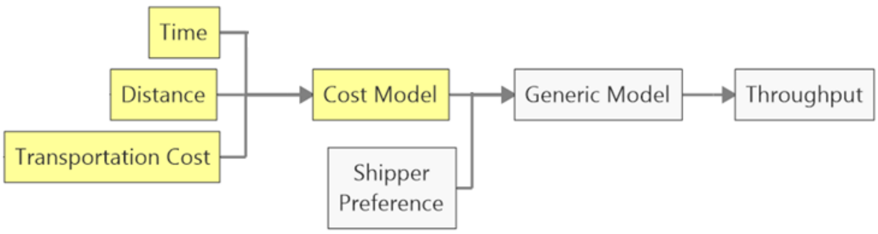

Figure 2: Intermodal solution with shipper preference

4.0 MODEL ANALYSIS

The dominant container shipping route for the area of study would be between the Far East and Europe. Thus, for the purpose of this study, six routes were studied between Shanghai to Suez Canal, going through a single transshipment node: Port Kelang, Johor Port, Port Tanjung Pelepas, Kuantan Port, Penang Port and Singapore Port. This network of routes represents the current model of the study, that is the current condition of ports without the construction of Kra Canal. A predictive model for this study was carried out by introducing the Kra Canal to the previous model and additional seventh route with the Songkhla Port as an additional transshipment node.

The input data of all the networks are summarized in Table 1. The total voyage distance for each possible route can be obtained from www.ports.com while the average fuel cost for the year 2017 accessed from http://shipandbunker.com. The total container throughput for each port are based on the Malaysia Marine Department (MMD) and relevant information from www.unctad.org. The consolidated port fees were obtained from each respective port authority.

Table 1: The input data

Transship-ment node	Total cost, Y_N (USD)	Transport cost, K_N (USD)	Consoli-dated port fees, C_N (USD)	Total distance (knots)	Transit time, T_N (days)	Fuel consumed per voyage (tonnes)	Port through-put, R_N (TEUs)
Port Kelang	953730.50	949824.25	3906.25	8020	17.63833333	2645.75	11,978,025
Johor Port	955395.30	949824.25	5571.056	8020	17.63833333	2645.75	900,692
Port Tanjung Pelepas	955168.02	949936.43	5231.58	8021	17.64041667	2646.0625	8,260,610
Kuantan Port	968830.02	962501.43	6328.59	8133	17.87375	2681.0625	147,041
Penang Port	953079.45	949824.25	3255.20	8020	17.63833333	2645.75	1,469,825
Singapore Port	951696.80	946862.50	4834.30	8056	17.58333333	2637.5	33,666,600

Generating the predictive model would require several rules to be applied. First, the shipper preferences of the ports were to remain proportionally constant with the current model. This is to reflect that there are no changes done to the intermodal network other than introducing a new route. Secondly, the total of throughput in the current model network are to remain constant in the predicted model network. This would allow the throughput to be redistributed to the ports in accordance to its respective total cost, Y_N and shipper preference, d_N. The percentage change in the port throughput would reflect the predicted change of the throughput market share of the individual ports post Kra Canal construction.

The key assumptions in the study would be the homogeneity of cargo and container vessel. This allows for direct route to route comparison rather than the cost of individual shipment. The overall shipper behavior is reflected in the route throughput. The vessel selected is the generic *Suezmax* with a service speed of 20 knots.

5.0 RESULTS AND DISCUSSION

The current model is based on the data collected in 2017. The shipper preference obtained in this model were also validated against the years 2015 and 2016 where there were no major changes in the port conditions. The results of the current model are illustrated in Table 2.

Table 2: Current model results

Hub	Total cost, Y_N in USD	Port throughput, R_N	Shipper preference, d_N
Port Kelang	953730.50	1.E+07	1.14E+13
Johor Port	955395.31	9.E+05	8.61E+11
Port Tanjung Pelepas	955168.02	8.E+06	7.89E+12
Kuantan Port	968830.03	1.E+05	1.42E+11
Penang Port	953079.46	1.E+06	1.40E+12
Singapore Port	951696.80	3.E+07	3.20E+13

There is only a slight difference between the total cost of routes. The high proportion of the absolute market share by Singapore Port could mainly be attributed to its high shipper preference. The comparison of the current model shipper preference, d_N is shown in Figure 3.

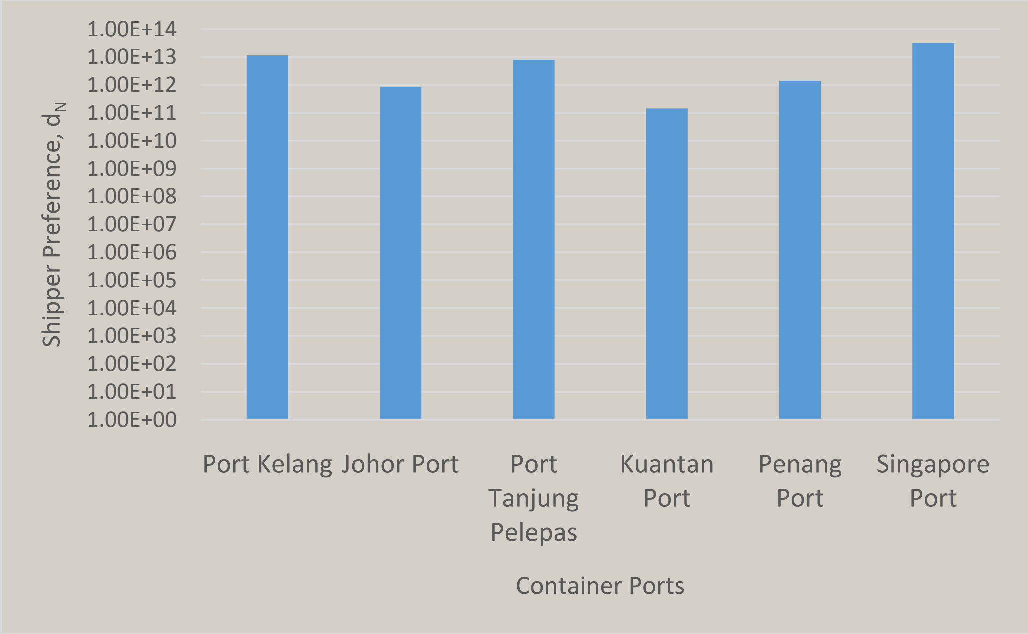

Figure 3: Shipper preference comparison

The predicted model is generated when the Kra Canal is introduced with an additional route through the Songkhla Port in the intermodal network. The modification of the intermodal network resulted in the redistribution of the port container throughput based on the new shipper preference. The reduction of all the current model port shipper preferences is proportional to the percentage throughput gained by the Songkhla Port. This is the case with the exception of the Penang Port since the shortest route passing through it would be through utilizing the Kra Canal. The results of the predicted model are shown in Table 3.

Table 3: Predicted model result

Hub	Total cost, Y_N in USD	Port throughput, R_N(New)	Shipper preference, d_N(New)
Port Kelang	953730.50	9.27E+06	8.85E+12
Johor Port	955395.31	6.97E+05	6.66E+11
Port Tanjung Pelepas	955168.02	6.39E+06	6.11E+12
Kuantan Port	968830.03	1.14E+05	1.10E+11
Penang Port (Post Kra)	920264.61	1.18E+06	1.08E+12
Singapore Port	951696.80	2.60E+07	2.48E+13
Songkhla Port	897042.84	1.27E+07	1.14E+13

The predicted effect of the realization of the Kra Canal on the container ports considered was performed by comparing the changes in the absolute market share between the current and predicted models as shown in Table 4 and Figure 4. Based on the results of the research, all current container ports will be experiencing a reduction in their absolute market share. Singapore Port in particular, despite still assuming the largest throughput absolute market share in the predicted model would also be the one losing out the most.

The average global throughput growth in 2017 is 3.1% [15]. Ports which lose their market share lower than the average growth in throughput are predicted to experience throughput growth despite the realization of the Kra Canal. The ones with loss higher than the average throughput growth are predicted to take a much longer time to recover their respective throughput to pre-Kra Canal condition/level.

Table 4: Absolute market share comparison

Hub	Current throughput market share (%)	Predicted throughput market share (%)	Change in market share (%)
Port Kelang	21.23	16.43	-4.80
Johor Port	1.60	1.24	-0.36
Port Tanjung Pelepas	14.64	11.33	-3.31
Kuantan Port	0.26	0.20	-0.06
Penang Port (Post Kra)	2.61	2.09	-0.52
Singapore Port	59.67	46.17	-13.50
Songkhla Port	N/A	22.55	N/A

6.0 CONCLUSIONS

This paper proposes an applicable intermodal network model utilizing shipper preference to determine the throughput performance of container ports. The result of this application has been used to model the current performance of the Malaysian and Singapore ports and a hypothetical model with the inclusion of the Kra Canal. The model is useful especially to service providers and policy makers in tracking competitiveness and planning development of the container ports. One of the insights that could be derived from the findings is that the port's shipper preference played a significant role for shipper in utilizing a route in addition to its total costs. For example, Singapore high shipper preference could be attributed to its lower average time in the port of 0.8 days compared to the regional average of 0.93 days. The effect of realization of the Kra Canal development on the Malaysian ports in terms of the throughput absolute market share was also presented. All the current Malaysian and Singapore container ports are predicted to be adversely affected with the canal development, albeit at varying degrees. It is also predicted that the Johor Port, Kuantan Port and Penang Port to experience a throughput growth despite suffering losses in the absolute market share.Admittedly, the analysis of this work is not without its constraint. Firstly, the research is based on the idealized assumption that the routes are only utilized by homogenous vessel and commodity. The generalization of the route competitiveness is more akin to the policy makers estimate in their strategic planning. Secondly, the origin and destination nodes selected for the research is limited to represent the dominant shipping route in the region. However, in doing so, discounted the smaller inter-regional shipments from the transshipment hubs. Incorporating the additional route networks may better reflect the shipper performance of the container ports.

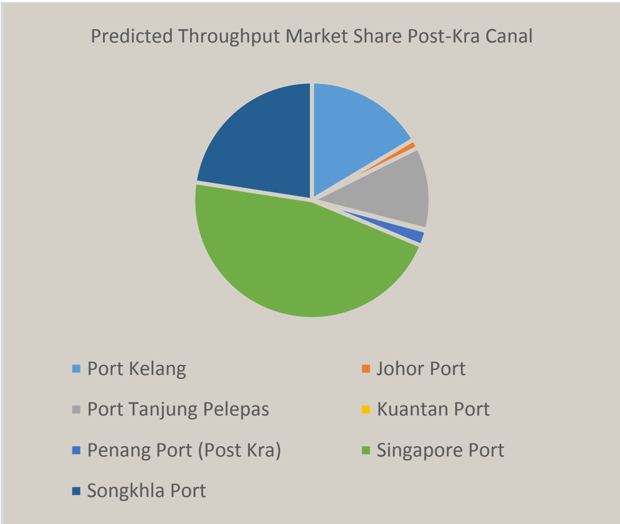

Figure 4: Throughput market share comparison

REFERENCES

1. Su S., 2015. Looking Ahead: The Port Industry - How Asean Ports Respond to the Changing Global Maritime Trade Trends? BMT Asia Pacific, Des Voeux Road Central, Hongkong.
2. Zeng Q., Wang G.W.Y., Qu C. and Li K.X., 2017. Impact of the Carat Canal on the Evolution of Hub Ports under China's Belt and Road Initiative, *Transportation Research Part E: Logistics and Transportation Review*, 117(September 2018): 96-107.
3. UNCTAD, 2016. Review of Maritime Transport 2016. New York: United Nations.
4. Abdul Rahman N.S.F., Mohd Salleh N.H., Ahmad Najib A.F. and Lun V.Y.H., 2016. A Descriptive Method for Analysing the Kra Canal Decision on Maritime Business Patterns in Malaysia, *Journal of Shipping and Trade*, 13(2016).
5. Yang X., Low J.M.W. and Tang L.C., 2011. Analysis of Intermodal Freight from China to Indian Ocean: A Goal Programming Approach, *Journal of Transport Geography*, 19(4): 515-527.
6. Kutin N., Nguyen T.T. and Vallée T., 2017. Relative Efficiencies of ASEAN Container Ports based on Data Envelopment Analysis,*The Asian Journal of Shipping and Logistics*, 33(2): 67-77.

7. Chen G., Cheung W., Chu S-C. and Xu L., 2017. Transshipment Hub Selection from a Shipper's and Freight Forwarder's Perspective, *Expert Systems with Applications*, 83: 396-404.
8. Jeevan J., Ghaderi H., Bandara Y.M., Saharuddin A.H. and Othman M.R., 2015. The Implications of the Growth of Port Throughput on the Port Capacity: The Case of Malaysian Major Container Seaports, *International Journal of e-Navigation and Maritime Economy*, 3: 84-98.
9. Bookbinder J.H. and Fox N.S., 1998. Intermodal Routing of Canada–Mexico Shipments under NAFTA, *Transportation Research Part E: Logistics and Transportation Review*, 34(4): 289-303.
10. Meng Q. and Wang S.A., 2011. Intermodal Container Flow Simulation Model and Its Applications, *Transportation Research Record*, (2224): 35-41.
11. Cho J.H., Kim H.S. and Choi H.R., 2012. An Intermodal Transport Network Planning Algorithm using Dynamic Programming - A Case Study from Busan to Rotterdam in Intermodal Freight Routing, *Applied Intelligence*, 36(3): 529-541.
12. Liu Z., Meng Q., Wang S. and Sun Z., 2014. Global Intermodal Liner Shipping Network Design, *Transportation Research Part E: Logistics and Transportation Review*, 61: 28-39.
13. Chang T-S, 2008. Best Routes Selection in International Intermodal Networks, *Computers & Operations Research*, 35(9): 2877-2891.
14. Gromicho J.A.S., Oudshoorn E. and Post G., 2011. Generating Price-effective Intermodal Routes, *Statistica Neerlandica*, 65(4): 432-445.
15. UNCTAD, 2017. *Review of Maritime Transport 2017*, New York: United Nations.