

THE EFFECT OF FUEL PRICE INCREASE ON TRANSPORT COST OF CONTAINER TRANSPORT VEHICLES

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ABSTRACT: This study presents the impact of fuel price increase on the transport cost of containers by using container vehicles. ArcGIS was used to build the transport network while MATLAB software was used to develop Dijkstra's shortest path algorithm and coding the transport cost equation. In this study, two case studies were analyzed with Johor Port as the origin and, the Port Klang and top-north-point were considered as destinations for cases 1 and 2. The optimum routes for each mode of transport were identified. The results of least-cost routes against fuel price increase were compared for shipment of containers from origin to destination in the intermodal network of Peninsular Malaysia. In the analysis, fuel price was increased from its current price sequentially to 100%. Based on the assumptions of this study, the results showed that transport cost of a container by train was significantly lower than truck even when the fuel price of the train was doubled. Comparing train-based and ship-based optimal routes revealed that transport cost by train, when its fuel price doubled, was slightly higher than ship in case 1. While in case 2, transport cost by train when its fuel price doubled was considerably cheaper than the ship-based route in its current fuel price. It can be concluded that fuel price increase has the highest impact on transport cost of containers by ship, followed by train and truck. The presented methodology and procedure are applicable for any origin-destination pair in the transport network.

Keywords: Fuel price, Transport cost, Container transport vehicle, Least-cost route

1. INTRODUCTION

One of the major components of globalization is the transportation sector, which plays a very significant role in daily activities and the economy. During the 20th century, trade scale changed from local to global and therefore freight transport system became a global network. In particular, freight transportation is one of the most important economic activities. Freight transport has been growing even more rapidly than passenger transport and is expected to continue to do so in the future [1]. Truck, train, and ship are the three common transport vehicles being used for movement of containers, which are characterized by a number of advantages and disadvantages. The cost of transportation is an important selection criterion among influential parameters on identifying the appropriate mode of transportation mode for freight shipment.

The main challenge of today's transport costs is oil price. Freight movement in most modes remains largely dependent on expensive and finite fossil fuels, predominantly diesel fuel [2]. The foremost single factor affecting the retail price of diesel fuel is the price of crude oil [3], [4]. Crude oil as an energy source is a vital component that determines the condition of the world economy [5]. Its price

fluctuations impact on all industrial sectors whether directly or indirectly, be it in banking, energy, retailing or transportation industries. The impact of oil prices on transport sector depends upon three issues, which are, the relevance of the oil price on the cost of the energy used for each transport mode, to what extent oil price is transferred to transport fuel prices, and the relative weight of the energy cost on total operating costs for each mode [6]. Fuel prices are a cost to transportation industries and a direct cost to consumers. Fuel price is one of the most important factors affecting transport cost, which comprises more than 50 percent of the total operating cost for the transportation industry nowadays [7]. Since the sensitivity of transport operating cost to the oil price change varies significantly across shipment modes, the oil price has become an important factor in freight mode choices. Casamassima et al. [6] revealed that the sensitivity of fuel costs of road mode and railway crude oil price was 40%, while maritime was 100% since marine fuels are exempted from government taxation. In addition, they estimated the influence of doubling of crude oil price on transport cost of road and rail freight was 10%, while for maritime was 50%.

There is a lack of knowledge in the literature regarding the effect of fuel price increase on

transport cost of containers as this consequently impact on freight modal choice decisions [8]. Macharis et al. [9] investigated the impact of fuel price increases on the market area of intermodal transport terminals by using LAMBIT model, which is a GIS-based model. They analyzed several fuel price scenarios in order to verify the impact of different fuel price evolutions on the market area of unimodal road transport compared to intermodal transport in Belgium. They also explored internalizing the externalities and presented break-even distances for both road and intermodal transportation systems subject to the alteration of fuel prices.

The aim of this paper is to investigate the impact of the fuel price increase on transport cost of containers shipment by truck, train, and ship in intermodal transport network of Peninsular Malaysia (Western part of Malaysia). To achieve the goal, it was desirable to identify the least-cost route between origin and destination based on road, railroad, and waterway modes of transport, and then comparing the cost of container transport through these routes based on a range of fuel prices from the current price to one-hundred percent increase. In this study, ArcMap software was used to build the transport network, and MATLAB software was used to develop the most famous shortest path algorithm (i.e., Dijkstra's algorithm) for analyzing intermodal transport networks. Dijkstra's algorithm is a common algorithm to solve the single source shortest path problem (one-to-all) in transport networks as well as finding the shortest paths from a single node to a single destination node. It identifies the shortest path between two selected vertices of a graph in which each edge of the graph has a weight or path length.

2. CRUDE OIL AND DIESEL PRICE RELATIONSHIP

Generally, diesel prices follow crude oil prices. According to statistics of crude oil and diesel prices recorded by U.S. Energy Information Administration [4], the changes of diesel price is in the same trend of crude oil price changes in the United States, which is as shown in Fig. 1. The historical crude oil price and diesel price in Malaysia are illustrated in Fig. 2 and 3. Comparing both prices showed that the diesel price fluctuations is in the same line of crude oil prices. For instance, when the price of crude oil in May 2008 was at its maximum price between 1997 and 2017 in Malaysia, the diesel price also experienced its maximum price at the same time. Therefore, the diesel price follows the crude oil price in Malaysia as well.

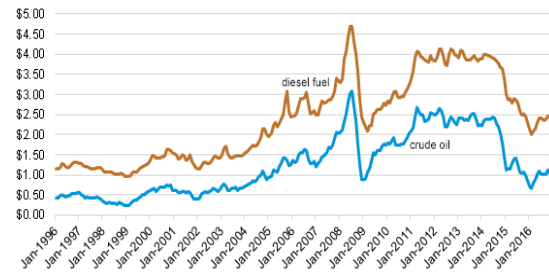


Fig.1 Average monthly U.S. crude oil and retail diesel fuel prices [4]

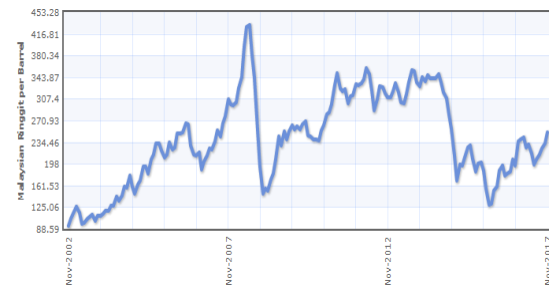


Fig.2 Historical crude oil price in Malaysia [10]

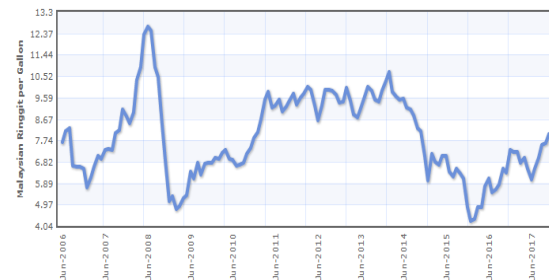


Fig.3 Historical diesel price in Malaysia [11]

According to World Bank, [12], the forecast for crude oil price shows a considerable increase from 55 to 80 dollar per barrel between 2014 and 2030. Consequently, it will cause an increase in fuel price. A fuel price increase affects the variable cost of both unimodal and intermodal transport [9]. The role of fuel cost in total freight transport costs differs by type of shipment, distance, load factors, but also per country [6].

3. TRANSPORT COST STRUCTURE

Generally, the freight transport involves many different activities in which each of them contributes to a portion of the total shipment cost. The total cost of freight movement can be calculated by defining a cost function. Mainly, the structure of the cost functions is determined by considering three issues, which are the scope of the total cost, the complexity of the freight transport units and unit

costs, and other specific issues.

The main issue in determining the structure of the freight cost function is the scope of the total cost. This scope involves a decision about the identification of the process of the freight transportation and parameters included in the freight cost function. In general, freight transport costs categorized to transportation costs (often referred to as direct costs; including crew wage, maintenance costs, fuel costs, facility/equipment costs and so on), inventory costs, handling costs, and their combinations. Secondly, when the scope is limited to the transport costs only, there are several cost components with different units, such as distance-based costs such as fuel (e.g. RM/km), time-based costs such as labour costs (e.g. RM/hour), and quantity-based costs such as transshipment costs (e.g. RM /TEU3) [9]. Thus, depending on what cost components are considered, how to express such units, how to aggregate/simplify the units, the form of transport cost function varies. Finally, the other issues such as the shape of the market area and transport speed [13], multiple types of vehicles [14], multi-commodity [15], the inclusion of external costs [16] also influence the form of cost functions.

The total freight transport cost in intermodal networks includes internal and external costs, as well as transfer cost. Internal or private costs are the direct expenses incurred by freight transport operators. These expenses consist of operating costs, as well as investments in capital facilities and rolling stock. It is operating costs that are most closely tied to the amount of service provided, including fuel, wages, maintenance, user charges, depreciation, and insurance [17]. The external costs are costs that networks impose on society, including environmental costs [18], [19]. In the literature, the most important external costs of transport are climate change, local and global air pollution, congestion, noise pollution, and traffic accidents (fatalities, injuries, and property damage). A transfer cost is a cost incurred in intermodal terminals for transferring freight from one transport mode to another, which can be fixed cost or variable cost. It is depending on issues such as in which intermodal point transfer occur, available modes at the intermodal terminal, and type and quantity of freight that is being shipped.

4. INTERMODAL TRANSPORT NETWORK OF PENINSULAR MALAYSIA

The intermodal transport network of Peninsular Malaysia is shown in Fig. 4. It includes networks of single-mode transport networks such as highway,

federal road, railroad and waterway, ports and intermodal terminals (mode-to-mode transfer points), and auxiliary lines. The auxiliary lines do not physically exist but used as a connector of available transport modes at ports or intermodal terminals. In constructing the network, highway and federal-road connected to one another at intersection points. Therefore, at such intersection points, there is a possibility to navigate from highway to federal-road and vice versa. However, there is no connection between road modes and other networks (i.e., railroad and waterway) at their intersection points. In this transport network, any node can be selected as origin or destination point. Mode-to-mode transfer and loading and unloading of containers on and off transport vehicles can occur at Ports and intermodal terminal nodes. Two case studies were analyzed in this study. The Johor Port in the south of Peninsular Malaysia was selected as the origin for both case studies. The Port Klang (destination 1) and top-north-point on the network (destination 2) were considered as destinations for cases 1 and 2 respectively as shown in Fig. 4. These origin and destination points were selected for this study due to the fact that Port Klang and Johor Port (origin) are the major and most famous Ports in Peninsular Malaysia. The top-north-point was considered because it appeared to be farthest from the origin point.

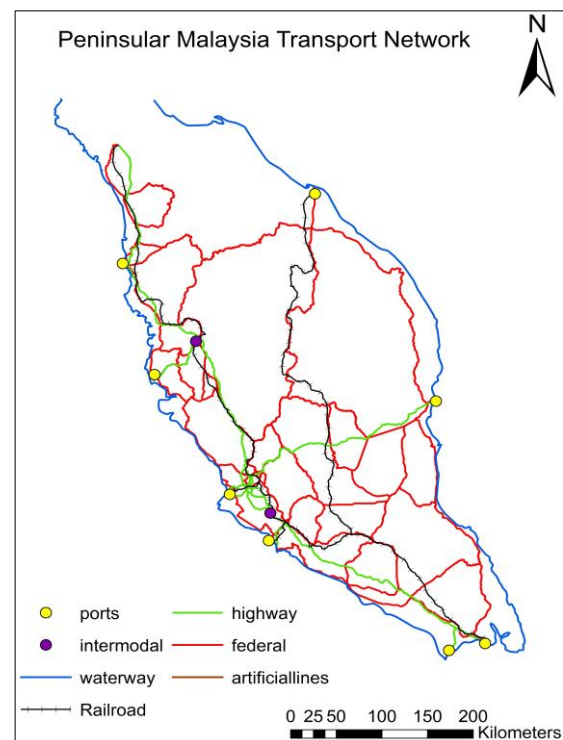


Fig.4 Intermodal transport network of Peninsular Malaysia)

5. TRANSPORT COST FORMULATION

In this study, total transport cost of containers is composed of transport cost of all segments involved in the optimum route and transfer cost at ports or intermodal points, where applicable. The variables considered for transportation cost calculation of involved segments were fuel price, fuel consumption, cost at modal change points, drivers' wage, maintenance, toll cost on the highway, number of containers, the capacity of a transport vehicle, distance and time involved. Transport cost of segments was estimated using Equation (1).

$$T_c = \sum (((F_p \times F_c \times T_d) + (W_a \times T_t) + (M_a \times T_d) \times (N_c/C_v)) + \sum (0.25 \times T_{dh} \times (N_c/C_v)) + \sum (C_{mc}) \quad (1)$$

where T_c , F_p , F_c , T_d , T_{dh} , and C_{mc} are transport cost (RM), fuel price (RM/liter), and fuel consumption (liter/km), travel distance (km), travel distance on highway (km), and cost for modal change (RM), respectively. W_a , T_t , M_a , N_c , and C_v represent wage (RM/h), travel time (h), maintenance (RM/km), the number of containers, and capacity of the vehicle (number of TEUs), respectively. TEU is the twenty-foot equivalent unit and it is used as a measure of capacity in container transportation. One TEU indicates the cargo capacity of a standard 20-foot intermodal container. RM is the unit for Malaysian currency known as Ringgit.

6. ASSUMPTIONS OF THE STUDY

The assumptions considered in this paper were as follows. A total of two hundred containers of 20-foot standard size was selected. The average toll cost of the highway was considered as RM 0.25 per truck per kilometer. According to Westport Malaysia [20], the cost for transshipment containers is mentioned as RM161 per TEU. The assumed values for considered variables on transport cost are presented in Table 1.

Table 1 Values for transport cost variables

Variables	Modes of transport		
	Truck	Train	Ship
Fuel consumption (l/km)	0.53	5	48.61
Driver wage (RM/h)	7	15	30
Maintenance of vehicle (RM/km)	0.5	3.8	10
The capacity of the vehicle (TEU)	2	70	200
Current fuel price (RM/l)	2.21	2.3	1.364

7. RESULTS AND DISCUSSION

The results of truck-based least cost analysis are shown in Fig. 5 and 6 for cases 1 and 2 respectively. As it can be clearly seen, the truck-based optimum routes for both cases included using the highway and federal road. The truck-based minimum total transport cost for cases 1 and 2 were estimated as RM 143527.66 and 201596.47 respectively. The results of train-based least cost analysis are illustrated in Fig. 7 and 8 for cases 1 and 2 respectively. The train-based minimum total transport cost for cases 1 and 2 were calculated as RM 83470.6 and 73367.07 respectively. The minimum transport cost in case 2 excludes the cost of unloading containers from the train since the destination is not an intermodal terminal or port. Fig. 9 and 10 visualize the results of ship-based least cost analysis for cases 1 and 2 respectively. As it has been pointed out, the ship-based optimal path for case 1 included direct container shipment by ship from origin to destination, while container shipment in case 2 composed of shipment by ship from origin to Penang Port (most closest port to the destination), and from Penang Port to destination by using truck through federal road. The ship-based minimum total transport cost for cases 1 and 2 were computed as RM 96725.25 and 159951.01 respectively.

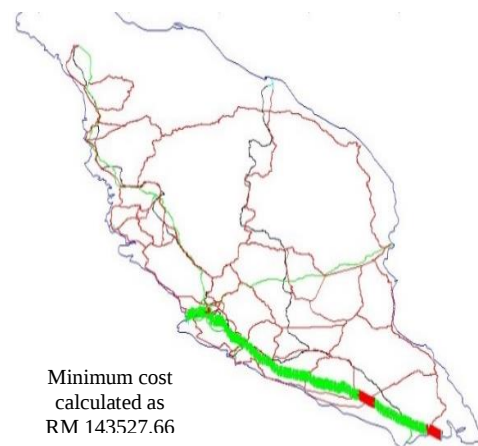


Fig.5 Results of truck-based cost analysis for case 1



Fig.6 Results of truck-based cost analysis for case 2

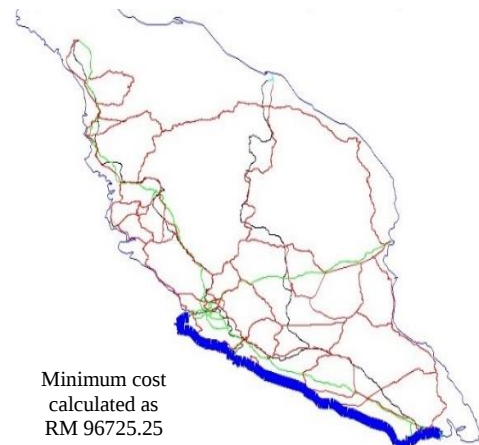


Fig.9 Result of ship-based cost analysis for case 1

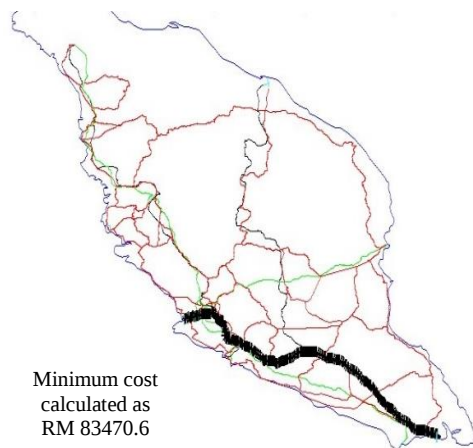


Fig.7 Result of train-based cost analysis for case 1

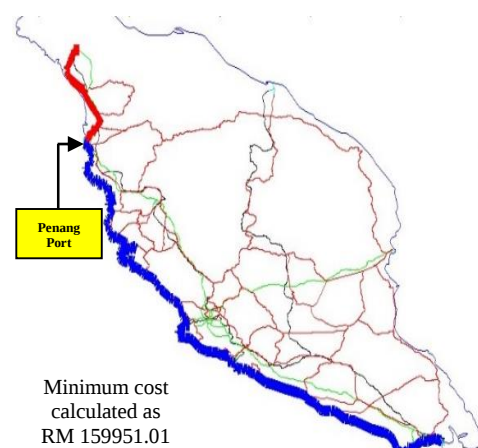


Fig.10 Result of ship-based cost analysis for case 2

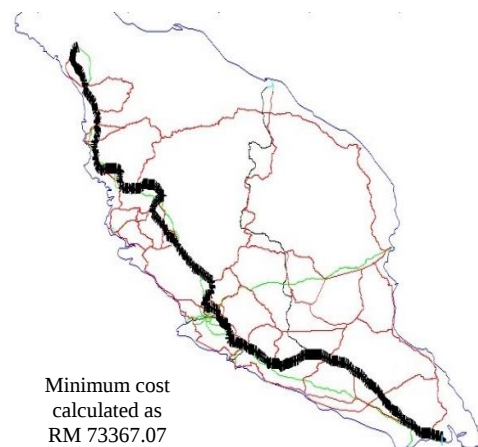


Fig.8 Result of train-based cost analysis for case 2

In case study 1, all least-cost routes include loading containers into transport vehicle at Johor Port (origin) and unloaded from transport vehicle at Port Klang (destination). Since the cost of modal change for 200 containers was RM 32200 at ports, the total transport cost of least-cost routes of the truck, train and ship were deducted by RM 64400 to obtain total transport cost of all segments involved in the routes for the movement of two-hundred containers. In case study 2, the total transport cost of truck-based and train-based least cost routes deducted by RM 32200 due to the cost of loading containers into transport vehicle at the origin, while ship-based least cost route deducted by RM 64400 due to cost of loading containers into a vehicle at the origin and ship-to-truck transfer cost at Penang Port. Finally, the result of calculations for both case studies divided by 200 to obtain total transport cost per container of all segments involved in the routes. The total transport cost of all involved segments in optimum routes per TEU was calculated against increase rates of fuel price and their result for case

1 is depicted in Fig. 11, and for case 2 is represented in Fig. 12.

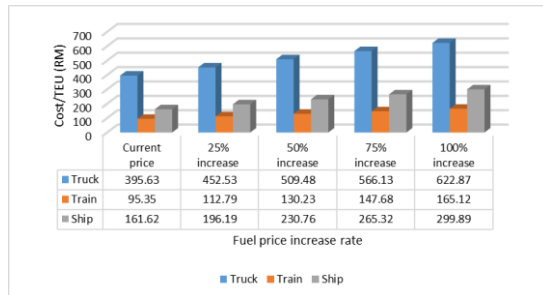


Fig.11 Transport cost by vehicles against fuel price increases for case 1

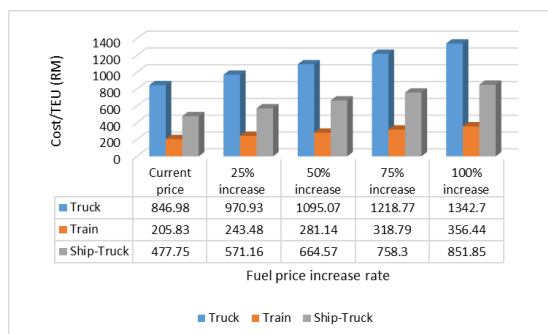


Fig.12 Transport cost by vehicles against fuel price increases for case 2

The results clearly indicate that in both case studies, the transport cost per container by train when its fuel price increased by 100%, were considerably lower than transport by truck based on its current fuel price (i.e., transport cost by truck was about 2.4 times more than transport cost by train). The similar comparison between ship-based and truck-based routes showed that transport cost per container by truck (current fuel price) was noticeably higher than transport cost by ship at 100% fuel price increase in case 1 (transport cost by truck was approximately 1.32 times higher than transport cost by ship), but transport cost per container of ship-based route was about RM 4.9 higher than truck-based route in case 2. These statistics show how transport by truck is significantly expensive when compared to train and ship. The similar comparison between train and ship indicate that transport cost per container by train at 100% fuel price increase was RM 3.5 more expensive than the ship (at its current fuel price) in case 1, while transport cost per container by train was about 34% less than the ship-based route in case 2. This information indicates that although the capacity of the ship is more than train and its fuel price is less than the train, but still the total transport

cost by train is cheaper than ship due to the effect of other influential parameters such as fuel consumption, speed, travel distance, etc. The fluctuations of transport cost in percentage for different modes of transport against the percentage of fuel price increase were compared as shown in Fig. 13 and 14 for cases 1 and 2 respectively. For cases 1, the percentage of transport cost increase per container against 100% fuel price increase for truck and train was 57.5% and 73.2% while case 2 were 58.5% and 73.2% respectively. Similarly, for the ship in case 1 and ship-truck for the case, 2 were obtained to be 85.6% and 78.3% respectively.

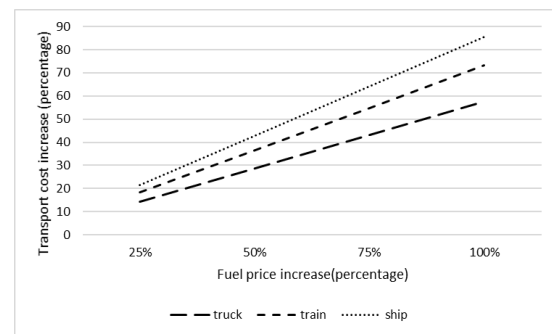


Fig.13 Comparison of cost of transport modes against fuel price increase for case 1

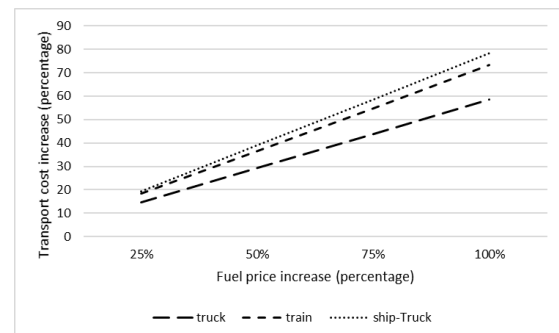


Fig.14 Comparison of cost of transport modes against fuel price increase for case 2

8. CONCLUSION

In this paper, the least-cost path between two pairs of origin and destination based on truck, train, and ship in intermodal transport network of Peninsular Malaysia were identified, and those routes were compared across a range of fuel prices increase. ArcMap was adopted to build transport network and MATLAB was used to develop the Dijkstra's shortest path algorithm and transport cost equation. Based on the assumptions of this study,

the results showed that firstly, shipment of containers by railroad mode was the cheapest mode of transport based on the current fuel price in both case studies, followed by ship and truck. Secondly, in both case studies, the transport cost of a container by truck based on its double fuel price was about 2.4 times higher than train based on its current fuel price. Thirdly, in case 1, the transport cost of a container by truck based on its double fuel price was about 32% more expensive than ship based on its current fuel price, while in case 2, the transport cost of a container through ship-based least cost route based on its double increased fuel price was slightly (RM 4.9) higher than truck-based route. Finally, fuel price increase has highest effect on transport cost of the ship, followed by train and truck. The advantage of the presented methodology is that it enables similar analysis for proposing least-cost routes and comparing different modes across a range of fuel prices between any origin-destination pairs in the transport network.

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