نشریه مهندسی عمران امیرکبیر

Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 50(3) (2018) 159-162
DOI: 10.22060/ceej.2017.11880.5092

A Disaggregate Analysis of Rail-Truck Mode Choice Behaviors for Freight Shipments in Iran and their Environment Effects

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ABSTRACT: Transportation infrastructure imposes enormous costs, along with several negative consequences, on the governments. Confronting such issues, freight transport policy analysts struggle to shift truck movements to rail to diminish transportation externalities that include environmental costs and safety issues. Therefore, policy-makers need to be aware of the consequences of their decisions beforehand. This study is mainly focused on two policies targeting fuel price and access to rail. A nation-wide freight mode choice model is developed for Iran, based on which, shippers' tendency to choose rail or truck is analyzed, given shipping cost, commodity weight, commodity type, and rail accessibility. Total fuel consumption and air pollution costs are compared in 30 scenarios. We found that total transportation costs will be reduced by more than 20 percent as a result of modal shift from truck to rail, if the government reallocates the gasoline subsidy to construction of prioritized railroads.

Review History:
Received: 13 August 2016
Revised: 5 February 2017
Accepted: 9 March 2017
Available Online: 8 March 2017

Keywords:
Freight Transportation
Mode Choice Policy
Energy Subsidy
Air Pollution

1- Introduction

In the year 2010, 89 percent of ton-kilometer transported freight in Iran was moved by truck, while its associated externalities are almost 10 times the rails' [1]. High level of external costs of truck movements, in terms of fuel consumption and air pollution, requires appropriate actions to shift from truck to more environmentally-safe alternatives such as rail. Therefore, providing satisfactory tools to analyze the competition between truck and rail is becoming critical to improve the efficiency of freight transportation system. This research is an attempt to measure the effect of reduction of subsidy on fuel, rail network expansion and allowing rail discount on mode choice decisions in a layout of 30 diverse scenarios.

Early mode choice models were primarily based on the shipping cost and time [2], while other influential variables such as flexibility, reliability and safety entered the behavioral models in the past decades [3-5]. Presence of meaningful trade-offs between shipping cost and benefits of reducing transit time, improving on-time arrival reliability and mitigating the risk of long arrival delays was reported by Brooks et al [6]. In a recent study, Hwang [7] developed a binomial logit market share model for mode choice decisions in which the effects of several variables including crude oil price, commodity value, and average shipment distance for rail and truck were evaluated. It was one of the recent efforts to account for environmental impacts such as CO_2, CH_4, and N_2O emissions in freight modal decisions. Environmental externalities of transportation systems have been heavily focused in the past decades. McKinnon [8] for instance, found that freight transport is the largest contributor to the carbon dioxide produced in the U.K., with a share of 6 percent. However, in Iran, trucking sector produced about 9 percent of the total carbon dioxide emissions in 2010 [9].

Tremendous effort inclines to shift freight traffic from road to rail to control energy use, air pollution, and traffic safety. Therefore, many freight mode choice studies have looked into policy sensitive variables that may be used to influence modal decisions. Samimi et al. [5] argued that rail shippers are more sensitive to costs, while truck users are more concerned about haul time, in the US. They also found that increasing fuel price is less likely to shift shippers from truck to rail [5]. Later, Hwang analyzed the effect of crude oil price on modal decisions. He found that sevenfold increase in fuel price causes approximately 40 percent reduction in truck share and, thereby 50 percent decrease in CO_2 emissions [7]. This study aims to illustrate applications of willingness-to-pay (WTP) models in assessing modal shifts in response to carbon pricing. It presents a nation-wide mode choice model in Iran, to measure shippers' tendency to use rail for different levels of rail accessibility and fuel price. A discussion is then conducted on cost and benefit analysis of allocating gasoline subsidy to improve rail network access.

2- Methodology

Data source used in the study was acquired from Iran's Railway Organization and Iran's Road Maintenance and

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Transportation Organization, with more than 155 thousand rail and 8.7 million truck shipment records. For each record, origin, destination, commodity type, shipping cost and travel mode are reported. Further, value and weight of shipments to/from 378 geographical zones categorized by 23 types of commodity according to the Standard Classification of Transported Goods (SCTG) are available. Shipping time and distance was estimated in both road and road/rail networks, given the origin and destination zones of each record. For intermodal shipments, the estimated travel time and distance include truck access to the nearest rail station, in addition to the rail haul time and distance. Level of industrial development of each region was correspondingly measured by the number of employees in the industry sectors, obtained from Iran's Ministry of Industry, Mine and Trade for the year 2011.

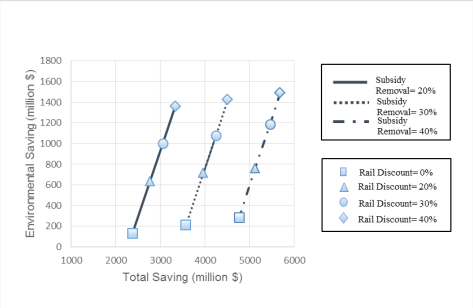
The mode choice model is derived for truck and rail/truck modes; where the intermodal mode includes a road section intended for reaching the nearest railway station adding up to the rail section. Therefore, the model was narrowed down to four groups of goods –i.e. mineral, petroleum, construction and raw metal goods- which account for 56 percent of the ton-kilometers of road transactions underwent analysis. Due to estimation results, transportation costs, interaction of the weight by distance, and access to railway can explain how the freight forwarders choose to transport their goods. The cost coefficient of mineral commodities has high elasticity and substantially influences the choice. This goes along with mineral commodities, being likely to be transported in large masses, and for which rail is more economical than road. The concurrent effect of weight and distance on the mode choice is why shipment weight by distance was preferred. For instance, large shipments are more likely to be delivered via rail in long hauls. Such decisions might be result of the fixed primary cost in the rail sector, and it being time-consuming [5, 10]. The negative elasticity value of this variable indicates as the ton-kilometer of the freight increases, the probability of opting road transportation decrease. However, if weight or distance is exclusively increased, this probability may not change. Considering the high elasticity of this variable in mineral and petroleum commodities, it has a substantial role in choosing the mode of transportation.

To observe the effect of railway accessibility on the mode choice, travel time between origin/destination and the nearest railway station were measured. In a way that, an increase in rail accessibility leads this variable to decrease. Regarding the negative value of this variable, railway accessibility can reduce the probability of selecting truck. However, the relatively lower elasticity of it, is indicative of its generally lower effect, in comparison with the former variables. Also increasing accessibility in origin has a greater effect than in destination, for mineral and petroleum commodities. The effect of number of employees working in the industry sector in the origin and destination was not significant on mode choice and was thus eliminated from the model.

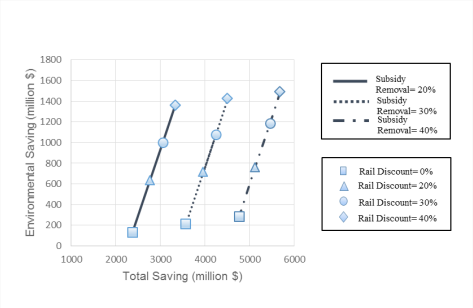
3- Policy Analysis

The scenarios proposed in this section are a product of gradual reduction of oil subsidy, allowing discounts on rail costs, and increasing the accessibility to rail. Impact of these scenarios on shifting freight to intermodal mode were analyzed based on the mode choice model developed in the previous section. Elimination of subsidies and allowing discounts will be reflected in the cost variable of the mode choice model; and increase in accessibility, will affect both accessibility and cost variables. In order to drive a cost benefit analysis for scenarios, each unit of transportation service used (ton-km of freight), would be assigned a price, reflecting its external costs imposed on society of the service. Rating these costs, a number of assumptions were made due to the Iran's macroeconomic statistics [9].

It is observed that the greater proportions of the benefit are linked with raw metal and mineral goods. Analysis showed that allowing rail discounts has a greater impact on the vehicle choice mode of raw metal and mineral goods, by contrast, reduction of subsidies has had the greatest impact on raw metal and construction goods. The average share of raw material, mineral, construction and petroleum goods in the profit gained by removing the subsidies are %24, %25, %38, and %13, respectively. Moreover the detailed cost-benefit analysis of all the scenarios, including subsidy removal and rail discount of up to 40 percent with a 10 percent interval, beside two status of rail accessibilities are presented in Figure 1.



a) Current status of rail accessibility



b) Increased rail accessibility

Figure 1. Analysis of scenarios of rail discount and gasoline subsidy reduction

4- Conclusion

A great proportion of good transactions in Iran is based on truck mode, despite the fact that fuel consumption and air pollution is considerably lower in the rail sector. Policy sensitive scenarios to shift modal decisions were therefore, analyzed, and their potential profit for the system were evaluated. A mode choice model was applied to investigate the policies of gasoline subsidy reduction, allowing discounts on the rail transportation costs, and increasing accessibility to the railway network. Accordingly, allowing discounts had the greatest impact on changing the transportation mode, and removing the subsidies led to substantial profit. Air pollution

response of these scenarios were studied, results suggest that in the compound scenarios, the profit from reducing air pollution starts from half the income of road commodity movement and arrives up to 1.5 of this income.

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Please cite this article using:

A. Samimi, E. Rahimi, H. R. Amini, A Disaggregate Analysis of Rail-Truck Mode Choice Behaviors for Freight Shipments in Iran and their Environment effects, *Amirkabir J. Civil Eng.*, 50(3) (2018) 519-528.

DOI: 10.22060/ceej.2017.11880.5092