COMPARISON OF ENVIRONMENTAL EXTERNAL COSTS OF RAIL TRANSPORT AND ROAD TRANSPORT (SAMPLE STUDY OF TEHRAN – QOM ROUTE)

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Abstract-External environmental costs of land transportation are costs imposed on the environment by the users of railroad and road transportation and yet are not compensated by those who impose them. The main goal of this research is quantitative evaluation of external environmental costs in railroad and road transportation sections and to compare the two. This is a field and library research which has calculated the external environmental costs including global warming costs and air pollutions costs based on the statistics of the railroad and vehicle traffic of the Tehran – Qom route for the year 1391 (March 20, 2012 to March 20, 2013). For this aim, in order to calculate the external environmental costs in the subject route, first the present transportation conditions of the route in the railroad and road sections were identified, and after identifying the impacts of the land transportation projects, the usable data for calculating the previously mentioned costs were extracted. Finally, by identification and use of the mathematical models used in similar research, the amount of the external environmental costs, the amount of air pollution, and the global warming for the Tehran – Qom freeway in the year 1391 (March 20, 2012 to March 20, 2013) was estimated at 1000 billion Rials. For the railroad transportation in the Tehran – Qom route, this amount was estimated at 20 billion Rials. The comparison between these costs in the two railroad and road section in the subject route revealed that with regard to the passenger and goods transportation capacity in the railroad transportation section, the development of the railroad transportation can impose significantly less external environment costs.

Keywords-Railroad and road transportation, External environmental costs, Air pollution, Global warming

I. INTRODUCTION

Transportation as one of the most important sections in every country's economy is one of the major consumers of natural resources, especially fossil fuels and other resources. Furthermore, this section has a significant share in negative impacts on the environment.

If air pollution is not among the most dramatic issues caused by industrial civilization, without any doubt it is among one of the most sophisticated ones. Even though usually its negative effects on humans are mainly focused on, however, this definition does not confine the pollution exclusively to these effects. Undesired substances can impact humans, plants, objects, materials, or the global environment, or it can create unsuitable effects by making the air hazy and foul smelling. Another undesirable effect of the air pollution is the global warming phenomenon which has led to undesirable atmospheric and climatic changes on the global scale which is the consequence of irresponsible use of what God has bestowed and the natural resources in the transportation section.

The International Energy Agency has forecasted that by 2050 the carbon dioxide emission in the transportation section will have a 120% growth, the number of vehicles worldwide will increase three folds compares with the year 2000, and more that 90 percent of the growth will take place in countries which are not OECD members. In Iran, the transportation section has the largest share of pollutants emission among the country's energy consumer sections (State Energy Balance Sheet, 1389 [March 20, 2010 to March 20, 2011]).

In order to cut the emission caused by transportation section, one of the most important and one the most effective solutions is to internalize the external costs of this section so that by comparing the costs in various methods of transportation the best economic and environmental option can be chosen for the future development of this section. Now, with regard to the issues put forward, the question of "can the development of railroads as a method of land transportation reduce the negative environmental effects of the country's transportation section by considering the issues of external expenses?" can be reviewed.

In the field of calculating the external costs of the land and rail transportation projects, much research has been carried out all around the world; among them, in a study titled *The Effects of Road Transportation in Mexico, Evaluation, and International Comparison*, the minimum amount of 59.42 billion US Dollars has been estimated to be to be the annual road transportation cost for Mexico (Cravioto, 2013).

In 2013, a study on internalization of the external costs of transportation with emphasis on its negative effects on the climate change phenomenon as a result of warming of the climate was carried out by Antonio Musso and Warner Rothengatter.

In that research, they suggest solutions for minimizing these costs. In this method, reasonable prices are suggested for evaluating the external costs (Rothengatter, Musso, 2013)

In 2012 in a paper with the subject of external costs of generating electricity from coal in Ahmadabad Power Plant in India, the electricity generation cycle,

its external costs, the damages inflicted on human's health, construction material, and agricultural products are examined based on life cycle analysis. This study shows that the air pollutions caused by generating electricity from coal and its costs cannot be neglected from the economic aspect (Mahapatra, 2013).

In 2012 a research under titled Evaluating the Social and Environmental Costs of Transportation of Goods, estimated the costs of crowdedness, waste of time, accidents, and also the noise pollution was evaluated for the city of Barcelona (Barcelo, 2013).

In Iran also there has been research on external environmental costs of transportation among which a research carried out in 1391 (March 20, 2012 – March 20, 2013) titled Evolution of the Global Warming External Costs Caused by Utilization of The Country's Freeways. In this research, the annual global warming external costs was estimated at 360 billion Rials of which 30 percent belonged to lorries and 25 percent belonged to passenger vehicles and vans (kazemi,2011).

Another research in 1389 (March 20, 2010 – March 20, 2011) titled Estimation of the Environmental External Costs of Land Transportation in Tehran – Qom Route was carried out with the aim of estimating the environmental costs of transportation in the subject section which calculated the environmental external costs of the road transportation. The results of that study revealed that among various types of vehicles, lorries with 3 axles were responsible for most of the environmental external costs in a single kilometer, In this research, the final external cost of Tehran – Qom freeway was estimated at 82 billion Tumans (kazemi,2011).

In the present research, the general goals is to make a comparison by estimating the environmental external costs of the land transportation in the two railroad and road section including the air pollution and global warming in Tehran – Qom route, with the assumption that the rail transportation section will impose less environmental external costs on the society. In this regard, estimating the annual fuel consumption and pollutant gases including SOx, NOx, CO, SPM, and NMVOC, in the subject section in railroad and road sections will be attempted.

Materials and Method:

In this research the main goal is to study the external costs of railroad and road transportation and comparing them for the Tehran – Qom. Therefore, initially, the identification of the external costs of the land transportation is attempted, and then with respect to the available data and collecting data from the authorized sources, the calculable external cost have been estimated using the existing relations and models.

Stages of research in this study are provided as below:

1- Identification of the current transportation condition in the subject rout in railroad and road

In this research, in order to execute the suggested models the Tehran- Qom and also Tehran – Qom have been evaluated as case study. The reason for selecting this route has been the availability of data on both the railroad and road; on the other hand, the possibility of comparing the environmental external costs in both railroad and road routes. These two connecting routes begin and end between Tehran and Qom and have been selected as case study. The Tehran – Qom freeway is one of the most traveled connecting routes in the country which connects the capital to the south and the south west of the country and after Tehran – Karaj freeway is the most travel interstate roads in Iran. With length of 138 kilometers, this freeway begins from south of Tehran and ends in the Qom City.

The Tehran – Qom railway has a special significance because it connects the north of Iran to its center, south, southwest, and southeast. The length of this railway is 144 kilometers.

The statistics on the road vehicle passage count has been obtained from the data available at the Organization for Maintaining Roads and Road Transportation. This statistic is published annually and daily by the Organization for Maintaining Roads and Road Transportation. Also, in the railway section, the average daily train passage in the Tehran – Qom route has been obtained from the Statistics and Information Technology Bureau of the Islamic Republic of Iran's Railway.

In the road section, based on the classification of the Organization for Maintaining Roads and Road Transportation, vehicles are divided in 5 categories of vans and passenger cars, minibus and light trucks with two axles, lorries with two or three axles, buses, and lorries with more than three axles. In the railway section, based on the statistics by the Iranian Railway, GM diesel locomotives are mainly used to haul the trains which use the subject route.

2- Identifying the effects of the external costs of the railroad and road transportation projects

The external costs of transportation extend to many areas and cover all sections of the society including the physical space, biological space and the economic-social-cultural area. The effects of these costs on different areas vary based on the nature and the severity of the effects. Based on the results of the precious studies and the effects of the land transportation, the total costs caused by the land transportation is divided into 20 major categories (kazemi,2011). In this research has been carried out with regard to the existing data on external environmental costs related to pollution of air and global warming. The most important pollutants of air include floating particles, nitrogen oxides, sulfur dioxide, ozone, volatile organic compounds, and carbon monoxide which based on the available data

in this research carbon monoxide nitrogen oxides, volatile organic compounds, and sulfur oxides are studied in case of emission, and carbon dioxide in case of global warming.

3- Identifying the usable data in calculating the external costs in railroad and road transportation

Based on the available data, in this research the index for emission and the costs of air pollution due to carbon dioxide which has been releases and its impact of the global warming phenomenon and emission of poisonous gases including SOx, NOxs, CO, SPM, and NMVOC have been studies.

It is to mention that some of the indexes of the transportation function include: the bulk of traffic, number of trips, and the type and the amount of fuel consumed by vehicles which have been taken into consideration. Based on the level of the aimed target, in different studies, in a regional, national, or global scale there are different prices for each ton of each pollutant released into the environment. The amounts required for estimating the cost of each ton of various pollutants emitted can be taken from other countries, the method is to use moderating indexes of equal purchasing power for Iran. In this reseat the concept of moderating indexes of equal purchasing power has been used. In this method, the moderating index is used based on the equality of purchasing power similar to relation (2) (Bickel et al., 2003).

Relation (1)

4-The calculation model for external environmental costs of land transportation related to air pollution and global warming

In order to identify the suitable model for external environmental costs of land transportation, with regard to the study of the calculation models for external expenses in different countries, the suitable models for calculating these costs for Iran were used.

The model for calculating the external cost of air pollution

The following pollutants are the most significant ones among all the various types of pollutants and usually air pollution is caused by these. Therefore, in calculating the external costs of air pollution CO, NOx, NMVO, SPM, and Sox are taken into consideration:

The model determined for calculating the costs of air pollution in the road section is as follows.

(Kazemi, 1389 [March 20, 2010 – March 20, 2011])

Relation (2)

$$C\,\mathrm{AP}_{RO}=\sum\sum(EF\mathrm{dir}(f)\times DF\mathrm{dir}+FC(f)\times DF\mathrm{FP}(f))$$

- ✓ C_{AP}^{RO}: Air pollution cost
- ✓ DF_{dir}: Damage caused by pollutant emission factor
- ✓ DF_{FP}: Damage caused by fuel production factor
- ✓ EF_{dir}: Direct pollutants emission factor
- ✓ FC: The vehicle's fuel consumption factor
- ✓ F: Type of fuel

Based on Relation (2), the model used for calculating the air pollution cost in the rail section is based on the air pollution cost model and as follows. (Kazemi, 1389 [March 20, 2010 – March 20, 2011])

$$C\,\mathrm{APR}_{I}=\sum(EF\mathrm{dir}(f)\times DF\mathrm{dir}+FC(f)\times DF\mathrm{FP}(f))$$

- ✓ C_{APRI}: Rail section air pollution cost
- ✓ DF_{dir}: Damage caused by pollutant emission factor
- ✓ DF_{FP}: Damage caused by fuel production factor
- ✓ EF_{dir}: Pollutant direct emission factor
- ✓ FC: The vehicle's fuel consumption factor
- ✓ F: Type of fuel

Based on the mentioned models, the main parameters play major roles in calculating these costs which in this study their quantities are calculated for the subject route in the road and railroad section:

A) Price of each tone of emitted pollutant

B) Amount of emission by each group of vehicles

D) The amount of pollutant emitted as the result of fuel production processes.

The model for calculating the external cost of global warming

The general approach for quantification of the external costs cause by global warming has the following steps:

1. Estimating the distance traveled (in kilometers) by different vehicles in the area, region, or across the country.
2. Multiplying the distance traveled by the vehicle by the emission factors (on gram(s)/kilometer) for different greenhouse gases.
3. Adding the different greenhouse gases emission to the total carbon dioxide emitted, the result will be the total emitted greenhouse gases which are causing the global warming.
4. Multiplying the total emitted carbon dioxide by the cost factor on the currency unit/ton basis; this estimate is used to evaluate the total external cost of global warming.

The most import cost factor in the final global warming cost of land transportation is the fuel consumption and the amount of carbon in the fuel. Therefore, in some studies the global warming cost is calculated on currency unit/ liter(s) of the fuel consumed basis. In this study, calculating the external

cost caused by global warming is carried out using the Relation (4) (Kazemi, 1389 [March 20, 2010 – March 20, 2011]).
Relation (4)

$$C_{GW}=\sum(EF_{dir}(m,v,g,l)\times DF_{dir}(m,g)+FC(m,v,f,l)\times DF_{FP}(m,f))$$

C_{GW}: The global warming cost of greenhouse gases emission EF_{dir}: Emission factor- direct emission
DF_{dir}: Damage factor- direct emission FC: Fuel consumption factor DF_{FP}: Damage factor – fuel production
m: method of transportation v: vehicle technology g: Greenhouse gas l:locations f: Type of fuel
In this method, generally, in order to calculate the external cost of the warming of the climate of each group of vehicles and their average carbon dioxide emission are multiplied by the average price for each ton. Therefore, the relation for calculating the final cost of climate warming depends on three main parameters each of which are influences by numerous other factors.
A) Price of each ton of the emitted carbon dioxide B) The amount of carbon dioxide emitted by each group of vehicles C) The amount carbon dioxide emitted as the result of fuel production process for vehicle use

RESULTS

The results of the identification of the current railroad and road transportation conditions in the Tehran- Qom route

The statistical population includes all the travels which have taken place in 1391 (March 20, 2012 – March 20, 2013) in the road section for Tehran- Qom freeway and in the Tehran- Qom railway. Table (1) shows the average daily traffic for Tehran- Qom freeway in 1391 (March 20, 2012 – March 20, 2013).

Table (1) average daily traffic for Tehran- Qom freeway in 1391 (March 20, 2012 – March 20, 2013)

Tehran- Qom Freeway (138 km)	Amount of passenger car and van traffic	Amount of light 2 axle truck and minibus traffic	Amount of 2 and 3 axle lorry traffic	Amount of bus traffic	Amount of 3 or more axles lorries traffic
The average traffic bulk	50305	474	248	2412	80

(State organization for maintenance of roads and transportation, 1391 (March 20, 2012 – March 20, 2013))

Based on the data acquired from the bureau of statistics and information technology of the Islamic Republic of Iran's Railway, one average 40 trains travel the Tehran- Qom railway each day which are mostly passenger trains. Based on the average of total train passages in the subject route in 1391 (March 20, 2012 – March 20, 2013) m the statistics results are as mentioned in Table (2).

Table (2) average railway traffic in Tehran- Qom railway In 1391 (March 20, 2012 – March 20, 2013)

Tehran- Qom Railway (144km)	Number of passenger trains	Number of freight trains
Average daily traffic in 1391 (March 20, 2012 – March 20, 2013)	37	3

(The bureau of statistics and information technology of the Islamic Republic of Iran's Railway)

Estimation of the external global warming costs of railroad and road transportation

In utilization of the models, three main parameters including the price of each ton of the carbon dioxide emitted, carbon dioxide emitted by each group of vehicles, and the amount of carbon dioxide emitted as the result of the fuel production processes have been taken into account. With regard to the fact that Iran's purchasing power has been a quarter of the European countries during past years, amount of 5 euros was acquired for each ton of carbon dioxide emitted in Iran. The average exchange rate for euro based on the government's rate as declared by the Iranian central bank in the year 1391 (March 20, 2012 – March 20, 2013)
Is 16000 Rials that based on the transaction rate which is double the government's rate equals approximately 32000 Rials which in this study under the assumption that the statistics and number given by the central bank and are authentic, the government's rate has been the basis for calculations.

Estimation of the external cost caused by global warming in the subject route

In table (3) the total external costs including the external cost caused by global warming and the air pollution based on kilometer [/] vehicle are shown.

Table (3) total external cost of the subject route based on kilometer/vehicle in Tumans [Each Tuman is 10 Rials]

External costs	Different types of vehicles					
	Passenger cars and vans	light 2 axle trucks and minibuses	Buses	2 and 3 axle lorries	3 or more axles lorries	GM diesel locomotive
Global Warming	2.3	8.35	12.17	11.7	12.41	107.46
Air pollution	31.7	58.45	87.36	83.75	89.28	773.1
Total	34	66.8	99.53	95.45	101.69	880.56

Estimate of the total external environmental cost of Tehran- Qom Freeway in 1391 (March 20, 2012 – March 20, 2013)

In order to estimate the total external costs of Tehran- Qom freeway in 1391 (March 20, 2012 – March 20, 2013), first the total external cost of the Tehran- Qom Freeway per kilometer is to be calculated. In Table (4) the calculated amounts for the external environmental costs of the Tehran- Qom Freeway are shown. The values in this table are acquired from the external environmental cost of one kilometer/vehicle

multiplied in the total vehicle each day at the Tehran-Qom Freeway.

Table (4) Total daily external costs of one kilometer/vehicle in the Tehran- Qom Freeway- In Tumans

		Different types of vehicles					
Tehran-Qom Freeway	External costs	Passenger cars and vans	light 2 axle trucks and minibuses	Buses	2 and 3 axle lorries	3 or more axles lorries	Total
	Global warming	115701	3958	29354	2901	993	152907
	Air pollution	1594668	27705	210712	20770	7142	1860997
Total		1710369	31663	240066	23971	8135	

By multiplying the values of table (4) by the length of the freeway (138 km) and the number of days in one year (365 days), the total external environmental costs of the Tehran- Qom Freeway in 1391 (March 20, 2012 – March 20, 2013) has been calculated and the results are shown in Table (5).

Table (5) total external environmental costs of the Tehran-Qom Freeway in 1391 (March 20, 2012 – March 20, 2013) in billion Tumans

		Different types of vehicles					
Tehran-Qom Freeway	External costs	Passenger cars and vans	light 2 axle trucks and minibuses	Buses	2 and 3 axle lorries	3 or more axles lorries	Total
	Global warming	5.827	0.199	1.478	0.146	0.05	7.7
	Air pollution	80.323	1.395	10.613	1.046	0.359	93.736
Total		86.15	1.594	12.091	1.192	0.409	101.436

Estimate of the total external environmental cost of Tehran- Qom railway in 1391 (March 20, 2012 – March 20, 2013)

In order to estimate the total external costs of Tehran-Qom railway in 1391 (March 20, 2012 – March 20, 2013), first the total external cost of the Tehran- Qom railway per kilometer is to be calculated. In Table (6) the calculated amounts for the external environmental costs of the Tehran- Qom railway are shown.

Table (6) Total daily external costs of one kilometer/vehicle in the Tehran- Qom Railway- In Tumans

		Different types of vehicles		
Tehran- Qom Railway	External costs	GM diesel locomotive		
		Passenger train	Freight train	Total
	Global warming	3976	322	4298
	Air pollution	28604	2319	30923
Total		32580	2641	

By multiplying the values of table (6) by the length of the railway (144 km) and the number of days in one year (365 days), the total external environmental costs of the Tehran- Qom Railway in 1391 (March 20, 2012 – March 20, 2013) has been calculated and the results are shown in Table (7).

Table (7) total external environmental costs of the Tehran-Qom Railway in 1391 (March 20, 2012 – March 20, 2013) in billion Tumans

		Different types of vehicles		
Tehran- Qom Railway	External costs	GM diesel locomotive		
		Passenger train	Freight train	Total
	Global warming	0.208	0.017	0.225
	Air pollution	1.503	0.121	1.624
Total		1.711	0.138	1.849

Finally, based on tables (5) and (7), the external environmental costs for the Tehran- Qom Freeway is estimated at 101.436 billion Tumans and the same cost for Tehran- Qom Railway is estimated at 1.849 billion Tumans. According to the transaction rates, these numbers are to be doubled.

CONCLUSIONS

The results acquired from this study reveal the importance of paying attention to the internalization of the external environmental costs in the land transportation section. In this research, by using the models used in research projects carried out in European countries, showed that the external environmental costs include the external cost of air pollution and the global warming in the subject route, every year impose heavy cost on the country's environment and the global warming issue which demands especial attention to the more environment friendly transportation and moving towards newer and more efficient solutions in the country.

Based on the acquired data, two main factors of traveled distance from point A to point B and the amount of vehicle traffic in the railroad and road sections have significant impact on the final external environmental costs. In order to have a comprehensive comparison between the external environmental costs in the two railroad and road section, due to the differences in both the length and the amount of traffic in the two section, the measurable capacities of the two sections can be used. In the calculations which have been carried out, the amount of external environmental costs is calculated per vehicle in one kilometer; therefore, it serves to have a reviewable comparison between the two sections based on the capacity of each vehicle for transportation of passengers and goods.

In the research that have been carried out, it was determined that the amount fuel consumed by the GM diesel locomotives which are used in the subject route is more than all other vehicles that travel that route. Therefore, compared to other vehicles, the external environmental costs imposed by this vehicle are shown to be more. However, the crucial and the notable point is that the capacity for transporting passengers and goods per each train that travels this rout is far superior to every other type of vehicle in the road section.

For instance, in the road section, the maximum number of passengers which can be transported by one vehicle is 40 people which belong to the bus. Based on the results of this study, the total average external environmental costs of the subject route on vehicle/kilometer is 99.5 Tumans for buses. If we divide this amount by the maximum passenger transportation capacity of the bus, the external environmental costs per passenger will be equal to 2.48. This is while in the railway section, on average, each train can transport 600 passengers, if we are to calculate the total amount of external cost calculated for this vehicle based on kilometer/vehicle which is 880.5 divided by the number transported passenger by each train, we will arrive at the number 1.46. This comparison becomes more distinguishable for the amount of goods transported by each vehicle in railroad and road section.

For example, that maximum load carried by a 3 or more axle lorry in the subject route in 25 tons, while each freight trains on average can transport 500 tons. Based on the results acquired from the study, each 3 or more axle lorry which has the highest environmental pollution cost, the average external environmental cost of which based on kilometer/vehicle is 101.69, while if we divide this number by the amount of load transported by each lorry, we will arrive at 4.06. Now, if we divide the total external environmental cost of the GM diesel locomotive which is 880.5 by the average amount of load transported in a kilometers which is 500 tons, we will arrive at 1.76. The result of this comparison shows that both in passenger transportation and cargo, the railway transportation imposes less external environmental costs on the environment per capita.

The general results from this research in form of answers to the proposed questions are as follows:

1- The fuel consumption of different vehicle in the railway section are respectively 4.5 liters of diesel fuel for GM diesel locomotive for traveling each kilometers, and in road section 0.52 liters of diesel fuel for three or more axle lorry, 0.51 liters of diesel fuel for bus, 0.49 liters of diesel fuel for two or three axle lorry, 0.35 liters of diesel fuel for minibus and two axle light truck, and 0.12 liters of gasoline for vans and passenger vehicles.

2- The average carbon dioxide emitted by each vehicle in each kilometer in grams is estimated to be respectively 1163 grams for GM diesel locomotive in railroad section, and 1344.3 for three or more axle lorry, 1318.4 for bus, 1266.7 for two or three axle lorry, 904.8 for minibus and two axle light truck, and 231.4 for vans and passenger vehicles.

3- Among the different types of vehicles in the road transportation section, three or more axle lorry imposes the highest external environmental costs in one kilometer/ vehicle.

4- Among the calculated external costs, the air pollution cost had the higest percentage of external environmental costs.

5- Compared with the Tehran- Qom Railway, the total annual external costs of is greater in Tehran- Qom freeway.

6- Among the various types of vehicles in the railroad and road section, the diesel locomotive used in this route had the highest fuel consumption.

7- Among the various types of vehicles in the railroad and road section, the GM diesel locomotive had the highest external environmental cost in one kilometer/vehicle.

8- The external environmental cost per capita of the road transportation is higher in both cargo transportation and passenger section.

A glance at the astronomical numbers given for the annual external environmental costs of the Tehran-Qom route reveals the importance of the external costs in the country and in the road transportation section. These numbers may seem unreal to many who are involved in the transportation section, however, the reality of the acquired results tells that the transportation section of the country is in desperate need of a more stable growth which is kinder to the environment and the economy of the country.

Increased use of the railroad transportation in different aspects compared to road transportation can be considered. On this basis, there can be a brief comparison between the statistics of road accidents and accidents in the railroad in the subject route, which based on the supplementary studies of this research, is bear zero. However, these statistics are not included in the results of this study, yet, these expenses can be taken into consideration in future studies. These statistics are significantly higher in the road section. With the increase of the railroad's share in transportation through development of connoting line and increase in the number locomotive, a positive role can be played in mitigating the destructive activities in the economic growth. Also, the living standards of the people can be positively increased by stable growth in the transportation section.

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