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A Dynamic Model for Evaluating the Utility of Railway Transit Corridors: a Case Study of Bandar Abbas- Sarakhs Corridor

Hamid Reza Ahadi[1*], Golshan Torabian[2]

[1,2]School of Railway Engineering, Iran University of Science and Technology

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A B S T R A C T

Currently, road transportation is the main mode of freight transit in Iran. About 90% of freight transit is through this mode of transportation. This is not in line with the transportation policies. Based on such policies 70**%** of the freight transit need to be through road transportation and 30**%** of the freight transit need to go through rail transportation. However, Iran's railway network is very wide and the share of railway in freight transit can be increased. Therefore, it is important to recognize the effective factors that can increase the share of rail transit. The purpose of this research is to recognize the factors that can improve the utility of railway transit corridors and to advance the competitive position of railway in freight transit. The concepts of utility and transit are described. The factors affecting the utility of railway transit corridors from the perspective of the owner of goods are determined by making a literature review and investigating the opinions of experts. These factors include transportation cost, commercial speed, reliability, safety, the system of tracing wagons and service frequency. A utility function for Bandar Abbas- Sarakhs corridor is developed that is based on the aforementioned factors. A dynamic model to evaluate the utility of the corridor is developed. After verifying the model, it is used for simulation of 20 years of service by using PLE software. The results of the simulation show that with simultaneous improvement in reliability, the system of tracing wagons at commercial speed also offering discount on the cost of transportation according to the demand of the owner of goods can play a significant role in increasing the utility of Bandar Abbas- Sarakhs corridor. Changing only one factor will not result in major changes in the utility of the corridor.

1. Introduction

Utility theory was first considered by Jeremy Bentham, an English philosopher [1]. Utility theory assumes that a decision maker can choose an option among the existing options which brings him the most utility or satisfaction. Utility function is used to make the preferences of decision makers into quantitative values in order to choose the best option with the maximum utility [2].

Transit means moving goods or passengers through a country which is neither their origin, nor destination. It is one of the most important revenue sources in many countries in the world. A transit corridor is a route used for transportation.

Freight transit plays a critical role in the creation of jobs, the creation of foreign exchange earnings, technology growth in transportation industry as well as the political security increase due to economic and commercial relationships with foreign countries.

*Corresponding author
Email address: ahadi@iust.ac.ir

Recently in Iran, a large amount of freight transit goes through road transportation, and the share of railway in freight transit is very low. It is different from the share of freight transit in most developed countries. This is not in line with the transportation policies of the country. Such policies state that 30% of freight transit need to go through railway. However, Iran's railway network is very wide. The share of railway in freight transit can be increased. Therefore, it is important to recognize and improve the factors that are vital for increasing the utility of railway transit corridors from the perspective of the owners of goods.

2. Literature Review

Regarding the factors affecting the utility of transit corridors, Banomyong has investigated four different routes in Vientiane-Singapore corridor by using a cost model of multimodal transportation. These routes include "road-sea" via Danang (Vietnam), "all-road" via Bangkok (Thailand), "road-sea" via Bangkok port and "road-rail-road" via Lad Krabang (Thailand). The results show that the third route ("road-sea" via Bangkok port), which has the lowest transportation cost, is the best route [3].

Kreutzberger et al. reviewed the studies related to evaluating the external factors (air pollution, noise, accidents, etc.) of road and intermodal (road-rail) transportation. The results show that intermodal transportation is preferable to road transportation according to the external factors [4].

Patterson et al. compared road transportation and intermodal transportation in the Quebec City-Windsor corridor. They used a stated preference method and then a logit model to compare the two mentioned modes of transportation. The most important factors considered in this evaluation are cost, reliability and safety [5].

A fuzzy analytic network process (FANP) was applied by Tuzkaya and Onut in order to select the best mode of transportation between Turkey and Germany. The most important criteria for choosing a mode of transportation are flexibility, reliability, cost, safety, product characteristics and commercial speed [6].

Yang et al. analyzed intermodal transportation from China to Indian Ocean by using goal programming approach. The most important factors in choosing the best route of transportation from China to Indian Ocean are transportation cost, transportation time and reliability [7].

Janic and Vleugel developed a method to estimate the reduction in externalities gained by substituting road with rail transportation in Trans-European corridors. The externalities include energy consumption, greenhouse gas emissions, noise, congestion and accidents. The results show that substituting road with rail transportation reduces energy consumption, greenhouse gas emissions and congestion, but it has no effect on noise and accidents [8].

Wang et al. recognized the factors effective in selecting the best mode of transportation among road and rail transportation modes in Maryland by collecting the revealed preference data. These factors include distance, fuel cost and product characteristics [9].

Wanders obtained the important factors for choosing the mode of transportation in Rotterdam-Venlo corridor and he has determined the share of each mode through a logit model. Transportation cost, reliability, travel time and CO_2 emissions are the most important factors in transportation mode choice [10].

Kim developed a mode choice model according to the transportation cost, transit time, reliability, safety and service frequency. New Zealand freight transportation department was selected as a case study. The results show that rail and sea transportation are less preferred than road transportation because of their low reliability and service frequency and long transit time [11].

In order to decrease the cost of transportation, CO_2 emissions and lead time and increase safety in multimodal transportation, Kengpol et al. presented an approach to choose the best route of transportation. A multimodal transportation service from Bangkok in Thailand to Da Nang port in Vietnam was chosen as the case study [12].

Sun and Lang have developed a bi-objective mixed integer linear programming model to find the best route in multimodal transportation in China. The objective functions of the problem were minimizing the total transit time and also the transportation cost [13].

Ghaderi et al. investigated the impact of reducing the transit time of trains on their reliability in the non-bulk rail network in Australia. The results show that reducing the transit time has a remarkable effect on improving the reliability [14].

Arencibia et al. obtained the most important attributes for selecting the best mode of transportation in the corridor linking Madrid with the Netherlands/Belgium/Northern France/West Germany. These attributes are reliability, transportation cost, transportation time and service frequency [15].

Liu used a multiple criteria decision-making technique named best-worst method in order to prioritize the important factors in choosing the mode of freight transportation in USA and Europe. The results show that the most important factors are transportation cost, transit time, reliability, flexibility, service frequency and CO_2 emissions. In order to increase the share of rail transportation, its cost should be decreased. Also reliability in rail transit should be improved [16].

Wang and Yeo applied integrated Fuzzy Delphi and Fuzzy ELECTRE methods to choose the best route of transportation from Korea to Central Asia. The most important factors to consider when choosing the best route are cost, reliability, transit time and safety. The results show that the route Incheon- Qingdao- Horgos-Almaty is preferred [17].

Floden et al. investigated the previous studies in order to recognize the effective factors in selecting the best mode of transportation. The results show that the vital factors for selecting the best mode of transportation are cost, time and reliability [18].

Woodburn investigated the effect of increasing the share of rail transportation on the environment in Britain. The results of investigation show that negative externalities are decreased by increasing the share of rail transportation [19].

Larranaga et al. applied a stated preference method to determine the logistic managers' preferences in Rio Grande do Sul. Transportation modes include road, road-rail and road-waterways. The results of the research show that the most important factors for choosing the best mode of transportation are cost, time and reliability. In order to increase the share of intermodal transportation, transportation cost should be reduced, also reliability need to be improved [20].

Gohari et al. developed a model for finding the best mode and route of transportation for freight movement through intermodal transportation network in Peninsular Malaysia. The most important factors in selecting the best mode and route of transportation are cost, transit time, distance and emissions of greenhouse gases. The results show that transporting freight through railway can decrease transportation cost and emissions of greenhouse gases, while road transportation has lower transit time compared to rail and sea transportation [21].

By reviewing 50 research articles that are related to evaluating the utility of transit corridors, the factors affecting the utility of them are recognized. These factors include transportation cost, transportation time, reliability, energy consumption, greenhouse gas emissions, safety, commercial speed, service frequency, flexibility, distance, product characteristics, noise pollution, accidents and traffic.

3. The Analytical Method

3.1. The Most Important Factors Affecting the Utility of Railway Transit Corridors from the Perspective of the Owner of Goods

To determine the most important factors affecting the utility of railway transit corridors, a ten point Likert scale is used. Accordingly, a questionnaire is provided and distributed among 27 of the experts and managers of Islamic Republic of Iran Railways Company. These include Tarkib Haml-o-Naghl International Shipping Company, Railway Transportation Company and Behtash Sepahan Company. The respondents gave a score between 1 and 10 to each factor obtained from literature review based on the importance of each of them in determining utility.

The results of evaluating questionnaires show that the score of transportation cost, commercial speed, reliability, safety and service frequency are above average score (5.5). Therefore, these factors are considered as the most important factors affecting the utility of railway transit corridors. According to the opinion of the managers and experts, the system of tracing wagons is also very important for increasing the utility of a railway transit corridor. Hence, this factor is added to the effective factors in the utility of a railway transit corridor.

3.2. Prioritizing the Effective Factors in Determining the Utility of Railway Transit Corridors

In order to prioritize the effective factors in determining the utility of railway transit corridors according to the intensity of the influence of each of them on utility, AHP[1] is used. Accordingly, a questionnaire is provided and distributed among 27 of the experts and managers to make pairwise comparisons among the mentioned factors. The results show that 21 questionnaires with inconsistency ratio less than or equal to 0.1 are filled in completely and have acceptable consistency. Subsequently, these questionnaires are used to calculate the weight of each factor.

After completing pairwise comparison matrices in expertchoice software, the weight of each factor is obtained. These weights are presented in Table1.

Table 1. The weights of the effective factors in determining the utility of railway transit corridors

priority	the name of the factor	weight
1	transportation cost	0.220
2	safety	0.182
3	reliability	0.175
4	the ability of tracing wagons	0.167
5	commercial speed	0.159
6	service frequency	0.098
	inconsistency ratio = 0.01	

3.3. Bandar Abbas-Sarakhs Railway Corridor

In this research, Bandar Abbas-Sarakhs railway corridor in Iran is investigated as the case study. This corridor is specified with a red line in Figure 1. It includes routs as follows: Bandar Abbas-Gol Gohar, Gol Gohar-Sirjan, Sirjan-Bafq, Bafq-Mobarakeh, Mobarakeh-Jandaq, Jandaq-Kalezard, Kalezard-Tabas, Tabas-Torbat-e Heydarieh, Torbat-e Heydarieh-Kashmar, Kashmar-Fariman, Fariman- Motahari and Motahari- Sarakhs.

Figure 1. Bandar Abbas-Sarakhs corridor

In recent years, the tonnage of freight transit in Bandar Abbas-Sarakhs road corridor has been much more than the tonnage of freight transit in its railway corridor. The share of railway in freight transit has been about 10%. Therefore, according to the demand of the owner of goods in this route and little share of railway in freight transit, this corridor is considered as the case study to improve the factors affecting the utility of it and then to increase its share in freight transit.

3.4. Data Collection

In this section, the factors affecting the utility of railway transit corridors are defined. These factors are then calculated for Bandar Abbas-Sarakhs railway corridor for the period of 2006 to 2016. It is worth mentioning that in order to calculate utility in terms of the mentioned factors, the value of them should be normalized. In order to normalize the value of each factor, a linear normalization technique is used. In this technique, the value of each factor should be compared to a desired value that is considered as the target value for that factor.

[1] analytic hierarchy process

3.4.1. Transportation cost

Considering that the destination of transit goods in Bandar Abbas-Sarakhs corridor is some independent countries that used to be part of the former Soviet Union, to calculate transportation cost in the mentioned corridor, transportation cost per ton-km according to the tariff policy of CIS[2] is considered. In order to normalize the values of the cost, the following equation is used:

$$\mathrm{NCO}_i = \frac{\mathrm{COI}_i - \mathrm{COA}_i}{\mathrm{COI}_i} \qquad (1)$$

In which:

NCO_i = normalized cost in year i

COI_i = transportation cost per ton − km in Iran in year i

COA_i = transportation cost per ton − km in USA in year i

USA is one of the most developed countries in rail transportation and the cost of transportation per ton-km in this country is very low compared to the cost of transportation per ton-km in Iran. Therefore, in order to normalize the cost of transportation per ton-km in Bandar Abbas-Sarakhs corridor, this cost is compared to the cost of transportation per ton-km in the USA that is the desired cost.

3.4.2. Commercial speed

Commercial speed is equal to the distance of shipment divided by total transit time (time interval between freight arrival from Bandar Abbas and its exit from Sarakhs). The values of Commercial speed are obtained from Islamic Republic of Iran Railways Company.

Islamic Republic of Iran Railways Company has a commitment to deliver the consignment of customers from Bandar Abbas to Sarakhs in 52 hours (commercial speed = 31 km/h). Accordingly, this speed is considered as the desirable speed and the normalized speed is calculated by dividing commercial speed per year to this speed.

3.4.3. Service frequency

Service frequency means the number of shipments accomplished or the number of trains dispatched in a specified period of time.

Service frequency per year is obtained according to the following equation:

$$\mathrm{FR}_\mathrm{i} = \frac{\mathrm{TDR}_\mathrm{i}}{\mathrm{CAT}} \qquad (2)$$

In which:

FR_i = service frequency in year i

TDR_i = the total demand of Bandar Abbas − Sarakhs railway corridor in year i

CAT = the capacity of each train in tons

On the other hand, desirable value for service frequency is obtained according to the following equation:

$$\mathrm{DFR}_\mathrm{i} = \frac{\mathrm{CAR}_\mathrm{i}}{\mathrm{CAT}} \qquad (3)$$

In which:

DFR_i = desired service frequency in year i

CAR_i = the capacity of Bandar Abbas − Sarakhs route in year i

CAT = the capacity of each train in tons

Finally, in order to normalize this factor, service frequency is divided by desired service frequency per year.

3.4.4. Safety

Safety is a qualitative factor. In order to make it into a quantitative factor, the following equation is used:

$$\mathrm{SA}_i = \frac{\mathrm{FR}_i - \mathrm{TA}_i}{\mathrm{FR}_i} \qquad (4)$$

In which:

SA_i = the safety of the route in year i

FR_i = service frequency in year i

TA_i = the number of trains involved in accidents in year i

Since this factor is dimensionless, it doesn't need to be normalized.

3.4.5. Reliability

Reliability means the ability of the rail transit system in Bandar Abbas-Sarakhs corridor in

[2] Commonwealth of Independent States

delivering consignment on time. According to the opinion of the experts, there are two important factors that increase reliability in the mentioned corridor: 1- demand, 2- locomotive. It means that increasing demand and the number of locomotives can increase the number of scheduled trains so that reliability increases.

It is worth mentioning that in order to calculate reliability in terms of the mentioned factors, the value of them should be normalized. Therefore, the following equation is used to calculate reliability for each year:

$$RE_i = w_1 * ND_i + w_2 * NL_i \tag{5}$$

In which:

RE_i = reliability in year i

ND_i = normalized demand in year i

NL_i = the normalized number of locomotives in year i

w_1 = the weight of demand

w_2 = the weight of locomotive

In order to determine the weights of each factor, a questionnaire is provided and distributed among 25 of the experts and managers to make pairwise comparisons among the mentioned factors. According to the results of pairwise comparisons and AHP, the weight of demand is 0.55 and the weight of locomotive is 0.45.

To calculate normalized demand and the normalized number of locomotives, the following equations are used:

$$ND_i = \frac{TDR_i}{CAR_i} \tag{6}$$

In which:

ND_i = normalized demand in year i

TDR_i = the total demand of Bandar Abbas − Sarakhs railway corridor in year i

CAR_i = the capacity of Bandar Abbas − Sarakhs route in year i

$$NL_i = \frac{L_i}{DL_i} \tag{7}$$

In which:

NL_i = the normalized number of locomotives in year i

L_i = number of locomotives in the railway network in year i

DL_i = the number of desired locomotives in year i

3.4.6. The ability of tracing wagons

The ability of tracing wagons is also a qualitative factor. In order to make it into a quantitative factor, an eleven-point scale is used. A questionnaire is provided and distributed among 24 of the experts and managers. The average score of this factor per year is calculated according to the filled questionnaires. This score is considered as the value of the factor for that year. To normalize these values, each of them are divided by 10 that is the maximum score.

3.5. Utility Function for Bandar Abbas-Sarakhs Corridor

After calculating transportation cost, commercial speed, reliability, safety, the system of tracing wagons and service frequency for Bandar Abbas-Sarakhs corridor, a utility function need to be determined. A linear regression model is used to determine the utility function. To perform regression analysis, the values of the utility of each year should be calculated. The utility of Bandar Abbas-Sarakhs corridor per year is calculated in terms of the following equation:

$$U_i = \frac{TDR_i}{TD_i} \tag{8}$$

In which:

U_i = the utility of bandar − abbas sarakhas railway corridor in year i

TDR_i = the total demand of Bandar Abbas − Sarakhs railway corridor in year i

TD_i = the total demand of Bandar Abbas − Sarakhs railway and road corridor in year i

After calculating the values of utility for all years, a utility function is estimated by linear regression model and also eviews software is applied. This utility function is as follows:

$$U_i = -0.256 * NCO_i + 0.139 * RE_i + 0.158 * SA_i + 0.151 * NSP_i + 0.129 * NFR_i + 0.168 * NTR_i \quad (9)$$

In which:

U_i = the utility of bandar − abbas sarakhas railway corridor in year i

NCO_i = normalized cost in year i

RE_i = reliability in year i

SA_i = the safety of the route in year i

NSP_i = normalized commercial speed in year i

NFR_i = normalized service frequency in year i

NTR_i = the normalized score of the ability of tracing wagons in year i

By increasing transportation cost, the utility of the mentioned corridor decreases and its sign in the utility function should be negative. On the other hand, by increasing commercial speed, reliability, safety, service frequency and the ability of tracing wagons, the utility of the corridor increases and their signs in the utility function should be positive. In Equation (9), the signs of all variables in the utility function are valid.

As explained in previous sections, the weights of each factor have also been estimated by AHP. As the linear relationship between the mentioned factors and utility has been confirmed according to the regression analysis, the following approximate utility function with the weights obtained from AHP can also be considered:

$$U_i = -0.22 * NCO_i + 0.175 * RE_i + 0.182 * SA_i + 0.159 * NSP_i + 0.098 * NFR_i + 0.167 * NTR_i \quad (10)$$

3.6. Dynamic Model for Bandar Abbas-Sarakhs Corridor

In this section, a dynamic model for evaluating the utility of Bandar Abbas-Sarakhs corridor and the effects of different factors on it is presented.

3.6.1. Causal loop diagram

The causal loop diagram of the rail transit system in Bandar Abbas-Sarakhs corridor, which is used for comprehensive understanding of the system, is shown in Figure 2.

This diagram includes two reinforcing feedback loops named R1 and R2. The same direction in changing factors is specified with sign “+” and different direction in changing factors is specified with sign “-“. As an example, improving the ability of tracing wagons improves commercial speed and in Figure 2, this effect is specified with positive sign or transportation cost is increased by increasing commercial speed and this effect is specified with positive sign, too.

3.6.2. Stock and flow diagram

The stock and flow diagram for the evaluation of the utility of Bandar Abbas- Sarakhs corridor is shown in Figure 3. In this diagram, level and rate variables and the way that they are related to each other in feedback loops are specified. Utility is added to the model as a level variable with an increase rate and a decrease rate. The ability of tracing wagons is considered as a level variable. In order to calculate its rate of change, the average percentage of changes in this variable in the time period of 2006 to 2016 is used.

Commercial speed is added to the model as a function of the ability of tracing wagons. The function of commercial speed in terms of the ability of tracing wagons is estimated by eviews software.

On the other hand, transportation cost is added to the model as a function of commercial speed. This function is estimated by eviews software. As mentioned in previous sections, the cost of transportation per ton-km in USA is used to normalize the cost of transportation in Bandar Abbas-Sarakhs corridor. The cost of transportation in USA is considered as a level variable. In order to calculate its rate of change, the average percentage of changes in this variable in the period of 2006 to 2016 is used.

Increasing utility results in increasing demand and the total tonnage of transit in Bandar Abbas-Sarakhs corridor. Therefore, the total tonnage of each year’s transit is a function of utility. To determine the exact function of the tonnage of

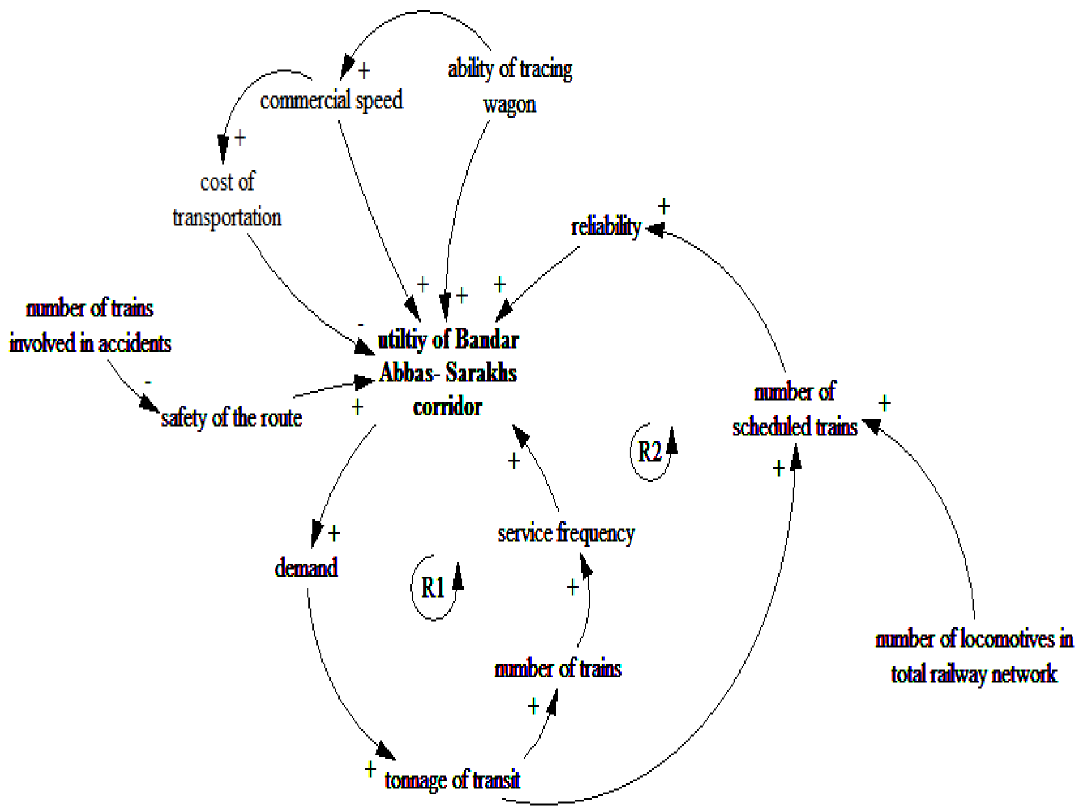

Figure 2. The casual loop diagram of the rail transit system

transit based on utility, this function is added to the model as a graph.

The capacity of Bandar Abbas-Sarakhs corridor is a function of the tonnage of transit. Since by increasing the tonnage of transit, the capacity of the corridor increases. To determine the exact function of the capacity of the corridor in terms of the tonnage of transit, this function is added to the model as a graph.

In this model, the number of trains involved in accidents is added to the model as a level variable, and to calculate its rate of change the average percentage of changes in this variable in the period of 2006 to 2016 is used.

To add the normalized number of locomotives to the model, the number of locomotives in the whole railway network and the number of desired locomotives is needed. The number of locomotives in the whole railway network and the number of desired locomotives is added to the model as the level variables, and to calculate their rate of change, the average percentage of changes in them in the period of 2006 to 2016 is used.

3.7. Verifying the Validation of the Dynamic Model

To verify the validation of the dynamic model, the information for the years 2014, 2015 and 2016 is used. The year 2013 is considered as the starting time of the simulation of the dynamic model. The output of the model for the variables in years 2014, 2015 and 2016 are compared to the real values of them in these years, and finally the average absolute value of the error of the model is obtained. The model is simulated by using vensim PLE software once with the variables' coefficients in the utility function gained from the regression analysis (the first model), and once with the variables' coefficients in the utility function gained from AHP (the second model). The average absolute value of error in the first model is equal to 5% and in the second model is equal to 6%.

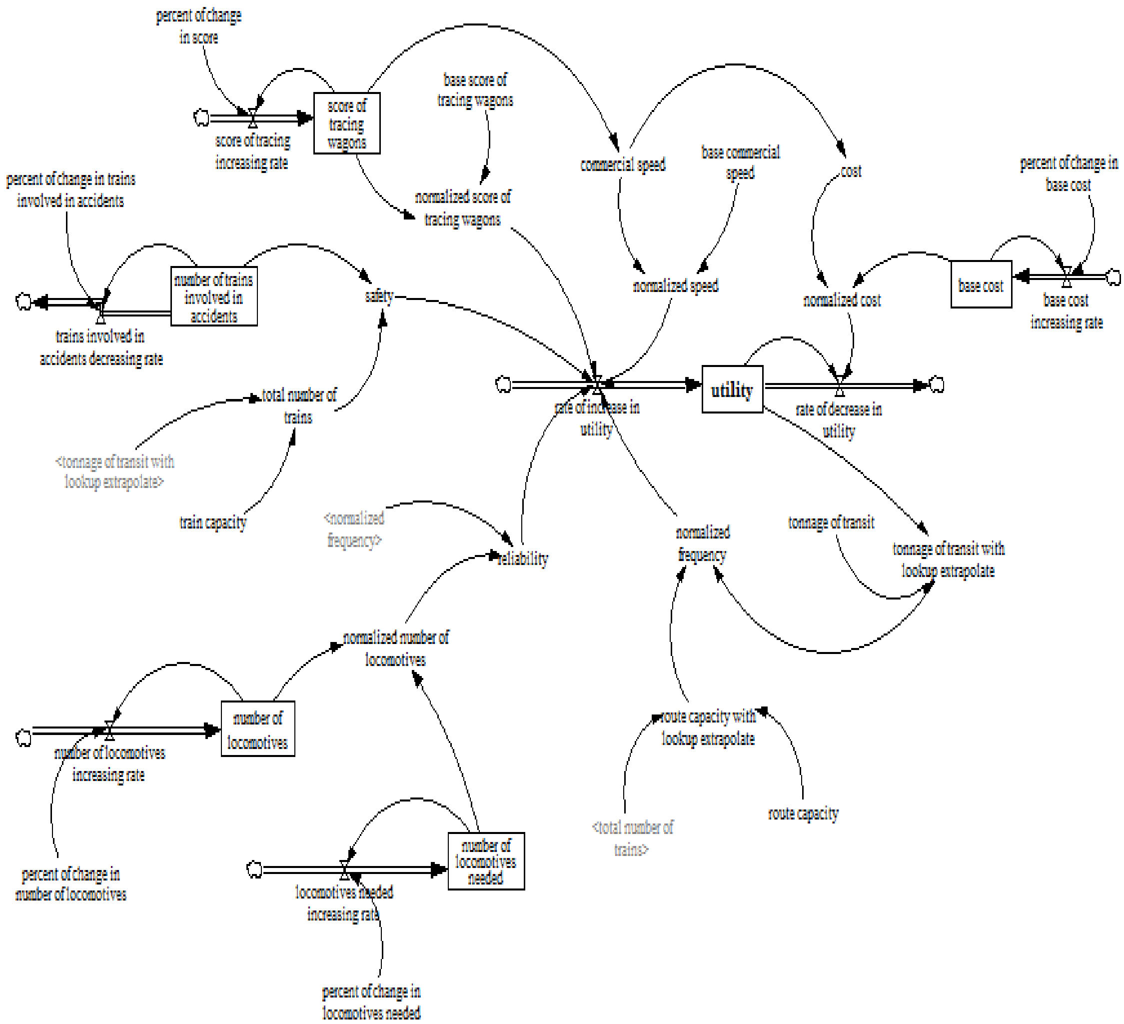

Figure 3. The stock and flow diagram of the rail transit system

Therefore, the validation of the first model is more acceptable than the validation of the second one. However, the validation of the second model is also acceptable.

4. Results

After simulating the model by vensim PLE software with the two groups of variables' coefficients in the utility function and verifying the validation of the two models, both models are simulated by vensim PLE software with the data duration for 20 years. Year 2013 is considered as the starting time of simulation and year 2033 is considered as its final time. Figure 4 depicts changes in utility in the simulation period on the basis of the two groups of variables' coefficients in the utility function. This figure shows that when the variables' coefficients in the utility

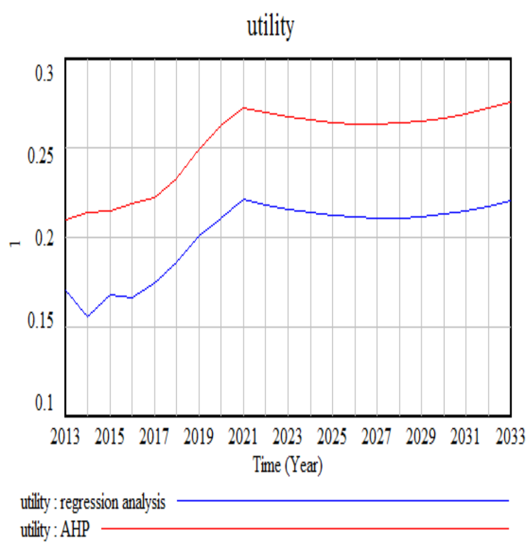

Figure 4. Changes in utility based on the two groups of variables' coefficients in the utility function and according to the current condition

function are those coefficients gained from AHP. Further increase in utility is obtained in the simulation period. Therefore, the model that is simulated according to the variables' coefficients in the utility function gained from AHP is considered as the final model and other assessments of the results are made according to this model.

Figure 5 shows that the demand of Bandar Abbas-Sarakhs corridor is decreased from 2013 to 2016 despite the increase in utility. Real information for the tonnage of transit show a decrease in the value of this variable in these years. This decrease is obvious in the output of the model, too. In these years, the tonnage of transit could have depended on the unexpected factors that have not been considered in the utility function. After that, by increasing utility, demand is increased until 2021, then it is decreased by decreasing utility till 2027 and finally it is increased by increasing utility and reaches to 510694 tons until 2033.

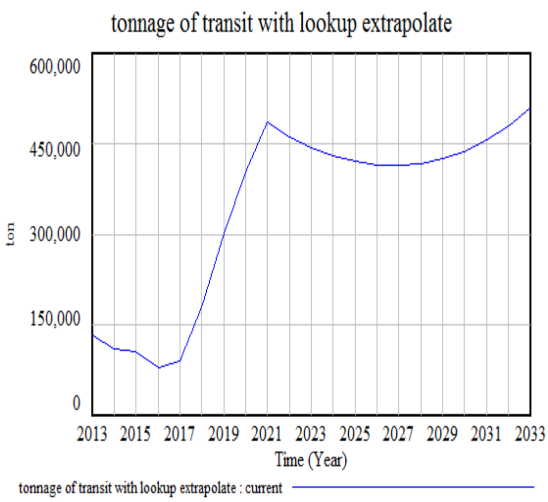

Figure 5. Changes in demand according to the current condition

5. Discussion

The results of the dynamic model developed for evaluating the utility of Bandar Abbas-Sarakhs corridor show an increasing trend for utility until 2033, and it is predicted that the amount of demand reaches to 510694 tons until 2033. Even according to the current capacity of the corridor, this is a low amount for demand. Hence, in this section the effects of changing some factors on the tonnage of transit in the mentioned corridor are investigated. It is important to say that transportation cost per ton km is determined according to the tariff policy of CIS, and it can't be changed easily. On the other hand, according to the simulation results, the safety of the corridor is very high in the simulation period, and it doesn't need to be changed. Also, the service frequency, determined according to the tonnage of transit, is a function of the utility of the corridor, and it can be increased only by improving utility. Therefore, the effects of changing in reliability, the system of tracing wagons and commercial speed on the tonnage of transit are investigated.

5.1. First Scenario: 20% Increase in the Number of Locomotives in the whole Railway Network

Reliability is an important factor affecting the utility of Bandar Abbas-Sarakhs corridor. Most of the trains in the mentioned corridor can't be dispatched on time due to the deficiency of existing locomotives in the whole railway network. Therefore, by increasing the number of locomotives in the whole railway network, reliability and as a result the tonnage of transit increase. The following Figure 6 shows changes in the demand of Bandar Abbas-Sarakhs corridor according to the current condition and after 20% increase in the number of locomotives. This figure shows that by increasing the number of locomotives in the whole railway network, the tonnage of transit increases.

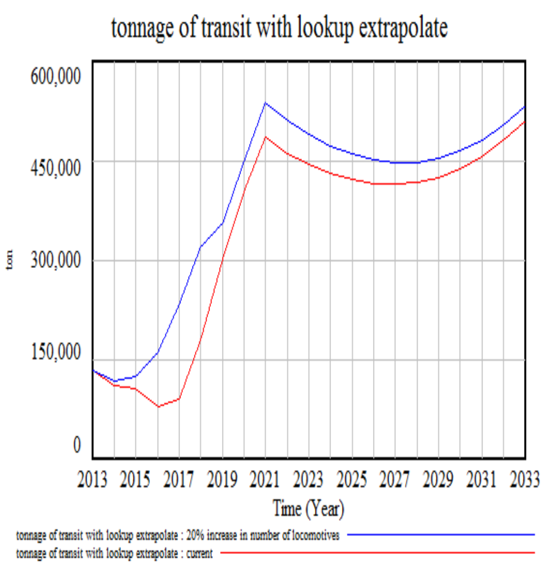

Figure 6. Changes in demand after 20% increase in the number of locomotives

5.2. Second Scenario: 20% Increase in the Score of the System of Tracing Wagons

Currently, the performance of the system of tracing wagons in Iran is not as sophisticated compared to the performance of the system of tracing wagons in the countries that are the members of UIC[3]. Improving the system of tracing wagons results in giving more information about consignment to its owner as well as increasing the utility of the corridor. Figure 7 indicates changes in the demand of Bandar Abbas-Sarakhs corridor according to the current condition and after 20% increase in the score of the system of tracing wagons. By improving the system of tracing wagons, the tonnage of transit increases.

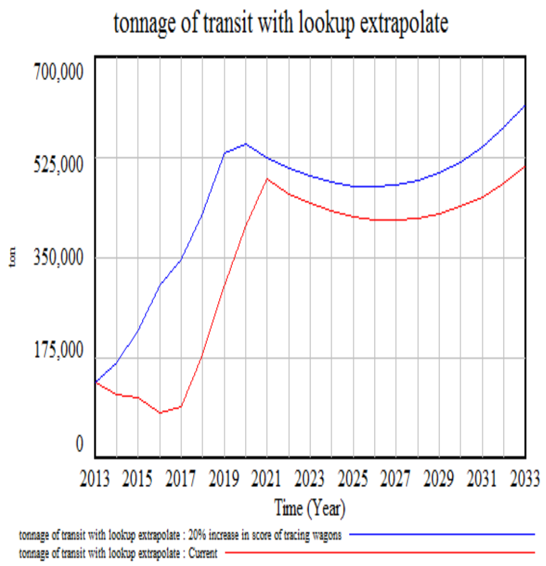

Figure 7. Changes in demand after 20% increase in the score of the system of tracing wagons

5.3. Third Scenario: 20% Increase in Commercial Speed

The commercial speed of freight trains in Bandar Abbas- Sarakhs corridor is about 5 km/h which is a low speed. Figure 8 depicts the changes in the demand of the mentioned corridor after 20% increase in commercial speed. As cited in previous sections, by increasing commercial speed, the cost of transportation increases, which is a very important factor for the owner of goods. Figure 8 reveals that by increasing commercial speed and as a result of increasing transportation cost, the tonnage of transit decreases.

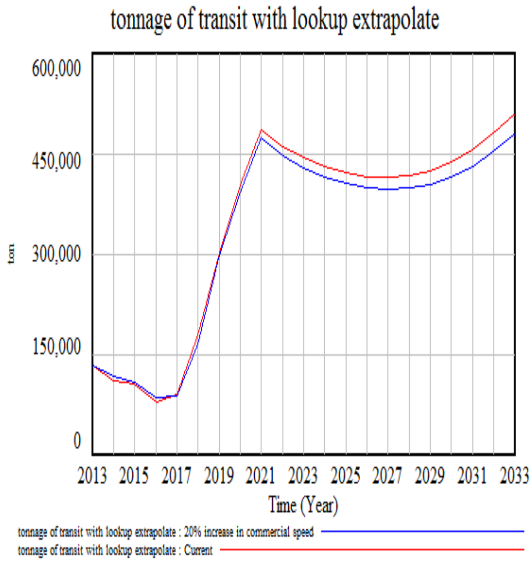

Figure 8. Changes in demand after 20% increase in commercial speed

5.4. Implementing all the Scenarios Simultaneously

Finally, the effect of implementing all the scenarios simultaneously on the tonnage of transit in the mentioned corridor is examined. Figure 9 shows that more increase in the tonnage of transit is obtained when all the scenarios are implemented simultaneously as the tonnage of transit reaches to about 640000 tons till 2033.

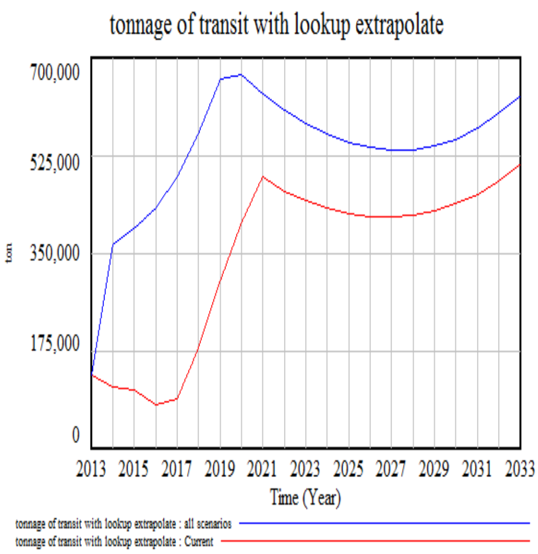

Figure 9. Changes in demand by implementing all the scenarios simultaneously

[3] International Union of Railways

It is worth mentioning that by increasing the ability of tracing wagons and commercial speed, transportation cost increases and due to its importance for the owner of goods, wide changes in demand can't be reached. Therefore, transportation companies can increase the utility of the mentioned corridor even more by giving discount on the cost of transportation according to the owner of goods' demand. Therefore, changing one variable can't increase utility too much and improving several variables simultaneously is needed.

6. Conclusions

In this research, initially the concepts of utility and transit are described. Articles related to the utility of transit corridors are investigated and as a result, the effective factors in the utility of transit corridors are obtained. These factors included transportation cost, transportation time, reliability, safety, distance, service frequency, flexibility, product characteristics, commercial speed, energy consumption, greenhouse gas emissions, noise pollution, accidents and traffic.

To obtain the most important factors affecting the utility of railway transit corridors, the opinions of the experts and managers of some international transportation companies and a ten-points Likert scale are used. These factors included transportation cost, commercial speed, reliability, safety, the ability of tracing wagons and service frequency.

To prioritize the factors based on the intensity of the influence of them on utility, AHP is used. The prioritizing of the factors from the most to the least important factor are as follows: 1- transportation cost, 2- safety, 3- reliability, 4- the ability of tracing wagons, 5- commercial speed, 6- service frequency.

The information of each factor for Bandar Abbas-Sarakhs corridor and for 2006- 2016 was collected. On the basis of this information and by using linear regression model, a utility function for the mentioned corridor is calculated by using Eviews software. The prioritizing of the factors from the most to the least important factor according to their weights gained from regression analysis is as follows: 1- transportation cost, 2- the ability of tracing wagons, 3- safety, 4- commercial speed, 5- reliability, 6- service frequency. Therefore, based on the linear relationship between the mentioned factors and utility, two utility functions are available including: one exact utility function with the factors' coefficients gained from regression analysis and one approximate utility function with the factors' coefficients gained from AHP.

A dynamic model is developed for evaluating the utility of Bandar Abbas-Sarakhs corridor. This model is simulated by using Vensim PLE software twice: once with the variables' coefficients in the utility function gained from regression analysis and once with the variables' coefficients in the utility function gained from AHP. After verifying the validation of both models, they were simulated by Vensim PLE software for a data duration of 20 years. The results showed that when the variables' coefficients in the utility function were those coefficients gained from AHP, further increase in utility was obtained in the simulation period. Therefore, this model is considered as the final model and the other assessments of results are made according to this model. The results of the simulation of the model showed that by increasing utility, demand grew from between 2016 to 2021, then it decreased by decreasing utility till 2027, and finally it grew by increasing utility and reached to 510694 tons until 2033. However, according to the current capacity of the corridor, this is a low amount for demand.

Finally, in order to increase the utility and the demand of the mentioned corridor, the number of locomotives in the whole railway network was changed to calculate the score of the system of tracing wagons and commercial speed. The results showed that to make wide changes in the tonnage of transit, simultaneous improvement in the mentioned factors and also giving discount on transport cost according to the demand of the owner of goods were needed. Therefore, to increase the utility of Bandar Abbas-Sarakhs corridor, the following solutions are presented:

- Schedule the movement of transit trains
- Increase the number of existing locomotives in the whole railway network to increase the number of scheduled trains and reliability
- Improve the system of tracing wagons to have better control over wagons' movement
- Increase the speed of freight trains by renovation of existing fleet and buying new high speed fleet

- Increase and improve in the equipment of loading and unloading and shunting and as a result improve in their operation time
- Decrease the stop time by not changing train arrangement on the way as much as possible
- Discount on the cost of transportation on the basis of the owner of goods' demand

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