A Methodology to Prioritize the Construction Projects of New Railway Infrastructures for Privatization in Railway Networks (Case Study: Iran)

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Abstract

This study aims to develop a novel methodology to prioritize the construction of new railway infrastructures for privatization. The private sector can cooperate to solve the capacity problems of railway networks, by construction of new infrastructure. The purpose of this study is to answer the basic question that whether the capacity problems of the railway networks can be solved simply by building the new infrastructures without capacity improvement solutions, or not. Another main question is that which of the new construction projects are more prioritized to be built. The main contribution of this paper is to propose a new methodology to answer the mentioned questions, based on railway capacity, traffic assignment and calculation of Net Present Value (NPV) indicator. To evaluate the proposed methodology, Iranian railway network is considered. The NPV indicator is calculated for 30-year duration, considering both direct and indirect benefits (benefits resulting from reduced accidents, reduced environmental pollutants, and fuel saving). The results show that building of new infrastructures, simultaneously with improving the capacity of the existing railways can lead to superior efficiency, compared to merely building new infrastructures. For the cases of building the construction projects without and with improving the existing railways, the values of maximum NPV were 88.1 and 221 thousand billion rials, respectively. Also, the values of absorbed demand were 52.18 and 46.72 million tons for two cases, respectively. The proposed methodology and the results of this study can be used as a practical tool for railway managements to identify the priority of different construction projects of new infrastructures.

Keywords: Railway transportation, capacity bottlenecks, infrastructure construction, private sector, traffic assignment.

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1. Introduction

The capability of the private sector to collaborate the construction of railway infrastructure projects is considered an attractive alternative for the governmental authorities, aiming at increasing the traffic absorption to the railway network. This collaboration can be fulfilled through three main approaches: only improvement of the existing railways, only construction of new infrastructures, and a combination of the two first approaches [Marinov and Viegas, 2011]. For participation of the private sector, a central railway government usually encounters with two main questions. First: is it efficient to solve the capacity problems of the railway network, merely by construction projects of new infrastructures, without capacity improvement for the existing railways. Second: assuming that the construction of new infrastructures is obligatory due to the governmental strategies, which of the candidate projects have the most priority to be constructed by the private sector [Kopicki and Thompson and King, 1995]. The main contribution of this paper is to propose a new methodology to answer the mentioned questions, based on railway capacity, traffic assignment and calculation of Net Present Value (NPV) indicator. The study aims to investigate the justification and priorities for assigning the projects of railway capacity construction to the private sector.

The rest of the article is organized as follows: in section 2, theoretical foundations of the research are presented. In section 3, the proposed research methodology is offered. In the section 4, the case study of the research (Iranian railway network) is presented to evaluate the proposed methodology. In section 5, the results and outputs are provided. The conclusions and the references and appendix are indicated in sections 6, 7 and 8, respectively.

2. Theoretical Foundations of the Research

In order to prioritize the projects of constructing new railway infrastructures to be assigned to the private sector, the concepts of demand, capacity and assignment should be reviewed. Therefore, the theoretical frameworks of the research are presented in three parts: in part 1, the concept of capacity in the railway network is examined. In part 2, traffic assignment in the railway network is introduced. Traffic assignment is necessary for finding capacity bottlenecks and as well as examining the effects of each new infrastructure. In part 3, the privatization requirements in the railway transportation system are investigated. In this section, some of the experiences of various countries around the world in relation to the privatization of railway transportation system are reviewed.

2.1 The Concept of Capacity in Railway Transportation

In spite of the concept of the capacity on roadways, capacity on railways is a complicated concept, which depends on the infrastructure, the schedules and the rolling stock [Kaas, 1998 and Landex, 2008]. Capacity in the railway system is defined as the maximum number of trains that can pass from a certain point of the railway line at a certain interval of time [Landex and Kaas and Hansen, 2006 and Krueger, 1999]. It is obvious that the running characteristics and the length of the train directly affect on the railway capacity, because the passage of different types of trains (fast and short, or slow and long trains) from the block sections may cause considerable variation for railway occupation [Krueger, 1999 and Landex, 2008].

International union of railways (UIC) presents a method to calculate capacity in which four kinds of headways are considered. The average headway of the trains is obtained through the following equation [Abril et al., 2008]:

$$\mathrm{t_{fm}} = \frac{\sum(\mathrm{n_{ij}} \times \mathrm{t_{fij}})}{\sum \mathrm{n_{ij}}} \qquad (1)$$

In Equation (1), i and j are considered as the representatives of a group of trains with approximately the same speed. n_{ij} is the number of train headways, t_{fij} is the headway time between two groups of trains. t_{fm} is the average headway between all the trains that are sent to the line [Abril et al., 2008]. Capacity (C) in the time window (T) is obtained via Equation (2).

$$\mathrm{C} = \frac{\mathrm{T} - \mathrm{W}}{\mathrm{t_{fm}} + \mathrm{t_r} + \mathrm{t_{zu}}} \qquad (2)$$

Where C is the railway capacity in terms of the number of trains, T is duration of time under study, W is maintenance window, t_{fm} is the average headway between all the trains that are deployed in line, t_r is retain time, and t_{zu} is additional time [Abril et al., 2008].

Capacity improvement strategies used in the railway network (construction of double truck railway, block signaling system, electrification, opening closed stations, and deploying long trains) and constructing new railway infrastructures can resolve the lack of capacity in the railway network [Khadem-Sameni and Preston and Armstrong, 2008].

2.2 Traffic Assignment in the Railway Network

The process of allocating a specific set of travel demand represented by the trips matrix (Origin Destination matrix) to the transportation network is usually implied to as traffic assignment. The substantial aims of traffic assignment procedures are to estimate the volume of traffic on the links of the network, as well as the estimation of the routes used between each origin to destination (O-D) pair [Hwang and Ouyang, 2014 and Dafermos and Sparrow, 1969]. Traffic assignment is necessary to identify capacity bottlenecks and the effects of any projects of constructing new infrastructure. Traffic assignment problem (TPA) in a transport network is generally to determine how to distribute the demands of source-destination pairs between existing routes. Traffic assignment methods are divided into static and dynamic ones [Saw, Katti and Joshi, 2015].

The static method focuses on the specified traffic loading on the network. There are various traffic assignment methods in static conditions, as follows: All or Nothing assignment, stochastic assignment, Capacity Restrained assignment, Incremental assignment, User equilibrium assignment and System Optimum assignment [Woodburn, 2003]. Badin and Hench applied user equilibrium assignment method in order to assign traffic in large-scale railway network. The applied algorithm was assigned based on the track as well as the freight demand in railway and road transportation according to Freight Analysis Framework (FAF) Software [Sheffi, 1985 and Uddin and Huynh, 2015]. Our present study have used two methods, All-or-Nothing assignment (AON) and Incremental assignment for investigating the justification and priority of assigning the construction projects to the private sector. In All or Nothing assignment (AON), all the traffic flows of an origin-destination are allocated to have the least travel resistance. In incremental assignment (IA), the total traffic of an origin-destination pair is divided into several components. Then, each traffic component is assigned based on the shortest path between the origin and destination. In this method, the travel time for each link in the network is a function of the volume of traffic on the link [Landex, 2008; Kato and Kaneko and Inoue, 2010; Shafipour et al., in press]. VISUM Cargo, FAF and TRANS-TOOLS are among the softwares with capability of traffic assignment in the railway network. In the present study, incremental assignment of traffic is performed with regard to capacity of the railway networks. In each iteration of this method, the shortest path is detected for each origin-destination pair, and the unit of traffic component is assigned to the detected path. After incremental assignment of all origins-destinations, the total volume of the traffic passing through each of block sections is compared with its capacity, and if the passing demand reaches to the capacity, the passage is blocked. Then in the next iteration, for each origin-destination pair, the shortest path is updated and the traffic components are carried through the network. The process continues for each origin-destination pair until the the end of its demand or the blockage of all the relevant paths. In all or nothing assignment (AON), it is assumed that the traffic volume of each network link has no effect on the travel time of that link. Moreover, the assignment procedure is performed solely based on finding the shortest path for an origin-destination pair and regardless of the capacity [Kato and Kaneko and Inoue, 2010 and Li et al., 2014]. According to the results, it is possible to identify capacity bottlenecks in the railway network. Bottleneck in the railway network occurs when the existing railway demand is more than the available capacity of network infrastructures [Drewello and Günther, 2012]. It is possible to identify capacity bottlenecks by calculating the ratio of volume to capacity (v/C) in the two above-mentioned assignment methods.

2.3 Some Privatization Experience in Railway Systems of the World

The concept of privatization is the transfer of organizational ownership –in whole or in part- to the private sector. In other word, privatization is the transformation of a public organization into an independent authority or government corporation [Savas, 2000]. Both of the public and private sectors perform significant roles in privatization, therefore it is common to refer to "public-private partnerships" (PPP). Both of these sectors have particular characteristics, and combining those characteristics may lead to improvement of the whole system [Hodge and Greve, 2007 and Goel and Budak, 2006].

we review the railway privatization in some countries. Any recommendations regarding successful privatization strategies could provide beneficial information. With regard to the advantages of railway transportation system, many countries have considered measures such as economic liberalization and assigning different railway spheres to the private sector in order to achieve sustainable development in the railway transportation system [Drewello and Günther, 2012]. Many countries around the world, since early 1980s have provided the ground to attract investment in railway system by introducing aid packages. In the Japanese National Railways (JNR), a variety of support strategies of private firms created an atmosphere of healthy competition between private companies, improved services, created favorable conditions for passengers and increased demand for railway travels [Shoji and Killeen, 2001 and Saito, 1997]. Argentina's state-owned railway doubled freight traffic and caused a fourfold increase in workforce productivity by assigning freight transfer to the private sector and implementing incentive policies [Drewello and Günther, 2012]. Since 1990, the Malaysian government used incentive policies to increase the share of private sector in the development of railway infrastructures. After financial reforms, the Malaysian National Railway was divided into two companies to take infrastructural and operational responsibilities [Naidu, 2007].

The Indian government implemented some plans since 2000 for the participation of private sector in transportation infrastructure services, including Own Your Wagon Scheme (OYWS) and Build-Own-Lease-Transfer Scheme (BOLT) [Puri, 2003]. In the UK, operational and infrastructural activities of railway were separated from each other since 1996 and both were assigned to the private sector [Glaister, 2004]. The review of various countries' experiences shows that the common pattern used in many railway network in the world is based on the separation of responsibilities in the areas of railway infrastructure and exploitation. Therefore, in this study, the privatization of railway transportation system in terms of infrastructure is investigated from the perspective of the projects of constructing new railway infrastructures.

Economic analysis of each of the schemes based on the net present value (NPV) is done in our paper, by calculating the costs and benefits of each construction project. NPV is defined as follows:

$$\mathrm{NPV}(\mathrm{i},\mathrm{N}) = \sum_{\mathrm{t}=0}^{\mathrm{N}} \frac{\mathrm{R_t}}{(1+\mathrm{i})^{\mathrm{t}}} \tag{3}$$

Where i and N are the discount rate and the life of the investment solution, R_t is the net cash flow according to difference between the benefits and the costs in period t, respectively [Mackevičius and Tomaševič, 2010]. The benefits are calculated based on the transport of each ton kilometer of freight demand from road transport system to railway transport system and are divided to direct benefits (NPV_1) and direct and indirect benefits (NPV_2). Direct benefits result from railway transportation tariffs in the railway system, while indirect benefits are shared by the whole society such as the benefits resulting from reduced accidents, reduced environmental pollutants, and fuel saving (See also Tamannaei et al., in press).

The problem of prioritizing the construction projects of new railway infrastructures for privatization in railway networks, considering railway capacity and traffic assignment is not addressed yet, to the best of our knowledge. Our research aims to prioritize the construction projects of new railway infrastructures for privatization in railway networks. We have employed Iranian railway network, to evaluate our proposed methodology.

3. The Proposed Research Methodology

In this study, a new methodology called Priority of Capacity Projects in Railway Network (PCPRN) algorithm is proposed to allow the prioritization of projects of constructing new railway infrastructures, in order to be assigned to the private sector. In PCPRN algorithm, the incremental assignment (IA) considering railway capacity, as well as all-or-nothing assignment (AON) are used. Moreover, the prioritization of new infrastructure projects is divided into two areas. The output of PCPRN algorithm makes it possible to compare two areas and prioritization of each construction project. Figure (1) illustrates PCPRN algorithm to determine the priority of assigning the projects of increasing capacity in railway network to the private sector. The PCPRN algorithm makes it possible to answer two basic questions presented in Section 1 of this paper.

It should be noted that the prioritization of building the new infrastructures, with capacity improvement solutions requires the implementation of three sub algorithms. In the first sub algorithm, the corridors with high potential railway demands are identified based on AON assignment operations. In the second sub algorithm, the capacity bottlenecks of the railway network are identified. In the third algorithm, the package of capacity improvement solutions for railway network is presented.

In PCPRN algorithm (shown in Figure 1), the goal is to prioritize the construction projects to assign to the private sector. The prioritization of the projects can determine the most appropriate projects for the private sector to construct.

3.1 Identifying the Corridors with High Potential Railway Demand (First Sub Algorithm)

Identification of the corridors with high potential railway demand is performed based on AON assignment operations. The AON assignment was done to identify the main corridors with high potential demand. AON assignment shows tendency lines of the demand in freight railway network in case of lack of capacity problems. The first sub algorithm for identifying the selected railway corridors is displayed in Fig. 2.

The purpose of the algorithm shown in Fig. 2 is to identify the railway corridors with high potential railway demand. It is necessary to impose some constraints, in order to recognize the corridors of the railway network, which are capable to absorb as much demand as possible.

Railway corridors are selected based on the calculation of average high potential railway demand (Mean), standard deviation (σ) and standard error associated with potential railway demand (SE).

In Fig 2, $Mean_j$ is the average high potential railway demand in the railway block sections of corridor j; σ_j is the standard deviation of high potential railway demand in the railway block sections of corridor$j$, and SEj is the standard error of the high potential railway demand in the railway block sections of corridor j.

The values of Tr_1, Tr_2 and Tr_3 are considered as the minimum average demand for the sample railway block sections of corridor, maximum permissible ratio of standard deviation to mean, and maximum standard error, respectively. According to the results of the traffic assignment, the parameters such as "mean" and "standard deviation" are calculated for each of the defined corridors.

For more clarification, the complete procedure of specifying the main corridors with high potential demand, for a specific construction scenario (constructing the railway project of Isfahan-Ahvaz) is attached in Appendix.

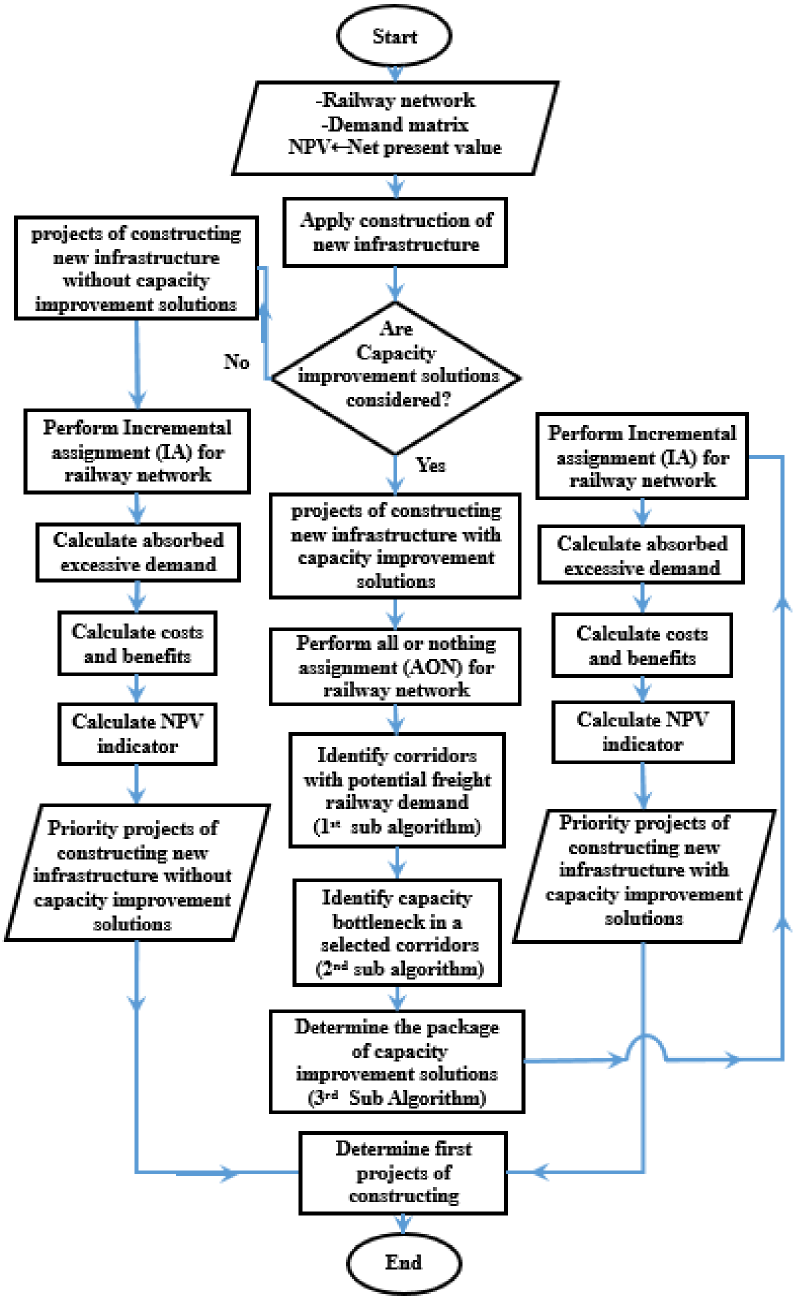

Figure 1. PCPRN algorithm to prioritize the projects of constructing new railway infrastructures without and with improving solutions to be assigned to the private sector

3.2 Capacity Bottlenecks in Railway Network (Second Sub Algorithm)

Capacity bottlenecks in a railway network are identified based on the calculation of volume to capacity ratio (v / C) in two methods of incremental assignment (IA) and all-or-nothing assignment (AON).

The second sub algorithm for identifying the capacity bottleneck in a selected railway (corridor identified based on the first sub algorithm) is displayed in Fig. 3. Capacity bottlenecks in Fig. 3 are identified based on two criteria presented in second sub algorithm. In this sub algorithm, v is the volume of traffic passing through the railway corridor j, and IA and AON are incremental assignment with considering capacity and all-or-nothing assignment, respectively. The phrase $(v/C)_{IA}^{j} = 1$ means that after IA method, the ratio of passing demand to capacity in corridor j will be equal to one. In other words, the whole capacity of block section j is used. The inequality $(v/C)_{AON}^{j} > 1$ means that the volume of demand passing through block section j is more than the calculated capacity in it. In other words, in case of lack of capacity problems in the railway network, potential railway demand is equal to volume v in the railway block section j.

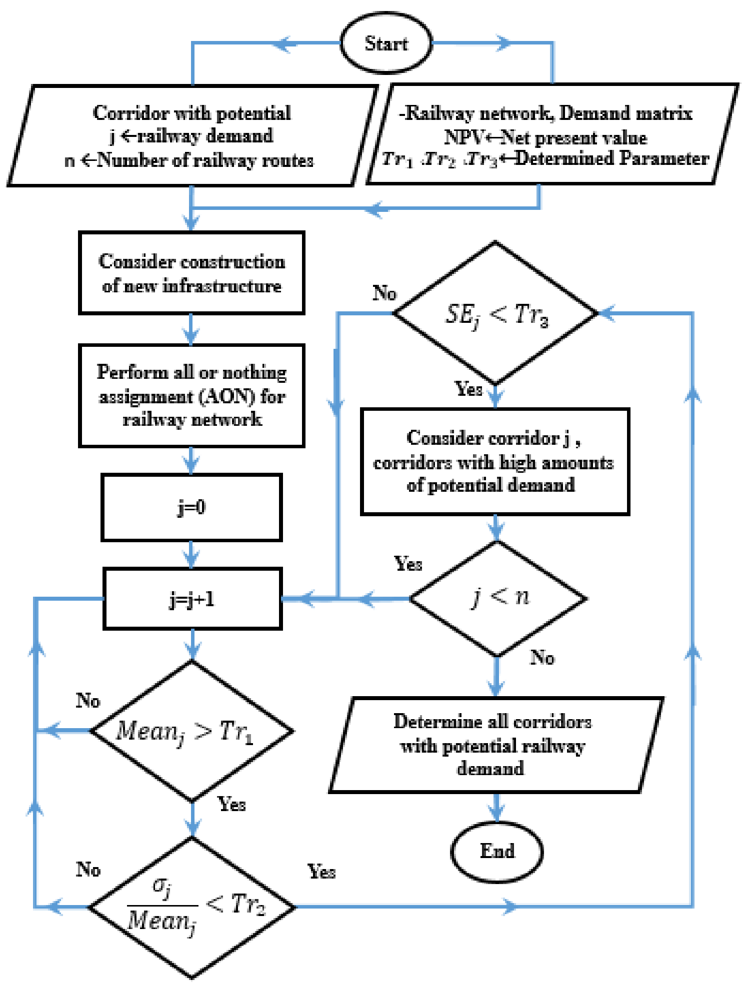

Figure 2. The first proposed sub algorithm to identify corridors with high potential freight railway demand

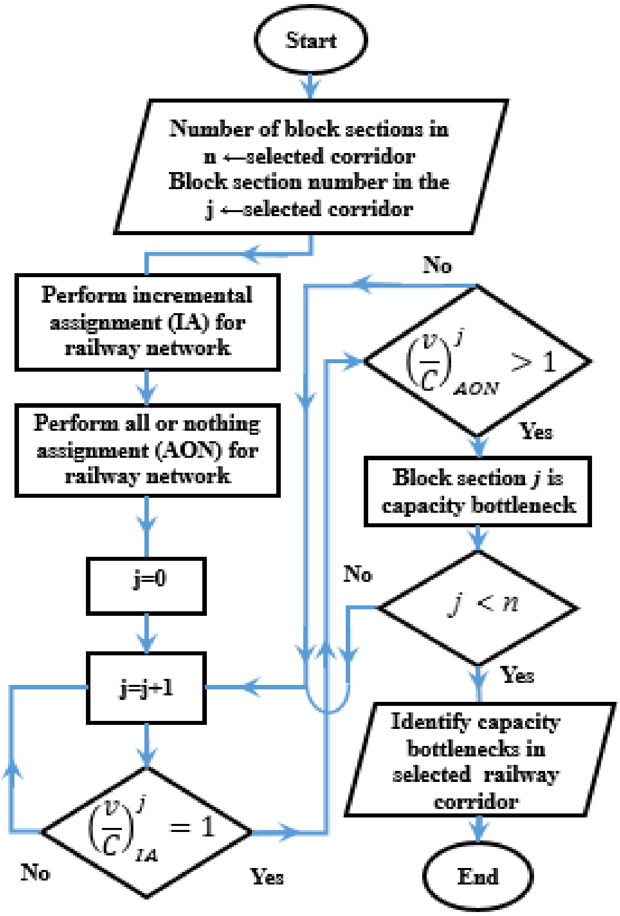

Figure 3. The second proposed sub algorithm to identify capacity bottleneck in a selected railway corridor

3.3 Determining the Package of Improvement Solutions for Modified Infrastructures of the Railway Network (Third Sub Algorithm)

In the third sub algorithm, the capacity improvement solutions in each selected railway corridor are identified. The set of capacity improvement solutions in the selected railway tracks is named capacity improvement package, in this paper. Since the third proposed algorithm is implemented to determine capacity improvement package in the modified infrastructures of railway network in each high potential railway corridor, the process of determining the best capacity improvement package in other selected railway corridors will be the same. After determining the best capacity improvement package in each of the selected railway corridors, the capacity improvement package in the project of constructing new infrastructure is specified. The desired trend is repeated in each of the projects of constructing new infrastructures. After determining the capacity improvement package, through incremental assignment (IA) of traffic and considering capacity and calculating the benefits and costs of construction project and its corresponding capacity improvement package, it is possible to prioritize the construction projects by considering capacity improvement packages

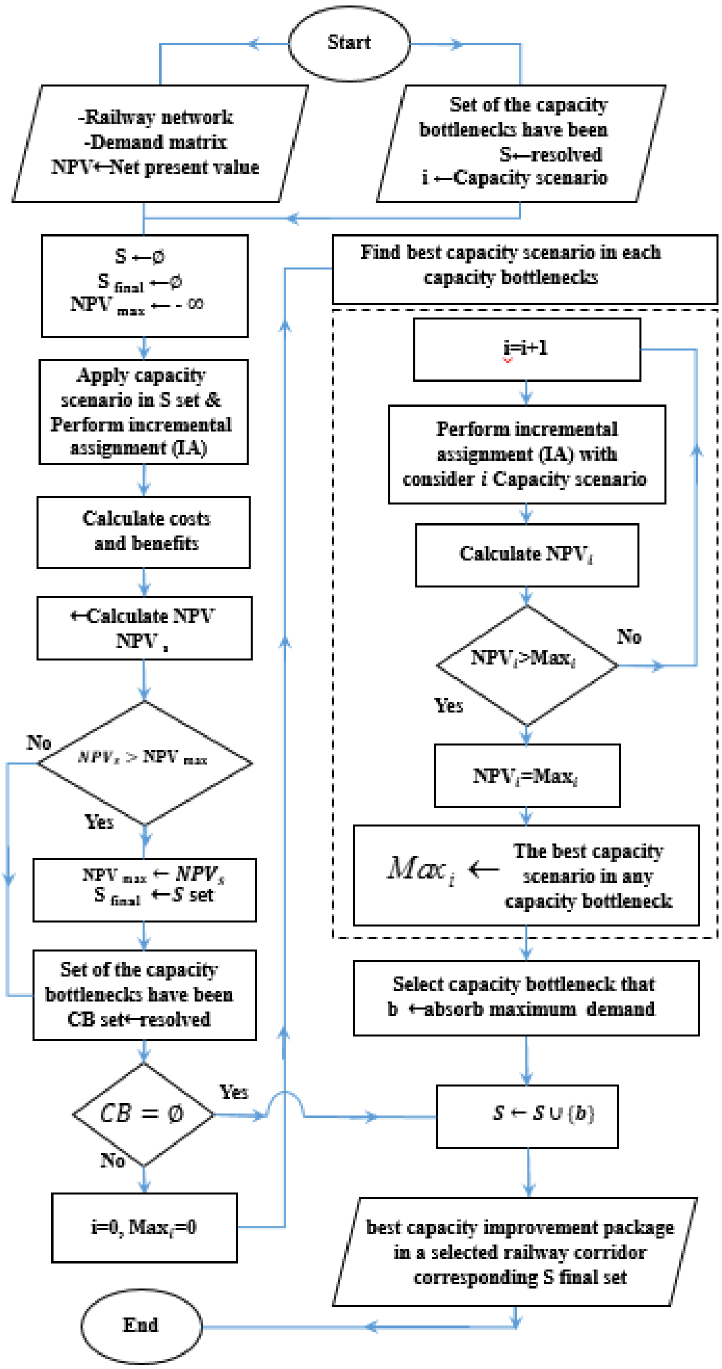

Figure 4. The third proposed sub algorithm to identify capacity improvement solutions in each selected railway corridor

Fig. 4 displays the proposed algorithm for finding best capacity improvement package in a selected railway project.

According to Figure 4, for each of the railway corridors identified by the first sub-algorithm (Figure 2), the incremental traffic assignment is firstly done, then the economic analysis is performed based on benefits and costs. The new capacity bottlenecks appeared in the mentioned corridor are specified. Between these bottlenecks, the one whose improvement causes the most value of the absorbed demand, is selected and then added to the set of improved bottlenecks of the corridor (called S). After applying the best solution for capacity increase for the selected bottleneck, the assignment is again performed for the updated network. This iterative process is continued and in each iteration, one bottleneck is added to set S. the algorithm is terminated when removing all bottlenecks of the corridor. The output of the algorithm is the best capacity package based on NPV index.

To participate in railway construction projects, the rate of return -i.e. the gain or loss on an investment over a specified time- for the private sector must be guaranteed by the governmental railway company. Therefore, in PCPRN algorithm shown in Figure 1, it is necessary to specify the benefits and costs, due to each of the construction projects. Then, the NPV indicator has been calculated based on benefits and costs. The prioritization of the projects can determine the most appropriate projects for the private sector to construct.

4. Case study (Iranian Railway Network)

In the present study, the prioritization of the projects of constructing new railway infrastructures to be assigned to the private sector is investigated in the Islamic Republic of Iranian Railway Network. In order to provide the matrix of railway and road network demands, the information of freight road and railway transportation systems were obtained.

The prioritization of the projects of constructing new infrastructure is done by calculating economic analysis. Economic analysis is possible by calculating the costs and benefits in each construction project. Therefore, the cost of the project of constructing new infrastructure and capacity improvement solutions in Iranian railway network were investigated. It is noted that the total cost related to opening of a closed station includes cost of equipment installation, cost of constructing station siding lines, and cost of railway switches.

The final cost of capacity improvement solutions in Iranian railway network is displayed in Table 1.

The total cost for promoting to double-track railways and constructing new infrastructure is based on the area type. Types of area are included in four items: Plain, Hills, Mountain and Severe Mountain. Direct and indirect benefits related to transport systems are presented in Table 2.

Table 1. Final cost of methods of improving capacity problems [Shafiepour, 2017]

Strategy	Area type	Unit	Cost Billion riyals
Promoting to double-track railways	Plain	Km	28
	Hills	Km	33
	Mountain	Km	38
	Severe Mountain	Km	54
Block signaling system	-	Km	1.25
Electrification railway	-	Km	7.65

opening the closed stations	-	Closed Station	50
Constructing new infrastructure	Plain	Km	28
	Hills	Km	33
	Mountain	Km	38
	Severe Mountain	Km	54

Table 2. Benefits of freight transfer from road system to railway system [Shafiepour, 2017]

Row	Profits of increased capacity		The amount of benefit (Riyals per 1000 ton km)
1	direct	Railroad transportation tariffs	500
2	indirect	Saving Fuel	450
3	indirect	Reduction of environmental pollutants	791
4	indirect	Reduction of accidents and damage to life and property	780

Table 3. Classification of nine projects of constructing new infrastructures

Row	Project of constructing new infrastructure	Project of constructing new infrastructure
1	Single project	Isfahan – Azna project
2		Isfahan – Ahvaz project
3		Badroud – Garmsar project
4		Yazd – Eghlid project
5		Gorgan-Mashhad project
6	Paired project	Isfahan – Azna and Yazd – Eghlid projects
7		Garmsar - Badroud and Yazd – Eghlid projects
8		Isfahan – Ahvaz and Yazd - Eghlid projects
9	All single projects	Construction of five single projects

Determining the prioritization and justification of assigning each construction project to private sector was done by calculating two indices of NPV_1 and NPV_2. To calculate NPV, 30-year duration is considered. Also, the value of the discount rate is considered 10%. This value is chosen, according to different interviews performed from the experts and managers of Islamic republic of Iranian railway research center. In this study, in order to assign traffic in the railway network, incremental assignment with considering capacity and all-or-nothing assignment were used. After consulting with the relevant experts, nine projects of constructing new infrastructure were taken into account and were divided to three parts. In part 1, five single projects of constructing new infrastructure were considered separately for Iranian railway network. In part 2, acceptable combinations of five projects of constructing infrastructure were examined in the form of construction project pairs and finally three pairs of infrastructure construction projects were considered. In part 3, the effect of simultaneous application of the set of the desired single projects was examined. Table 3 displays nine construction projects of new infrastructures.

The five projects, as the candidates of construction, are as follows: Isfahan-Azna, Isfahan-Ahvaz, Badroud-Garmsar, Yazd-Eghlid, and Gorgan-Mashhad.

The results of AON assignment achieved by construction of all five mentioned projects are shown in Figure 5.

PCPRN algorithm was implemented in order to prioritize the projects of constructing new railway infrastructures to be assigned to private sector. Table 3 displays the construction projects with prioritization in terms of three criteria: absorbed network demand, NPV_1 and NPV_2, considered in both areas of constructing new infrastructure with and without capacity improvement solutions.

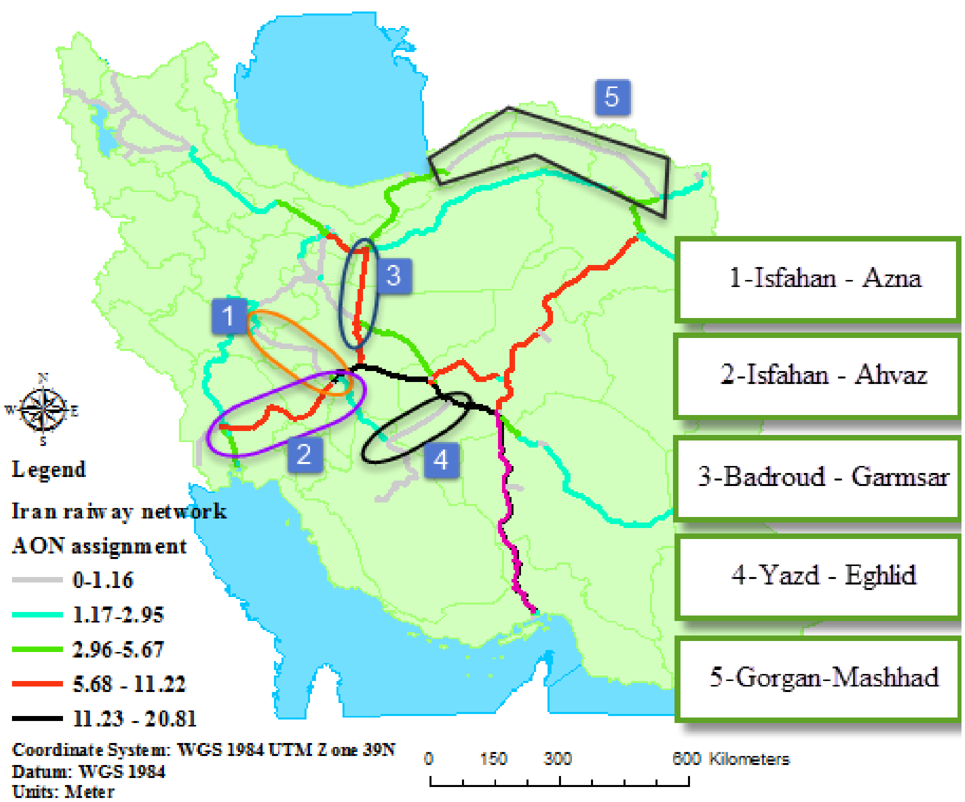

Figure 5. The results of AON assignment achieved by construction of all five new projects

As shown in Table 4, for the construction projects implemented along with the capacity improvement solutions, NPV_1 and NPV_2 have better performance in terms of absorbed network demand, rather than the implementation of construction projects without capacity improvement solutions. Table 4 displays classification projects of constructing new infrastructure in Iranian railway.

1. Results and Discussion

In order to prioritize the projects of constructing new railway infrastructures to be assigned to the private sector, the concepts of demand, capacity and assignment are taken into account in this paper. The matrix of railway freight demand in year 2019 for Iranian railway network was considered.

This matrix is considered as an input of our paper, and is extracted from an official report ordered by Islamic republic of Iran railway research center [Iranian railway research center, 2016]. The capacity bottlenecks of the network were identified based on the results of two methods of IA assignment and AON assignment.

The results of IA assignment in projects of constructing new infrastructures without the improvement of modified network capacity showed that despite the elimination of capacity bottlenecks of a part of network, the remaining capacity bottlenecks prevent the transfer of traffic demand from other parts of network to the position of construction project. Consequently, the potential capacity of new infrastructure has not been used properly. The second main question can be rewritten as follows: If the construction of new infrastructures is considered necessary and mandatory in the upstream policies of the Islamic Republic of Iranian Railway Company, which construction projects have more prioritization and justification for privatization? The private sector can take measures to solve the capacity problems of railway network with three main approaches: only improvement of the existing railways, only construction of infrastructures, and a combination of the two first approaches.

In order to answer this question, PCPRN algorithm was implemented for each of the projects of constructing new infrastructures. In the first sub algorithm (identification of the corridors with high potential railway demand) the values of Tr_1, Tr_2 and Tr_3 according to the terms of Iranian railway are considered as 6.5 million tons, 15%, and 0.5, respectively, the cost of constructing new infrastructures was calculated. After incremental assignment with considering capacity, economic analysis was executed based on the net present values NPV_1 and NPV_2, which were calculated based on costs and benefits of transferring units of ton-kilometer freight demands from road to railway transport system.

Table 4. Classification Projects of constructing new infrastructure in Iranian railway according to improvement or lack of improvement of capacity

Type of selected closed railway perspective	The number of construction projects with prioritization in terms of		
	Absorbed railway demand	Direct benefits	Direct and indirect benefits
The project of constructing new infrastructure with capacity improvement solutions	9	7	9
The project of constructing new infrastructure without capacity improvement solutions	1	3	1

The results showed that in order to prioritize the construction projects, the intended objective should be first determined. Whether the objective is to absorb more demands or to justify privatization in terms of direct benefits (NPV_1) or direct and indirect benefits (NPV_2), construction projects are differently prioritized. It should be noted that the absorbed demand criterion cannot be considered as an appropriate criterion for prioritization of construction projects, because of its weakness to consider the costs. Construction projects prioritization based on NPV_1 only considers the direct benefits of the projects, while the transfer of the freight demands from road to railway transport system leads to increase the certain benefits from the perspective of indirect (national) interests. Therefore, in this study construction projects prioritization is considered based on NPV_2. In other words, assigning construction projects to private sector can be done by considering all the costs, direct and indirect benefits. Table 5 presents the results of construction projects prioritization according to the criterion of NPV_2.

It needs to be mentioned that the basic demand absorbed to the network without applying any construction project is equal to 40.42 million tons. In response to the second basic question, prioritization based on NPV_2 (Table 5) showed that the projects of constructing Garmsar–Badroud and Yazd–Eghlid railway projects along with the capacity improvement solutions, has obtained the greatest priority for the privatization. In this case, NPV_2 and absorbed railway demand indices are equal to 221 thousand billion riyals and 52.18 million tons, respectively.

It is understood from Table 5 that the construction of new infrastructures without capacity improvement solutions will not necessarily be the best possible option to increase absorbed railway demand. Fig. 6 shows the railway network corridors in terms of potential railway demand (according to the first sub algorithm). Fig. 7 illustrates the capacity package associated to the construction of Garmsar–Badroud and Yazd–Eghlid projects by considering the capacity improvement solutions (according to the third sub algorithm).

Conclusions

This study aimed to develop a new methodology for prioritizing the projects of constructing new railway infrastructures to be assigned to the private sector. The private sector participation includes both capacity improvement solutions of the current network, and constructing new railway infrastructures. In order to calculate the capacity of railway network, the method of UIC405 was applied. The freight demand matrix was assigned to the railway network by means of “traffic assignment” process. Then, incremental assignment (IA) with considering capacity and All-Or-Nothing assignment (AON) were implemented and the capacity bottlenecks of the network were identified. Economic analysis was performed based on the net present value. The obtained profits are calculated in two states: direct benefits (NPV_1), as well as both direct and indirect benefits (NPV_2). NPV indicators were calculated for a 30-year duration, a discount rate of 10%. The review of the top 10 prioritized construction packages showed that the construction of new infrastructures by considering capacity improvement could have better payoffs, in comparison to projects of merely constructing new infrastructures without capacity improvement. Prioritization of construction packages in terms of NPV_2 index showed that among the top 10 prioritized projects, the first to ninth priorities are related to the construction projects with capacity improvement solutions and the tenth priority is related to the project implementation without the improvement of railway network capacity. In order to prioritize the projects of constructing new infrastructures based on the governmental authority policies, NPV_2 was considered as the main criterion for prioritizing the construction projects. The projects of constructing Garmsar-Badroud and Yazd-Eghlid railway projects along with the capacity improvement solutions, obtained the greatest priority for the privatization. NPV_2 and absorbed railway demand indices are respectively equal to 221 thousand billion riyals and 52.18 million tons for this case. Examining all of ten prioritized packages showed that simultaneously with the construction of new railway projects, the improvement of capacity in existing network should be taken into account. Implementing construction projects leads to the increase of absorbed railway demand on one hand; however, the high cost of investment in construction projects should be considered on the other hand.

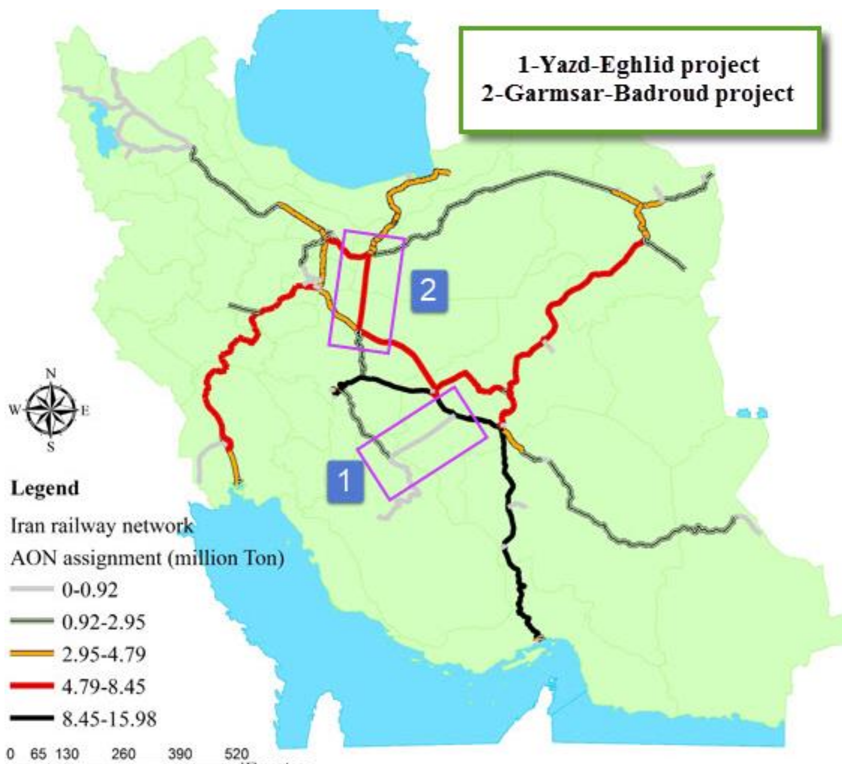

Figure 6. Corridors with high potential railway demand in the project of constructing Garmsar–Badroud and Yazd–Eghlid projects

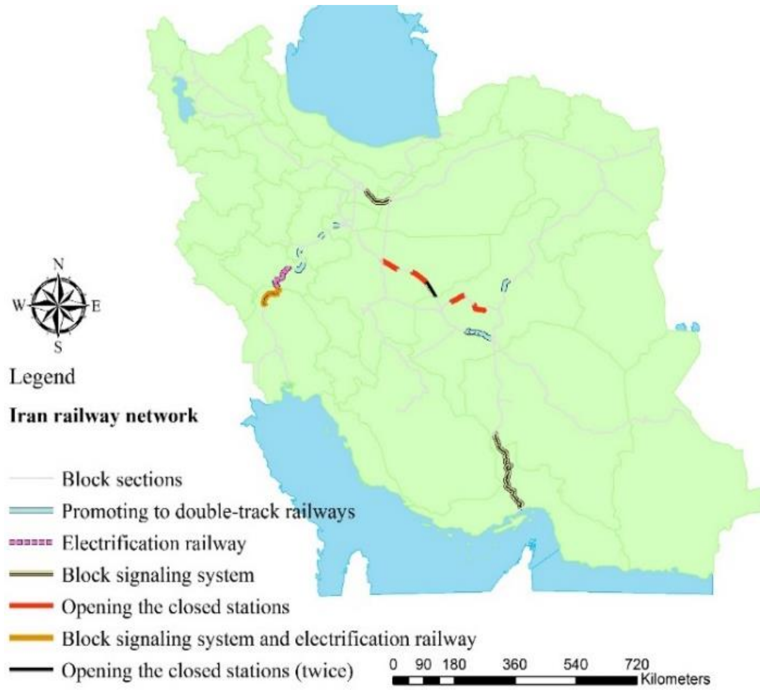

Figure 7. Capacity package in the project of constructing Garmsar – Badroud and Yazd – Eghlid projects by considering capacity improvement solutions

Table 5. Top ten prioritized packages of constructing new infrastructures

	Prioritization of construction packages	Absorbed demand (Million tons)	NPV_1Index (Billion riyals)	NPV_2 Index (Billion riyals)
1	Constructing Garmsar-Badroud and Yazd-Eghlid projects + improving capacity	52.18	2.62E+04	2.21E+05
2	Constructing Yazd-Eghlid project + improving capacity	50.34	2.68E+04	2.14E+05
3	Constructing Isfahan- Azna and Yazd-Eghlid projects + improving capacity	49.19	1.57E+04	1.81E+05
4	Constructing Gorgan-Mashhad project + improving capacity	48.90	4.35E+03	1.75E+05
5	Constructing Isfahan-Ahvaz and Yazd-Eghlid projects + improving capacity	48.86	6.20E+03	1.75E+05
6	Constructing Isfahan-Ahvaz project + improving capacity	46.53	3.10E+02	1.65E+05
7	Constructing Isfahan-Azna project + improving capacity	48.16	1.42E+04	1.58E+05
8	Considering 5 construction projects + improving capacity	49.62	-3.18E+04	1.46E+05
9	Constructing Garmsar-Badroud project + improving capacity	46.69	9.25E+03	1.27E+05
10	Considering 5 single construction projects	46.72	-3.96E+04	8.81E+04

7. References

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8. Appendix

Isfahan-Ahvaz corridor was selected as one of the new railway construction projects, presented in Table 3. Figure A1 shows the results of AON assignment associated to this corridor.

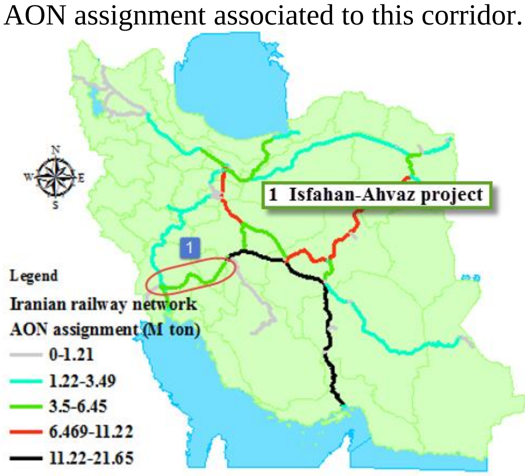


Figure A1. The result of AON assignment, considering Isfahan – Ahvaz corridor

The corridors with high amounts of potential demand (obtained from the proposed sub algorithm shown in Figure 2) are illustrated in Figure A2. The first sub algorithm was run for each the selected corridors. In Figure A3 to A8, the result of AON assignment in six corridors given in Figure A2 is shown

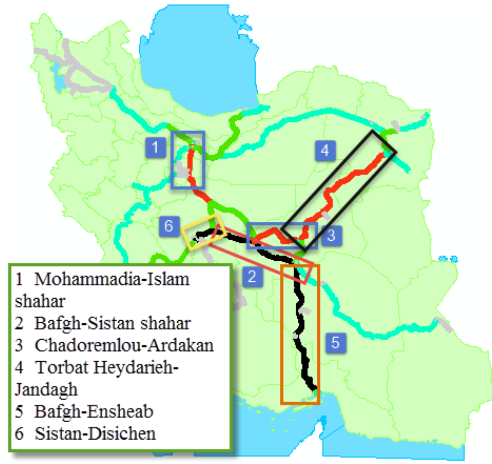
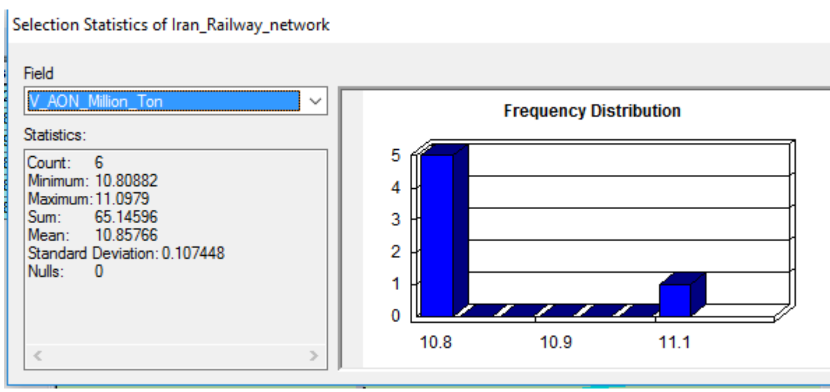


Figure A2. The corridors with high amounts of potential demand in Isfahan – Ahvaz project



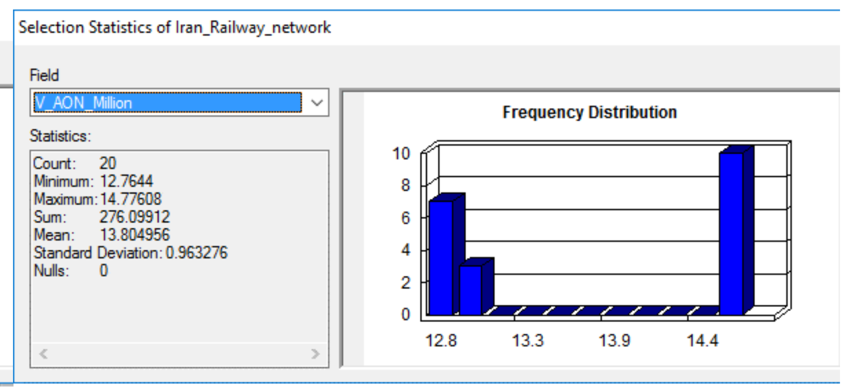


Figure A3. The result of AON assignment in Mohammadia-Islam shahar route

Figure A4. The result of AON assignment in Bafgh-Sistan route

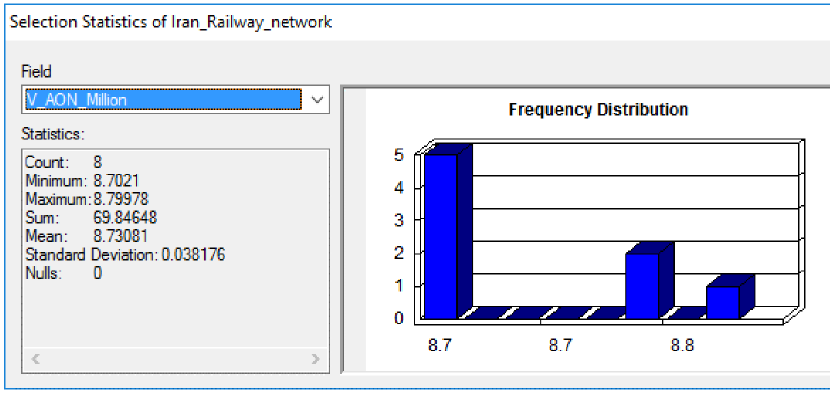


Figure A5. The result of AON assignment in Chadoremlou-Ardakan route

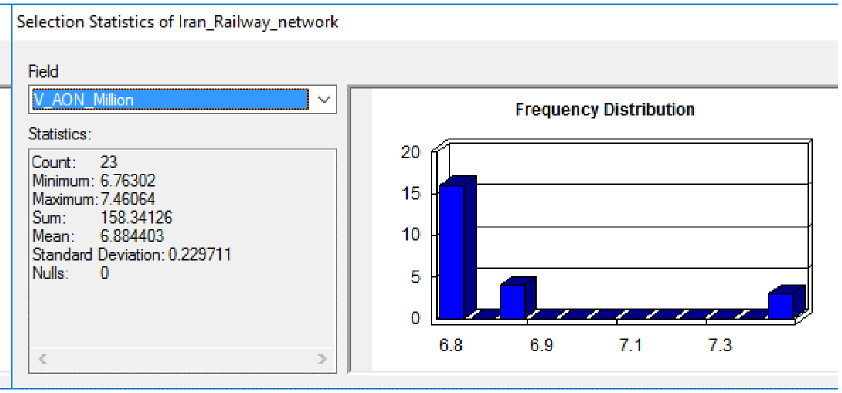


Figure A6. The result of AON assignment in Torbat Heydarieh-Jandagh route

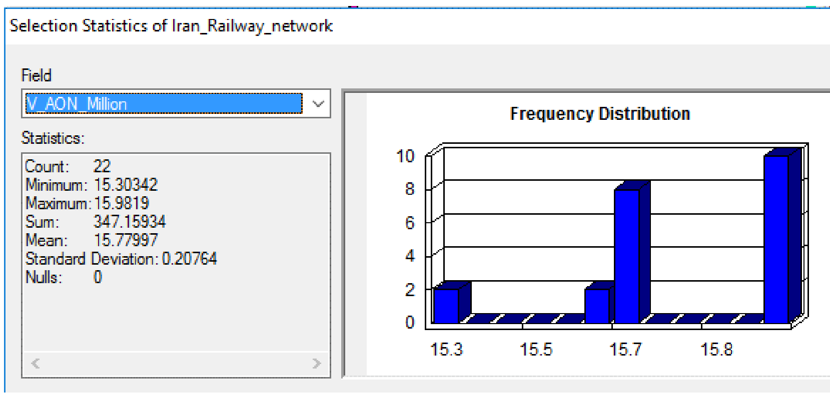


Figure A7. The result of AON assignment in Bafgh-Ensheab route

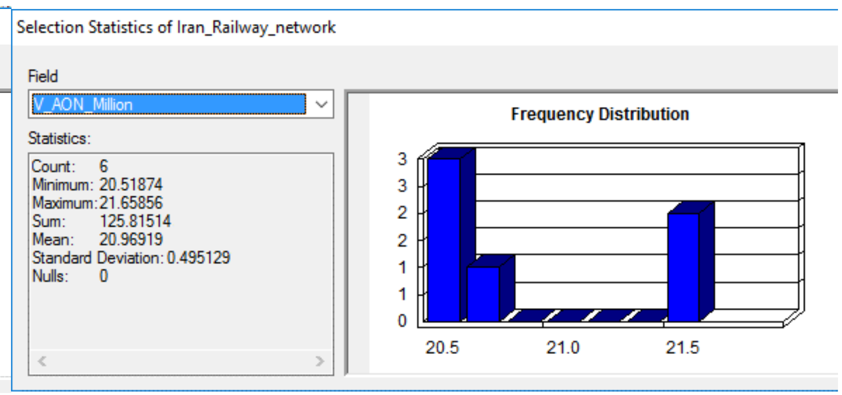


Figure A8. The result of AON assignment in Sistan-Disichen route

In the Table A1, the final result of calculate the mean, standard deviation and standard error are shown.

Table A1. the result of constructing the railway corridor of Isfahan-Ahvaz.

selected corridor	mean (Million tons)	standard deviation	$(\frac{Standard\ devition}{mean})\%$	standard error
Mohammadia-Islam shahar	10.86	0.11	1.01	0.04
Bafgh-Sistan	13.8	0.96	6.96	0.21
Chadoremlou-Ardakan	8.7	0.04	0.46	0.01
Torbat Heydarieh-Jandagh	6.88	0.23	3.34	0.05
Bafgh-Ensheab	15.78	0.21	1.33	0.04
Sistan-Disichen	20.97	0.5	2.38	0.20