International Freight demand forecast of Tajikistan Railway Feasibility Study Project*

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Abstract

International freight demand forecast and finding the potential of a new infrastructure in attrackting the traffic from opponent routes are two of the main responsibilities of transport planners, in international transportation projects. These are important for justifying the huge investment required for building a new transport infrastructure as a link in a global transit corridor. On the other hand, for designing the network and its technical requirements also, such data are essential. These forecasts require upstream regional transportation studies and detailed information on foreign trade between countries in zone of influence of such projects, in terms of both tonnage and value, which are not easy to achieve in most cases. Before this study, such forecasts were mostly done based on scenario planning and scattered data which gathered from some rare sources available in this respect. Of course, the accordance of these data with real operation is always a big question. In this paper, for the first time, base on reliable international sources, besides preparation of commodity flow matrix between countries in zone of influence of Tajikistan's New Railway line, using two different models of elasticity and time series, the international freight demand for this transit route was forecasted in form of an international contract for the next 20 years. For this purpose, we used ArcGIS software's capabilities besides our calibrated EMME2 transport model.

Key words: ***International freight transport demand forecast, Transit routes, foreign trade, Zone of influence, Elasticity model, Tajikistan railway project, ArcGIS, EMME2***

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* The Proposed project inTtajikstan is part of corridor between china and Europe that crosses from Kyrgyzstan-Ttajikstan – Afghanistan – Iran. The lengh of this route will be about 690 km.
Kashghar- irkeshdam (in china) – saritash karamic (Kyrgyzstan) – jirgatal – tajikabad- noorabad – abigharm-feizabad – yanghibazar iliyak station – kurghan tubeh – kalkhozabad – nighnipanj (in tajikstan) – shirkhan Bandar – kundoz- mazari sharif – heart (in afghanistan).

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Introduction

Nowadays, transportation is one of the main foundations of sustainable and balanced development of most countries, as transport networks are closely correlated with important factors like economy and security. A review on the process of socio- economic development of countries will show the influence of transport development on economic growth.

Transport sector is the interface of most economic activities. In other word, value added of all economic activities, are directly or indirectly influenced with transport sector activities. Indeed, development of economic sectors of the country like industry, mining and agriculture as well as tourism industry won't be possible without development of transport sector.

Different modes of transport, with their special specifications, have an important role in movement of goods. Railway mode, because of its obvious advantages, like less environmental pollutions, better safety in comparison with other modes, less land acquisition and lower fuel consumption, will provide more social benefits to society. That's why most of the countries support this mode of transport.

Study is the stepping stone of implementation. For this purpose, access to accurate statistics and information besides using analytical softwares, are key factors for better studying the feasibility of transport infrastructure networks. In this paper, we have tried to use GIS software capabilities, as a strong instrument for doing descriptive - locational analysis and also a well known tool for preparing a decision support system (DSS), besides our well developed EMME2 tansport model to better forecast the international transport demand of Tajikistan new railway project.

In this paper, international sources and valid internet websites in the field of transit and transport besides available internal statistics have been used.

Figure 1- *Location of Tajikistan Rail project in Asia-Europe transit corridor and in respect to economic zones of China*

1- Main steps toward International freight demand forecast

One of the first steps of any feasibility study, especially when development of a new line is under study is with no doubt, getting reliable information about the flow of people and goods through it. As Tajikistan railway network does not exist so the next step will be assessing the potential of the new infrastructure to absorb traffic of the previous lines in the region. For this purpose we assumed that the rest of the network from Tajikistan to China and South East Asia and also to Europe is complete so freight traffic can choose this route as an opponent for traditional marine route. Then using transportation planning software of emme2 we assigned the freight traffic of 2010 to the network of Asia – Europe in which besides rail lines, road network and marine route also exist. The assigned traffic show us the potential of new railway line of Tajikistan to get traffic shifted from other previous lines. In this step we also found ODs that with high probability will use the new line. The final step was forecasting of the future traffic of the new line per direction, which will be used as an input for the operation and fleet group of consultant to calculate the required facilities and installations.

2- Commodity Flow Matrix (CFM) of Asia-Europe

For the purpose of international freight demand forecast, first of all we need to have reliable information about transport tonnages by commodity types. Preliminary searches showed us that most of recorded statistics regarding trade flows between countries are expressed in terms of value, not in tonnage. The only reliable source which had some data on trade flows by OD countries and tonnage was euro-stat. But, detailed investigations by technical team showed there are a lot of missed data especially for CIS countries. It means that even for flows that we are sure of them; there were no data on the database. The other point regarding euro-stat database was that, the data scope only includes trade flows between Europe and other countries, but we know that besides Europe, trade flow between Middle East or north east African countries and south East Asia also can use the new line, and these data does not exist in the specified database.

When it was clarified that euro-stat database can't be used, technical team decided to change the methodology to produce CFM. In this respect, we used WTO and World band data bases which had trade flows By OD countries and type of commodity for an acceptable time series, but only in value in terms of US dollar. On the other hand, we investigated to find a logical relation between value and tonnage of different commodity types to convert value to tonnage. For this purpose, we checked different sources on internet and confronted with IMF data series which is one the most reliable data sets, providing the required data but for a small range of goods. Then we discussed to see if this method may result in required information or not. The result of our brain storming session convinced us to search more to find real data. In this stage we found UN comtrade data base which helped us a lot to get what we wanted.

2.1. UN Comtrade, the coverage and limitations of the data

2.1.1. Coverage

The United Nations Commodity Trade Statistics Database (UN Comtrade) contains detailed imports and exports statistics reported by statistical authorities of close to 200 countries or areas. It concerns annual trade data from 1962 to the most recent year. UN Comtrade is considered the most comprehensive trade database available with more than 1 billion records. A typical record is – for instance – the exports of cars from Germany to the

United States in 2004 in terms of value (US dollars), weight and supplementary quantity (number of cars). The database is continuously updated. Whenever trade data are received from the national authorities, they are standardized by the UN Statistics Division and then added to UN Comtrade.

2.1.2. Limitations

UN Comtrade is available to the general public and should be used with good knowledge of its limitations. Please read the following points:

1. The values of the reported detailed commodity data do not necessarily sum up to the total trade value for a given country dataset. Due to confidentiality, countries may not report some of its detailed trade. This trade will - however - be included at the higher commodity level and in the total trade value. For instance, trade data not reported for a specific 6-digit HS code will be included in the total trade and may be included in the 2-digit HS chapter. Similar situations could occur for other commodity classifications.

2. Countries (or areas) do not necessarily report their trade statistics for each and every year. This means that aggregations of data into groups of countries may involve countries with no reported data for a specific year. UN Comtrade does not contain estimates for missing data. Therefore, trade of a country group could be understated due to unavailability of some country data.

3. Data are made available in several commodity classifications, but not all countries necessarily report in the most recent commodity classification. Again, UN Comtrade does not contain estimates for data of countries which do not report in the most recent classification.

4. When data are converted from a more recent to an older classification it may occur that some of the converted commodity codes contain more (or less) products than what is implied by the official commodity heading. No adjustments are made for these cases.

5. Imports reported by one country do not coincide with exports reported by its trading partner. Differences are due to various factors including

valuation (imports CIF, exports FOB), differences in inclusions/ exclusions of particular commodities, timing etc.

2.1.3. Data attributes

The data that extracted from UN data base includes following attributes:

REPORTER	REPORT_NAM	PARTNER	PARTN_NAM	TRADE flow	COMM	COMMODITY_NAM	SUMOFNETWE (kg)	SUMOFVALUE

Reporter, reports the foreign trade flow including its partner, type of commodity, weather it's inward or outward and also the value and tonnage of trade.

3. Scope of the work and external zones of influence

With respect to our study, the international railway project of Tajikistan is situated in the middle of Asia-Europe transport corridors. The zone of influence of this line will cover most of European, Asian and also some of African countries.

The initial step toward building CFM Tajikistan, we should find zone of influence or OD pairs which had transactions with each other in previous years and may use the new corridor, if it will be more economic. Doing this, all countries in the list of comtrade data base were thouroghly checked and almost all europian countries, some African countries and most of Asian countries were selected. Then in the next step some countries like china splited into smaller zones and finally 131 zones were taken into account as follows:

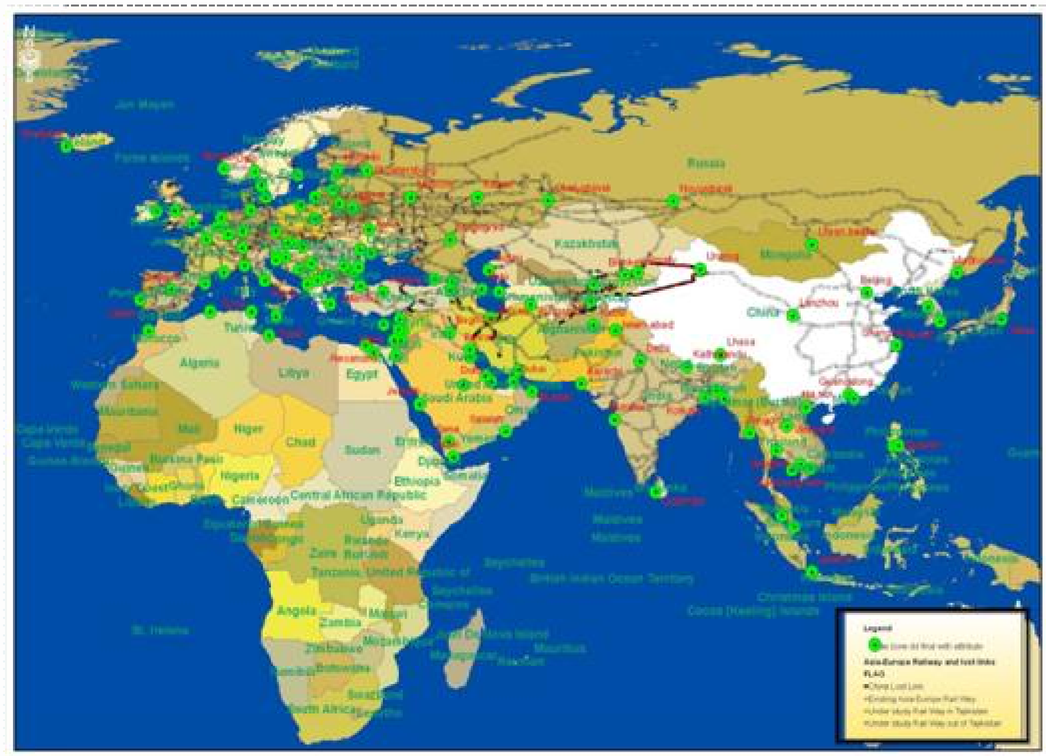

Figure2. *Under Study Zones*

Then all the commodity flows between these countries for 2010, were extracted from the data base.

4. Data Correction and Network Assignment

4.1. Data Correction

As it was described in the limitation of database heading, the data from reporter about their import and export does not necessarily match the data from partners. It means that for example, total import of country A from country B, when country A is reporting this transaction, may not match export of country B to A as it's reported by B. In some case even there are some missed data it means that for example country B as a reporter doesn't reported any export to A. In such cases if there is a record reported by a country about it's trade with another country (which was not reported), we have taken into account that this flow exist. When the amounts reported by each two pairs in the commodity flow do not match each other, we have taken into account that the bigger amount has been transported.

Also, as we were working with a huge data base that for some countries in each year the records of data were more than 300,000 records, we tried a lot to merge the data records and make it smaller. Then we assigned this merged matrix on the complete network of Asia- Europe including all Rail, Road and possible marine routes, and found the potential of Tajikistan new rail line in absorbing traffic from other opponent routes. This process is discussed in detail, in the next part.

4.2. Assignment

4.2.1. Network preparation

This section describes the methodology of building a freight planning network by utilizing the DCW spatial database for the subsequent freight assignment modeling task. An exclusive freight network was developed to support a comprehensive freight analysis. This analysis in turn was used to identify system-wide capacity deficiency elements for the nation's highways, railways and see ways to synthesize freight movement related to capacity issues. The geospatial coverage of the Asia - Europe network was developed by using of DCW database which is a comprehensive geographic information system (GIS)-based network database of the nation's major road and rail networks. It represents more than 492,000 km of the nation's highways and 236,000 km railways and include only 66000 km see ways. This aggregated network includes basic attribute data such as length, number of lane, speed, marginal cost, type, etc which is used for assignment algorithm in transportation soft ware. Figure 3 Shows Asia – Europe Transportation Base Networks including Road, Rail and See ways.

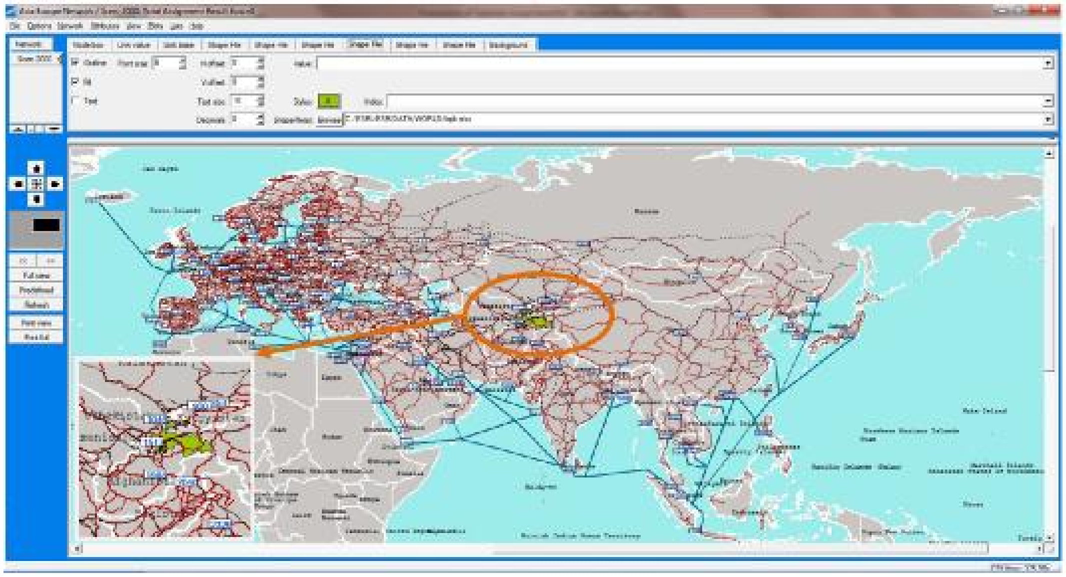

Figure3. *Asia – Europe Transportation Base Network*

A line layer (or network) in a map consists of many line features, each of which begins and ends at a point called an “endpoint,” and each of which is defined by a series of coordinates. Each line feature has two directions. These are the topological direction and the flow direction. The topological direction of a line feature is defined by the order in which the coordinates appear. If the beginning coordinate of a line feature is A and the ending coordinate is B, the topological direction of the line is AB and the opposite direction is BA. However, both “topological” and “flow direction” are important features for a network to be used in freight assignment procedures.

The “topological” direction ensures quality integration of network data that are collected in some fashion of topological or survey chain direction. Typically, most important component of network development is node and link connectivity.

Asia - Europe network development utilizes both Transportation and GIS software programs with custom macros to ensure proper topological and flow direction including network connectivity. For flow direction, appropriate one-way pairs were added to links for those cities with population greater than or equal to 100,000.

The outcome of this task was a routable transportation network ready to load with traffic volume and other attributable information required for the development of subsequent link parameters that are themselves required for freight assignment.

4.2.2. The Cost and Time Function

EMME/2 allows the use of a wide variety of functions, which may be specified for links as well as for transfer nodes, to represent the various factors, such as cost, time, reliability, energy, possible environmental or hazardous impacts, etc., that determine how the transportation system is used to move the demand. Up to three functions may be specified on a link (transfer) for each product defined in the current scenario. Link and transfer functions are unit cost functions.

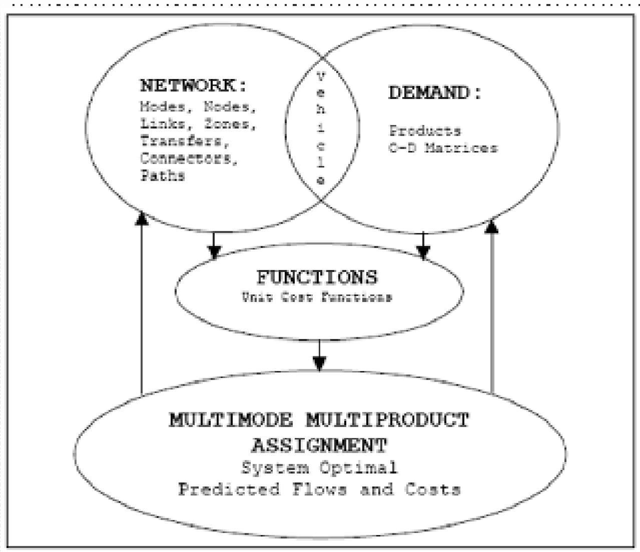

Figure4. *The main elements of the EMME/2 modeling framework*

They are multiplied by the product volumes, and then combined according to user specifications, to form the generalized cost objective function used to assign the commodities to the multimodal network.

Travel time on a given link is estimated by dividing its length by the travel speed on that link. Therefore, travel time for a given link changes as the travel speed fluctuates. The speed of a given link can also be affected by roadway type or other conditions as indicated earlier. Consequently, this reduced speed would introduce a penalty to the initial link travel time. Thus the impedance function of a link can be mathematically expressed as:

$$T_j = \frac{L_j}{S_j} r_j + f_j$$

Where
T_j = the link free flow travel time
L_j = the length of link j in km
S_j = the free flow speed on link j in km-per-hour
r_j = travel time adjustment factors, which is a function of the number of lanes, urban bypass, traffic restriction, truck route designation, tolls, and the link reliability
f_j = the penalty.

It is clear that the unit costs for each type of commodity an for each country and also for distances less then 200 km and grater then 200km are different. In this study, the average unit costs that were taken into account are base on Traceca WebGIS information as follows:

- For roads per 1ton kilometer is around 5 Cent(USD)
- For railways per 1ton kilometer is around 3 Cent(USD)
- For sea routes per 1ton kilometer is around 1.15 Cent (USD)

4.2.3. Link Capacity

The capacity of a given link can be defined as the a maximum sustainable flow rate at which freight reasonably can be expected to traverse a point or uniform segment of a lane or roadway, railway or sea route during a specified period of time, under given topographic, traffic composition and environmental conditions; this capacity is usually expressed as total tonnage per year. In this paper we assumed 27 million tones of capacity for Roads, 11 million for Railways and 912 million tones for sea routes from starting point in south East Asia to Europe.

4.2.4. Freight Assignment

This chapter describes the processes of network preparation for freight demand modeling and associated freight assignment procedures and calibration.

Traffic assignment models are used to estimate the flow of freight on a network to establish the traffic flow patterns and analyze congestion points. Intra-zonal movements (local traffic) are not included in the assignment process. Even though the highway capacity analysis is focused on a detailed assessment of freight flows and impacts on the highway system, highway and rail way bottlenecks are highly dependent on the interaction of total freight traffic. In this regard, freight flows are assigned on the freight analysis network. Detailed demand analysis of passenger traffic was not performed as part of this study. The assignment model and procedure applied to the freight demand modeling are described in the following sections.

4.2.5. Assignment Algorithm

The Stochastic User Equilibrium (SUE) traffic assignment procedure in EMME/2 with user defined volume delay function (VDF) is used. This assignment is constrained by the transportation network's current capacity. The SUE is a generalization of user equilibrium (a modified capacity constraint approach) that assumes travelers may not have perfect information concerning network congestion and delay and/or perceive travel costs in different ways; therefore, they may change the travel pattern by taking alternate routes as the network (or a specific link of a network) gets congested. The selected VDF for assignment is the Bureau of Public Roads (BPR) function. The general form of the BPR function is shown in following equation:

$$t = t_i \bullet \left[1 + \alpha_i \left(\frac{x_i}{C_i} \right)^{\beta_i} \right]$$

Where:

t = Congested travel time
ti = Free flow travel time on link i
Ci = Practical Capacity of link i
xi = Flow on link i
αi = Calibration constant
βi = Calibration constant.

As it was easier for us to assume the total approximate capacity of a link from very beginning to its end, we used modified BPR function by Dowling, in this form of BPR, α is equal to 0.2 for arterials and β is 10

4.2.6. Assignment functions and results

Speed Assumption: Road = 40 km/h   Rail = 30 km/h   Sea= 10 km/h

Cost Function 1: Fd= (length/speed)*unit cost

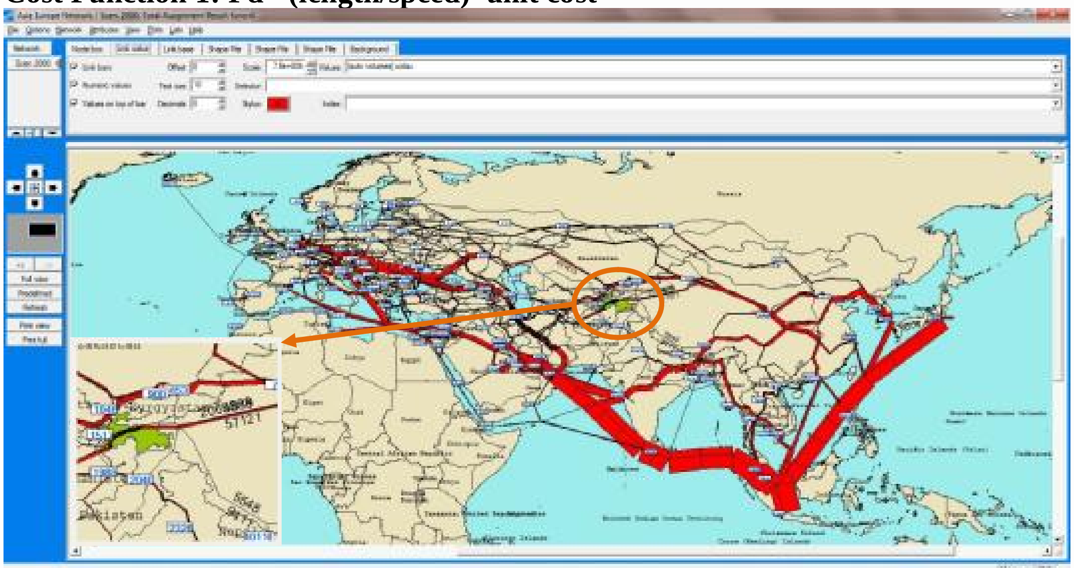

Figure5. *Assignment result of cost function 1*

Cost Function 2: Fd= (length/speed)*unit cost*(1+0.2*(volau/capacity)^10)

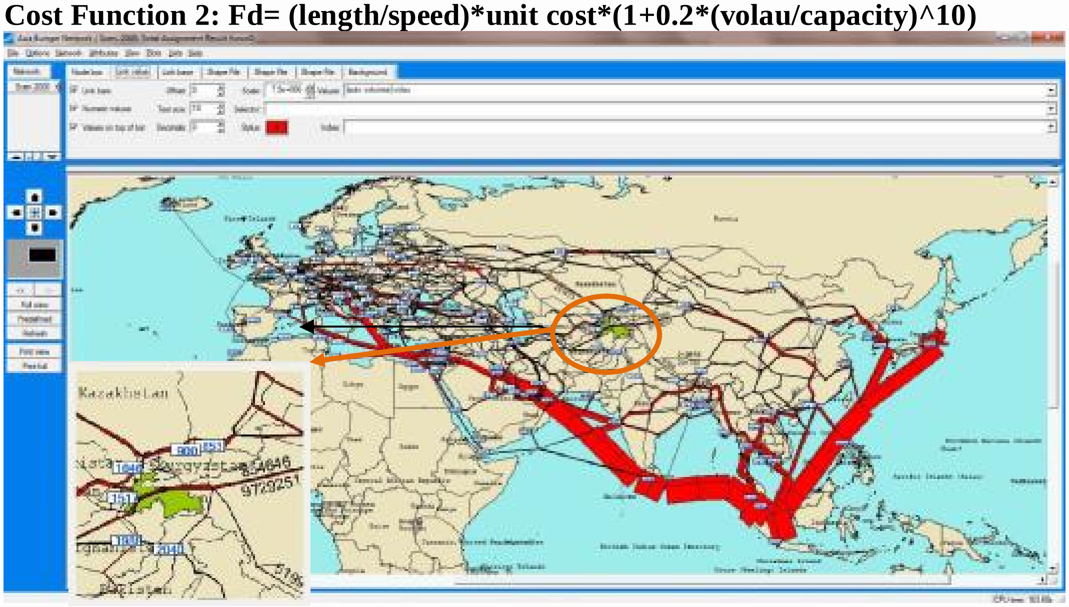

Figure6. *Assignment result of cost function 2*

Cost Function 3: Fd= (length/speed)*(1+0.2*(volau/capacity)^10)

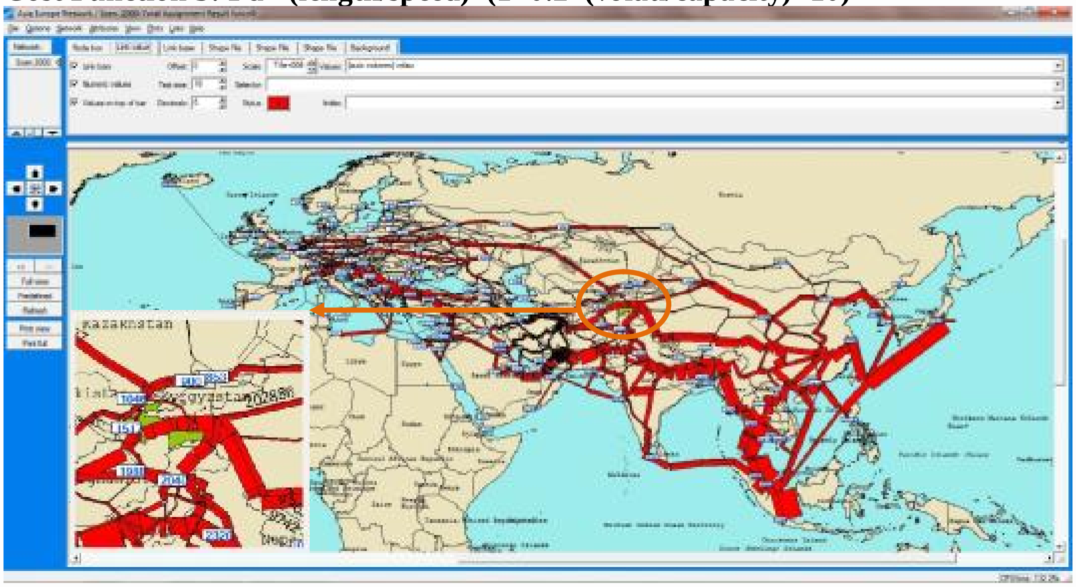

Figure7. *Assignment result of cost function 3*

Table1. *Final results of assignment based on different functions*

Function	Mode Choice via Tajikistan	Iteration	Volume (Ton) Direction : East2West	Volume (Ton) Direction : West2East
(Length/Speed) * Unit Cost	Rail via under study corridor	15	6510	3297161
	Road (Paralel Choice)	15	18118	57268
(Length/Speed) * Unit Cost*(1+0.2*(volau/Capacity)^10)	Rail via under study corridor	15	200855	3011057
	Road (Paralel Choice)	15	472336	12711402
(Length/Speed) *(1+0.2*(volau/Capacity)^10) بدون هزینه	Rail via under study corridor	15	248634	5841838
	Road (Paralel Choice)	15	1561004	28711118

5. Modal split

As we used real data on both transport times and costs for each mode of transport on its own network based on data that achieved from Traceca website, the modal shift and assignment processes are done simultaneously and by running the transport software, the share of each mode besides traffic of each link will be resulted.

6. International traffic forecast

After assignment process, the amount of traffic assigned to the new line will clarify, and then the next step is calculation of future traffic. For this purpose, using ArcGIS software capabilities and using the same formula that was used in assignment stage, we checked each OD pair to see whose traffic will use the new corridor. It means that inside of the initial zone of influence which was an 87 to 87 matrix we shorten the list to reach to real users of the new corridor. Result of this process showed us that among the initial list of countries, Eastern Europe, some of North African, some of Middle East countries and on the other side some of Asian (east part) countries will use the new corridor. The reason is that the traditional marine route between Asia and Europe uses economy of scale so it is cheaper than other alternatives and will handle most of the commodities in between Western Europe and Eastern Asia. The list of these countries is as follows:

Table2. *Country groupes in each region*

East Asia	East Europe	Middle east & North east Africa
China	Azerbaijan	Bahrain
China, Macao SAR	Armenia	Egypt
Rep. of Korea	Albania	Iran
Japan	Bosnia Herzegovina	Kuwait
nepal	Bulgaria	Lebanon
Philippines	Cyprus	Libya
Kazakhstan	Georgia	Qatar
	Greece	Saudi Arabia
	Romania	Syria
	Russian Federation	Turkmenistan
	Serbia	United Arab Emirates
	TFYR of Macedonia	
	Turkey	
	malta	

With this short list, we are sure that most of the assigned traffic to Tajikistan new rail line will be from trade flows between these countries. Then the time series of commodity flows between these countries for a 10 years' time interval was extracted from data base which used as a bases for future traffic forecasts.

For future traffic forecast, two seprate methods were used one of these method was time series analysis and finding growth rate based on real 10 years data available and the other method was calculation of elasticity between trade flows and GDP of Tajikistan.

Table3. Time series of trade flow between Country groupes in zone of influence of Tajikistan

Year	Eastern Asia from/to Eastern Europe		Eastern Asia from/to MiddleEeast, NorthAfrica		Eastern Asia from/to EE/ME,NA		Total	Tajikistan GDP/Capita
	1	2	1	2	1	2		
2000	44,729,742,869	52,179,782,248	340,698,585,106	10,134,943,579	385,428,327,975	62,314,725,827	447,743,053,802	883
2001	58,208,462,439	55,415,287,349	348,333,596,428	12,652,171,191	406,542,058,867	68,067,458,540	474,609,517,407	975
2002	67,558,758,979	60,251,285,915	332,068,930,566	15,493,091,406	399,627,689,545	75,744,377,321	475,372,066,866	1059
2003	75,280,955,253	24,527,477,096	367,036,272,968	14,443,779,624	442,317,228,221	38,971,256,720	481,288,484,941	1168
2004	89,937,303,001	70,046,295,049	272,039,753,524	14,513,550,146	361,977,056,525	84,559,845,195	446,536,901,720	1297
2005	93,397,163,359	66,245,462,833	278,954,165,044	22,663,366,097	372,351,328,403	88,908,828,930	461,260,157,333	1398
2006	90,739,997,326	80,245,305,914	415,908,557,068	37,617,324,338	506,648,554,394	117,862,630,252	624,511,184,646	1513
2007	109,305,048,289	83,264,081,905	409,389,921,908	46,335,404,851	518,694,970,197	129,599,486,756	648,294,456,953	1643
2008	117,036,200,017	90,018,313,082	430,660,810,372	49,347,327,450	547,697,010,389	139,365,640,532	687,062,650,921	1773
2009	120,622,175,386	70,134,954,750	416,755,226,244	36,360,770,419	537,377,401,630	106,495,725,169	643,873,126,799	1823
2010	129,280,746,464	22,248,055,895	437,516,192,129	37,688,425,590	566,796,938,593	59,936,481,485	626,733,420,078	1924

1: Import 2: Export

7- Conclusions

Time series calculation shows that the growth rate for import of Eastern Asia from/to EE/ME, NA is 3.9% and for the other side this growth rate is 5.5.

Te results of time series analysis and elasticity are shown in the following figures. The difference between results of these two methods in 2031 is about 17 percent, so to be in safe side we used the results of times series analysis.

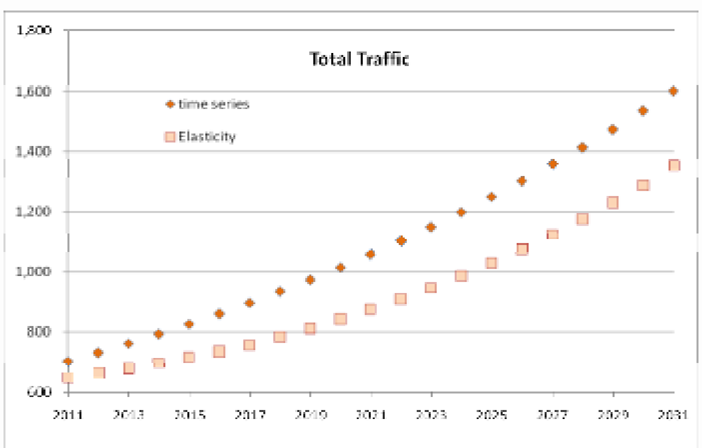

Figure8. *Results of Total freight demand forecast using two different models*

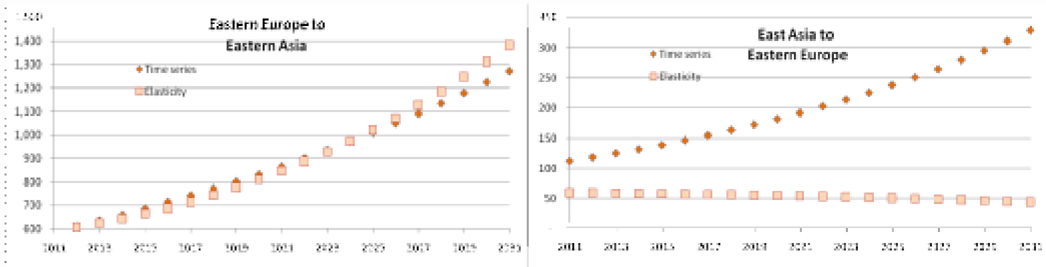

Figure9. *Results of directional demand forecast using two different models*

Based on the growth factors calculated in this process, in the following table the final results of Tajikistan new rail line traffic forecast is presented.

Table4. *International freight demand forecast of Tajikistan new rail line*

No.	Year	Future Traffic of Tajikistan new rail line	
		Eastern Europe to Eastern Asia	East Asia to Eastern Europe
1	2011	3.756.778	212.018
2	2012	3.904.486	223.690
3	2013	4.058.002	236.005
4	2014	4.217.554	248.998
5	2015	4.383.379	262.706
6	2016	4.555.724	277.168
7	2017	4.734.845	292.427
8	2018	4.921.009	308.526
9	2019	5.114.493	325.511
10	2020	5.315.584	343.432
11	2021	5.524.581	362.338
12	2022	5.741.796	382.286
13	2023	5.967.551	403.332
14	2024	6.202.182	425.537
15	2025	6.446.038	448.964
16	2026	6.699.483	473.680
17	2027	6.962.892	499.758
18	2028	7.236.658	527.271
19	2029	7.521.188	556.298
20	2030	7.816.905	586.924
21	2031	8.124.249	619.236

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