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Economic Cost Analysis of Freight Transport between Istanbul and Frankfurt In Terms of Transportation Modes

Ufuk Kırbaş[1*], Emine Baş[2]
[1](Department of Civil Engineering, OndokuzMayıs University, Turkey),
[2](Department of Civil Engineering, OndokuzMayıs University, Turkey)
Corresponding Author:UfukKırbaş[*]

Abstract: *Turkey is an important stopping point for the distribution of Russian and Middle East energy resources, agricultural products grown in the Middle Eastern lands, and commercial products, which are produced cheaper in Asia and the Middle East, than Europe and the world. However, the existence of a transportation system that is dependent on the highway transportation and, therefore, an unbalanced transportation network causes serious problems. In order to overcome these problems, the transportation system should be considered as a whole. Transportation systems should be planned in such a way as to ensure coordinated operation of the country's resourcesand also, the modes of transport must be fast, economic, safe andsensitiveenvironmentally. In this study, transportation modes (in Turkey)were compared with each other in terms of freight transport, CO_2 emission and distribution of investments. Later, cost analysis for each mode of transportation was carried out separately, followed by cost analysis for multimodal transportation systems. The cost analyses were carried out using, a "Valued Cost Analysis" method. A scenario analysis also has been carried out in this study framework. According to this scenario, it is assumed that 19000 tons of cargo is carried in Istanbul - Frankfurt route. The costs calculated for carriages made by only highway, only railway, seaway and highway together and railway and highway together separately; these costs are compared with each other and the lowest cost mode of transportation is determined.*

Keywords: *Cost Analysis,Highway, Railway, Seaway,Transportation*

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I. Introduction

Highway transport in our country has shown a very rapid increase especially in recent years. This increase is too rapid to compare with other modes of transportation. In fact, almost 90% of freight and passenger transport are done by highway. One of the most important reasons for this increase is that the highway demand creates its own supply. This has provided free market conditions. Therefore, the highway network system and transport conditions (both for cargo and passenger transport) have improved considerably compared to other modes of transport. However, nowadays, it is seen that this increase creates threats within itself compared to other modes of transportation.

Especially in recent years, when we look at the world, intermodal transportation systems that provide integrated, economical and safe transportation are increasing and encouraged.Inter-species transport systems can be used together with highway, railway and seaway if necessary. These integrated transport systems are designed to ensure that they are transported with lower costs.

This study mainly focuses on this unbalanced distribution among transportation modes and the magnitude of this problem is illustrated by comparing it with the transport systems of other countries.In this study,it is aimed to emphasize that the cost and environmental damage of Highway-weighted freight transportation, which exists in Turkey, are excessive.In the last part of the study, cost analysis of transportation modesin terms of freight transport, it is applied to the default freight transport scenario between Istanbul and Frankfurt, the most suitable transport system was questioned.

II. Comparison of Transportation ModesIn Turkey

Domestic Freight Transportation of Transportation Modes by Year 2015

Table 1 shows the freight transport data according to the year 2015 transport modes in Turkey [1]. As can be seen in the table, the most dominant transportation system in freight transportation is highway freight transport.In line with the decisions taken in the 11th Transportation Conference, it is aimed to increase the share of freight transport of railway to 15% at the end of 2023, to reduce the share of highways by 60% and to increase the share of seaway routes to 10% [2].

Table 1: Distribution of domestic freight transport by mode of transport in 2015 [1].

Mode of Transport	Ton – km (million)	Load Carrying Ratio	2023 Final Goals
Highway	244,329	% 89.80	% 60.00
Railway	10,474	% 3.90	% 15.00
Seaway	17,204	% 6.30	% 10.00
Others	25	% -	% 15.00

However, when compared to European Union (EU) countries, freight rates in the EU countries are more balanced than freight rates in Turkey. In EU countries, the average usage rate of highways is 49.4%, the usage rate of railway is 11.5%, and the usage rate of seaway is 31.6% on average [3].

Foreign Freight Transportation of Transportation Modes by Year 2015

Looking at the import and export figures for 2015, it is seen that seaway transportation is dominant in the international transportation rates, contrary to domestic transportation. Seaway freight has a share of 60.01%, highway 16.59% and railway 0.58% in the transportation of imported cargoes. Similar ratios are seen in the transport of exported cargoes.Table 2 shows the freight transport data according to the year 2015 transport modes

Table 2: Distribution of foreign freight forwarding by transport modes in 2015 [4].

Mode of transport	Billion - $		Freight Transport Rates	
	Import	Export	Import	Export
Highway	34.4	46.7	% 16.59	% 22.53
Railway	1.2	0.8	% 0.58	% 0.39
Seaway	124.4	78.1	% 60.01	% 37.67
Others	47.3	17.3	% 22.82	% 8.35
Total	207.3	142.9	% 100	% 100

Similar ratios are observed when European countries' distribution of foreign trade amounts of 2013 according to their transportation modes. 47.7% of the cargoes imported by the EU countries were transported by seaway, 19.6% by highway and 1.4% by railway. Similar ratios are seen in the transport of exported cargoes seen in Table 3.

Table 3: European countries' distribution of foreign trade amounts by year 2013 [3].

Mode of transport	Billion - EUR		Freight Transport Rates	
	Import	Export	Import	Export
Highway	339.7	215.6	% 19.60	% 12.80
Railway	23.6	18.4	% 1.40	% 1.10
Seaway	827.8	905.8	% 47.70	% 53.80
Others	545.5	545	% 31.30	% 3.30
Total	1736.6	1684.8	% 100	% 100

CO_2 Equivalent Emissions from the Transportation Sector

CO_2 emission, carbon-containing fuels (gasoline, engine, LPG) burn to form carbon dioxide and this is the mixing of carbon dioxide into the atmosphere. This emission (as well as the cause of air pollution) is the result of the burning of carbon dioxide, which is also caused by the atmospheric greenhouse effect. CO_2 equivalent emission indicates how much heat the fuels have in relation to the same amount of CO_2.Table 4 presents CO_2 equivalent emissions from the transport sector in Turkey. According to Turkey's greenhouse gas emissions data, 15.76% of the total 467.6 million tons of equivalent CO_2 emissions is due to the transportation sector. The most reason for greenhouse gas emissions from transport modes is highway with 91%. CO_2 emissions from highway transport consists 78% diesel fuel, 8.78% gasoline use and 12.88% LPG. Bio-fuel and natural gases have only 0.34% share of CO_2 emissions.

Table 4:CO_2 equivalent emissions values resulting from the transport sector in Turkey (2014) [4].

Mode of transport	Percent	Million - Ton
Highway	% 91.0	67.067
Railway	% 0.80	0.590
Seaway	% 1.80	1.327
Others	% 6.40	4.717

Table 5 shows CO_2 equivalents of emissions from the transport sector in EU countries. According to the greenhouse gas emissions of EU countries 29% of the total 3.995 million-ton CO_2 equivalent emission is due to the transportation sector. In the EU countries, the highest CO_2 emission from transportation modes is highway

with a rate of 71.8%.But the remarkable detail is that seaway freight transport creates air pollution by only 1.8% in Turkey, while this rate is 13.9% in EU countries.One of the main reasons for this situation is due to the more intensive usage of sea transport [3, 5].

Table 5: CO_2 equivalent emission values from the transport sector in EU countries (2014) [3, 5].

Mode of transport	Percent	Million - Ton
Highway	% 71.80	833.02
Railway	% 0.80	9.28
Seaway	% 13.90	161.27
Others	% 13.50	156.63

Distribution of Transportation System Investments between 2003 and 2015

Table 6 shows the distribution of transportation investments in Turkey in 2003-2015. According to this data the largest share in investments is owned by the highway with 63.65%.Highway is followed by railway with 18.39% and seaway with 1.26%.

Table 6: Distribution of transportation to the modes of investments held in Turkey between 2003 and 2015 [1].

Mode of transport	Percent
Highway	% 63.65
Railway	% 18.39
Seaway	% 1.26
Others	% 16.69

The distribution of transportation investments in EU countries is shown in Table 7. European countries on average made 65.02% of their transport investments in the highway, 26.57% in the railway and 0.38% in the maritime area. In terms of average rates, the distribution of investments by EU countries in their transport systems is similar to the distribution of investments in Turkey [5].

Table 7: Distribution of transport investments by modes in EU countries (2015) [5].

Country	Highway	Railway	Seaway	Airway
England	% 43.18	% 43.65	% 2.51	% 10.66
Greece	% 63.91	% 29.64	% 4.01	% 2.45
Germany	% 62.03	% 28.05	% 3.40	% 6.52
Italy	% 52.43	% 38.85	% 6.24	% 2.48
Spain	% 46.76	% 32.48	% 11.34	% 9.43
France	% 69.87	% 23.39	% 1.72	% 5.02
Austria	% 74.03	% 17.92	% 8.05	% 0.00
Poland	% 82.74	% 13.88	% 0.59	% 2.78
Romania	% 91.93	% 7.13	% 0.38	% 0.57
Average	% 65.02	% 26.57	% 3.82	% 4.59

III. Materials And Methods

Costs of Transportation Modes

Transportation costs for transport modes are one of the most important factors in the economy of a country, a region or a city [6]. The total cost of a product is the sum of production costs and transportation costs. Low transportation costs are very important for the industrial structure that will be installed in the competitive business environment. For this reason, both the supplier's transport costs to the manufacturer and the transport costs to the retailer so it is very important to accurately calculate and reduce the total transport costs. Transport system that achieves the lowest shipping costs; it is a vital need for the economies of countries, regions or cities.

When calculating transportation costs, it is also necessary to take into consideration all the infrastructure, vehicles, maintenance and repair, fuel costs, as well as external costs such as accident, emission and noise costs. As mentioned before, the economics of the transportation system is very important.Therefore, in the scope of this study, not only technical, economic and operational costs but also external costs (accident, noise and emission costs) are taken into account when calculating the total transport costs for different transport modes and "Value Added Cost Method" which is taken into account in the price increases that may occur during the lifetime of the transport system [7]. The cost values per unit load calculated according to this method include;

- Investmentcostsperunitload (U_c),
- Operating-maintenancecostsperunitload (U_m),
- Fuelandlubricatingoilcostsperunitload (U_f),
- Externalcostsperunitload (U_{ex}).

The equations for investment cost (U_c), operating-maintenance cost (U_m), fuel and lubricating oil cost (U_f) and external costs (U_{ex}) per unit of delivered unit load are given below;

Investment cost per unit load (U_c) ($ /Ton);

$$U_c=\frac{\left\{\sum_{t=1}^{n} I_c\left[\left(1-\frac{t-1}{n}\right)i+\frac{1}{n}\right](1+r)^{-1}\right\}[2L+V_sZ_{sa}]}{2(Y_kY_d+aA_kA_d)V_s(8760-Z_{bt}-Z_{bk})\sum_{t=1}^{n}(1+r)^{-t}} \quad (1)$$

Operating-maintenance costs per unit load (U_m) ($ /Ton);

$$U_m=\frac{\left\{\sum_{t=1}^{n}\left[C_{mo}(1+e_m)^t+\left(sI_c\left(1-\frac{t}{n}\right)\right)(1+e_s)^t\right](1+r)^{-1}\right\}[2L+V_sZ_{sa}]}{2(Y_kY_d+aA_kA_d)V_s(8760-Z_{bt}-Z_{bk})\sum_{t=1}^{n}(1+r)^{-t}} \quad (2)$$

Unitfuelandlubricatingoilcosts (Uf) ($ / Ton);

$$U_f=\frac{[B_fP_f+B_oP_o]L\sum_{t=1}^{n}\left[(1+e_f)^t(1+r)^{-t}\right]}{(Y_kY_d+aA_kA_d)\left[\sum_{t=1}^{n}\left[(1+r)^{-t}\right]\right]} \quad (3)$$

Externalcostsperunitload (Uex) ($ / Ton);

$$U_{ex}=\frac{[c_{ac}+c_p+c_n]L\sum_{t=1}^{n}\left[\left(\frac{1+e_f}{1+r}\right)^t\right]}{(1+e_x)\left[\sum_{t=1}^{n}\left[(1+r)^{-t}\right]\right]}\left(\frac{Y_d^*}{Y_d}\right) \quad (4)$$

The parameters used in the models are shown in Table 10.

Costs of Intermodal Transportation Modes

It can be calculated by the following equations to calculate the total cost per unit load in various modes of transportation by taking the total cost per unit load calculated for highway, seaway and railway.

IntermodalFreightCostperUnitLoad;

$$U_K=X.(U_L)_{Seaway}.L_T+Y.(U_L)_{Railway}.L_T+Z.(U_L)_{Highway}.L_T \quad (5)$$

IntermodalFreightCostperUnitLoadandUnitLineLength;

$$U_K=\frac{U_K}{L_T}=X.(U_L)_{Seaway}+Y.(U_L)_{Railway}+Z.(U_L)_{Highway} \quad (6)$$

UnitCostper Handling;

$$U_{YB}=\frac{\zeta.C_{yb}.\sum_{t=1}^{n}\left(\frac{1+e_{yb}}{1+r}\right)^t}{(1+e_{yb})\sum_{t=1}^{n}(1+r)^{-t}} \quad (7)$$

StockCostperUnitLoad;

$$U_D=\frac{\Psi.C_d.\sum_{t=1}^{n}\left(\frac{1+e_d}{1+r}\right)^t}{(1+e_d)\sum_{t=1}^{n}(1+r)^{-t}} \quad (8)$$

Value Used in Cost Analysis forTransportationModes;

Within the scope of this study, all transport modesinterest rate is 8%, operation-maintenance, discount rate 10%, the annual fuel price increase for the foreseeable future is 5%, annual increases in operating-maintenance, external, handling and stocking costs were taken as 3% [7].

- Thecost of a standard 30 ton lorryforthehighway,
- Thecost of adding a load of 700 tons of transportationcapacityfortherailway,
- Thecost of a cargoship of 3300 DWT (DeadWeightTonnage) has beentakenintoaccountfortheseaway.

Since there is no other sufficient study in Turkey, the external costs used for transportation modes and vehicle types were taken from the national master plan (see in Table 8).

Table 8: Specific external costs [7].

EnvironmentalImpacts	Highway ($ / Ton-km)	Railway ($ /Ton-km)	Seaway ($ / Ton-km)
Accident (c_{ac})	$3.3x10^{-3}$	$0.4x10^{-3}$	$0.6x10^{-4}$
Emission(c_p)	$4.5x10^{-4}$	$1.1x10^{-4}$	$3.85x10^{-4}$
Noise (c_n)	$2.2x10^{-4}$	$1.5x10^{-4}$	0.00

Table 9 shows the number of vehicles, the equivalence factor, and the superstructure degradation factor, while the annual maintenance-repair cost per lorry is calculated for highway transport [7].

Table 9: Number of vehicles, equivalence factor and superstructure distortion factor according to the type of vehicle to be used in highway transport [7, 8].

Vehicle Type	Number of Vehicle (Number)	Equivalent Factor	SuperstructureDistortionFactor
Cars(J=1)	N_1=10,586,337	g_1=0.15	λ_1=0.00086
Van (J=2)	N_2=449,213	g_2=0.25	λ_2=0.071
Bus(J=3)	N_3=217,056	g_3=0.50	λ_3=0.143
Pickup Truck (J=4)	N_4=3,255,299	g_4=0.25	λ_4=0.071
Lorry (J=5)	N_5=563,023	g_5=1.00	λ_5=0.285
Truck (J=6)	N_6=241,296	g_6=2.00	λ_6=0.428

General Directorate of Highways gives the number of heavy vehicles (lorry, trucks) in Turkey as a single item under the title of "lorry". The values used in Table 9. Turkey Statistical Institute (TSI)'s were taken from 2015 data. According to TSI's data, the number of lorry in 2015 is 804,319. In the table classification, 70% of these vehicles are lorry and 30% are trucks [9].

IV. Findings

Cost Analysis of Transportation

Other technical and economic data on transport modes presented in Table 10 were obtained from the following institutions and from the thesis; Highways 7th Region (Samsun) Directorate, TCDD Samsun Regional Directorate, TCDD Samsun Port Management Directorate, TCDD Wagon Maintenance and Repair Department engineers and officials, Samsun Chamber of Drivers and Automobile Chamber, doctoral thesis study [9] and were obtained from face-to-face interviews conducted with the representatives of the relevant companies.

Table 10: Technical and economic data of vehicles.

	Symbol	Unit	Lorry	Freight Train	Load Ship
Vehicle Initial Investment Rate	I_c	$	100,000	7,650,000	4,650,000
Life of the vehicle (year)	n	Year	10	20	20
Insurance Percentage (% Ic)	s	$	0.03422	0.004243	0.01373
Vehicle Service Speed	V_s	Km /Hour	75	35	25
Load Capacity	Y_k	Tonne	30	700	2970
Annual Care-Attitude Time	Z_{bt}	Hours	720	1,460	300
Daily Business Stay Out Time	Z_{bk}	Hour/Day	14	9	3
Fuel Consumption per Km	B_f	Liter/Km	0.45	6.7	12
Oil Consumption per Km	B_o	Liter/Km	0.0040	0.040	0.11
Fuel Price	P_f	$ /Liter	1.709	1.709	0.619
Oil Price	P_o	$ /Liter	6.5	6.5	1.450
Annual Operating-Maintenance Costs	C_{mo}	$ /Year	25,500	570,500	485,000
Interest Rate	i		0.08	0.08	0.08
Discount Rate	r		0.1	0.1	0.1
Price increase for Operation-Maintenance	e_m		0.03	0.03	0.03
Price Increase for Fuel	e_f		0.05	0.05	0.05
Price Increase for Insurance	e_s		0.03	0.03	0.03
Price Increase for Outside Cost	e_x		0.03	0.03	0.03
Waiting Time Between Flights	Z_{sa}	Hour	6.00	12.00	9.00
Specific Accident Cost	c_{ac}		$3.3x10^{-3}$	$0.4x10^{-3}$	$0.6x10^{-4}$
Specific Emission Cost	c_p		$4.5x10^{-4}$	$1.1x10^{-4}$	$3.85x10^{-4}$
Specific Noise Cost	c_n		$2.2x10^{-4}$	$1.5x10^{-4}$	0.00
Vehicle Occupancy Rate	Y_d				
Specific Vehicle Occupancy Rate	Y_d^*				

Cost Analysis of Freight Carriage between Istanbul and Frankfurt

The main reason for the Istanbul - Frankfurt route in the scope of the study is Germany, the country in which the country imports and exports the most. The data of 10 countries that we import and export most in 2015, which is shown in Table 11, confirms this.

Table 11: 10 countries that our country imports and exports most in 2015 [10].

	Import	Export
1	China	**Germany**
2	**Germany**	England
3	Russian Federation	Iraq
4	USA	Italy
5	Italy	USA
6	France	France
7	South Korea	BAE
8	India	Spain
9	Spain	Iran
10	England	Netherlands

Total imports and exports between our country and Germany in 2008 were $ 31.6 billion, down from $ 23.9 billion in 2009 due to the global financial crisis in the world, particularly in EU countries. The trade loss between the two countries is about 24%. Trade relations between the two countries increased between 2010 and 2011, but in 2012 there was a slight decline, especially in imports. In particular, the import ceiling has risen in 2013, with imports and exports totaling $ 37.9 billion. In the following years, commercial relations between Germany and Turkey declined, especially due to the effects of regional political crises. The change is shown in Figure 1.

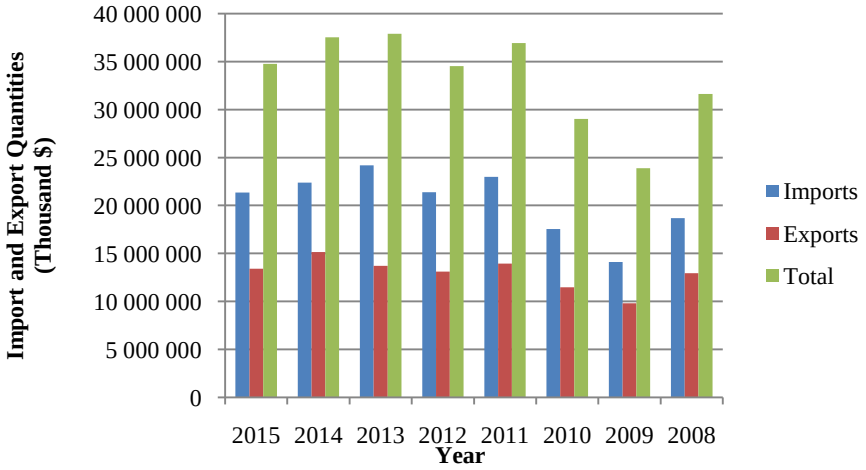

Figure 1: Shows theimportandexportquantities of Turkeywith Germany between 2008 and 2015.

Scenario was developed within the scope of this study. According to this scenario, it is assumed that 19,000 tons of cargo will be transported from Istanbul to Frankfurt. According to this assumption, different modes of transport have been carried out by themselves or in combination with other modesandmodeled the economic costs of all of them.

There are four different scenarios in this review; from Istanbul to Frankfurt directly by highway, directly by railway, Istanbul to Amsterdam Port by seaway and from Amsterdam to Frankfurt by highway and Istanbul and Istanbul has been examined by seaway from Amsterdam Port and from Amsterdam to Frankfurt by railway.

- TransportationbyHighway: Thesituationthatfreight is transporteddirectlyfromIstanbulto Frankfurt byhighway has beenexamined. Inthisscenario transport is carriedoutwithstandardlorry of 30 tonscapacity. It is assumedthat on thisroute, a load of 19,000 tonswillrequire 633 fulllorriesanda lorry33.33% full.
- TransportationbyRailway: Thesituation in whichfreight is transporteddirectlyfromIstanbulto Frankfurt byrailway has beenexamined. Transport in thisscenario is carriedoutwith a standardfreighttrain of 700 tonscapacity. Itwasassumedthat 27 full-lengthfreighttrainsanda train14.27% full-loadwould be neededtocarry 19,000 tons of lightalongthisline.
- Multimodal Transport (Seaway-Highway): Firstly, cargoesweretransportedbyseawayfromIstanbulto Amsterdam Port, thenfrom Amsterdam Port to Frankfurt byhighway. Fortheseaway it wasassumedthat it would be necessarytohave 6 fullloadedcargoshipswith a cargocarryingcapacity of 3300 DWT anda 39.73% fullcargofreight, 633 fulllorriesand a 33.33% fulllorryforthehighway.
- Multimodal Transport (Seaway-Railway): Firstly, thecargowastransportedfromIstanbulto Amsterdam byseawayandthenfrom Amsterdam to Frankfurt byrailway. Fortheseaway it wasassumedthattherewould be a

needfor 6 fullyloadedfreightyardswith a freightcarryingcapacity of 3300 DWT anda 39.73% fullfreightyards, 27 fullloadfreighttrainsfortherailwayand a 14.27% fullfreighttrains.

Handling, storage and port costs are taken into consideration in addition to the costs of single transportation in inter-modes transportation. In the scope of this study, the burden was taken as 4.27 $ / ton for warehouse handling and 2.85 $ / ton for handling lorry or train. Loads downloaded from the ship were assumed to be stocked for 1 day and stocking cost of 1 ton was taken as 0.43 $ / day [9]. Table 12 contains technical data used in scenario reviews.

Table 12: Istanbul-Frankfurt freight transport data.

Cargo LoadAmount	19,000 tons
Distances	
Istanbul Frankfurt HighwayLength	2,284 km
Istanbul Frankfurt RailwayLength	1,867 km
Istanbul Amsterdam SeawayLength	6,193 km
Amsterdam-Frankfurt HighwayLength	442 km
Amsterdam-Frankfurt RailwayLength	364 km
Number of TransportationVehiclesNeeded	
Number of Lorries	633 number full lorry 1 number 33.33% full lorry
Number of Freight Train	27 number fully loaded freight train 1 number 14.27% full load train
Number of LoadShip	6 number fully loaded cargo ships 1 number 39.73% full load ship

Carrying Cost PerUnit Load by Highway

In the developed scenario, the cost analysis result in case of highway transportation between Istanbul and Frankfurt is given in Table 13. The total cost of transporting 1 ton of cargo by highway is 406.977 $, while the total cost of transporting 19,000 tons of cargo is 1,935,038.030 $.

Table 13:Cost of transportationwithonlyhighway.

	Y_d= % 33.33	Y_d= % 100	TOTAL
U_c($/Ton)	17.150	5.716	
U_m ($/Ton)	35.871	11.956	
U_f($/Ton)	230.884	76.954	
U_{ex}($/Ton)	21.335	7.111	
U_T ($/Ton)	305.240	101.737	406.977
U_T ($)	3,052.400	1,931,985.630	1,935,038.030

Carrying Cost Per Unit Load by Railway

In the developed scenario, the cost analysis result of the case of the railway transportation of the load between Istanbul and Frankfurt is given in Table 14. The total cost of transporting 1 ton of cargo by railway is $ 642.560 while the total cost of transporting 19,000 ton of cargo is $ 1,572.824.400.

Table 14: Cost of transportationwithonlyrailway.

	Y_d= % 14.27	Y_d= % 100	TOTAL
U_c($/Ton)	117.685	16.794	
U_m ($/Ton)	110.258	15.734	
U_f($/Ton)	326.954	46.656	
U_{ex}($/Ton)	7.420	1.059	
U_T ($/Ton)	562.317	80.560	642.560
U_T ($)	56,231.700	1,516,592.700	1,572,824.400

Carrying Cost Per Unit Load by Intermodal Transportation (Seaway-Highway)

In the developed scenario, the cost analysis values in the case of loading between Istanbul and Frankfurt first by seaway and then by highway are given in Table 15. The total cost of transporting 19,000 tons of cargo in the event of the cargo being carried by seaway and highway is $ 1,363,510.790. Handling and storage costs also affect intermodal transportation costs. The total stocking and handling costs of the loads are $ 143.450.

Table 15: Costs of transportation with intermodal transportation (Seaway and Highway).

	Y_d= % 33.33	Y_d= % 100	TOTAL($)
U_c($/Ton)	4.559	1.520	
U_m ($/Ton)	9.536	3.178	
U_f($/Ton)	44.481	14.892	
U_{ex}($/Ton)	4.129	1.376	
U_T ($/Ton)	62.705	20.966	
U_T ($)	627.050	398,144.340	398,771.390
	Y_d= % 39.73	Y_d= % 100	
U_c($/Ton)	14.031	5.574	
U_m ($/Ton)	19.158	7.612	
U_f($/Ton)	59.487	23.634	
U_{ex}($/Ton)	5.893	2.341	
U_T ($/Ton)	98.569	39.161	
U_T ($)	128,139.700	693,149.700	821,289.400
Total Cost of Handling			135,280
StockingCost			8,170
TOTAL($)			1,363,510.790

Carrying Cost Per Unit Load by Intermodal Transportation (Seaway-Railway)

In the developed scenario, the cost analysis values in the case of loading between Istanbul and Frankfurt first by seaway and then by railway are given in Table 16. The total cost of transporting 19,000 tons of cargo in the event of the cargo being carried by seaway and railway is $ 1,180,374.900. Handling and storage costs also affect intermodal transportation costs. The total stocking and handling costs of the loads are $ 143.450.

Table 16: Costs of transportation with intermodal transportation (Seaway and Railway).

	Y_d= % 39.73	Y_d= % 100	TOTAL($)
U_c($/Ton)	14.031	5.574	
U_m ($/Ton)	19.158	7.612	
U_f($/Ton)	59.487	23.634	
U_{ex}($/Ton)	5.893	2.341	
U_T ($/Ton)	98.569	39.161	
U_T ($)	128,139.700	693,149.700	128,139.700
	Y_d= % 14.27	Y_d= % 100	
U_c($/Ton)	32.523	4.641	
U_m ($/Ton)	30.471	4.378	
U_f($/Ton)	63.745	9.096	
U_{ex}($/Ton)	1.447	0.206	
U_T ($/Ton)	128.186	18.321	
U_T ($)	12,818.600	346,266.900	359,085.500
Total Cost of Handling			135,280
Stocking Cost			8,170
TOTAL($)			1,180,374.900

Table 17: Total transportation cost for 19,000 ton load between Istanbul and Frankfurt [3].

	Unit Load Cost U_T ($/Ton)	Total Transportation Cost U_T ($/Ton)
ByHighway	406.977	1,935,038.030
ByRailway	642.560	1,572,824.400
BySeawayandHighway	221.401	1,363,510.790
BySeawayandRailway	284.237	1,180,374.900

When a cargo transport of 19,000 tons between Istanbul and Frankfurt is examined, the total transportation cost is also seen in Table 17. According to this table, the lowest level is the intermodal transportation between seaway and railway. The highest total transport cost for transporting the same amount of cargo on this route is achieved only by highway transport.

V. Discussion And Conclusions

Within the scope of this study, firstly, the transportation modes of highway, railway and seaway in Turkey are compared with each other and EU countries in the following areas. These areas are freight transport, CO_2 emissions and transport investments. In Turkey, dominance of highway is seen especially in domestic

freight transport. This represents our strategic objectives in the transport sector as a country. It also shows that we are far away from the distributions in EU countries. A similar situation can be said for CO_2 emission and investment rates.

In this scenario, it is assumed that a load of 19,000 tons was carried between Istanbul and Frankfurt. In addition, the transport costs of transport modes alone and inter-modal uses are calculated. As a result of this cost analysis, it is seen that the cost of the most used highway haulage is the highest. The lowest-cost transport is the intermodal transport that seaway and railway are used together with.

The results obtained in this study show that the rate of the most used highway transport in Turkey needs to be reduced and that the number of transports between modes should be increased. It is also seen that the seaway freight transport with the lowest unit cost is required to be extended. It is emphasized that other modes of transport should be expanded. In this case, it is pointed out that highway accidents, emission and noise costs will also decrease. In this study, comparison of transportation types was carried out only considering the costs. However, in the selection of transportation modes; cost, security, speed, comfort, flexibility, the geographical structure and location of countries are influential. Considering these criteria in future studies, much more realistic and usable results can be achieved. In addition, the use of the current values of the specific external cost values used in the cost analysis in this study will further clarify the superiority of the cost of cross-species transport in terms of cost.

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