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Case Study

An approach for analysing transportation costs and a case study

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Abstract

One of the important parameters in the determination of optimal transportation system is economy. Therefore, a realistic method based on the technical, economical and operational parameters of various transportation modes, namely, road, railway, and sea routes is required in the analysis of costs. This method will take into consideration the probable price escalations during the lifetime of a certain transportation system. The cost of a unit of cargo or passenger per route length should be considered since it is an indicator of economics. In this paper, an approach for transportation cost analysis based on the economic analysis of the alternative modes of cargo or passenger transportation, is presented.

Keywords: Logistics; Economics; Transportation; Cost

1. Introduction

Transportation cost is a vital factor in the economy of a nation, a region, or a city. Low costs give an advantage to a business concern to be competitive. Therefore, it is necessary to calculate the total transportation costs accurately and try to minimize them. This is also necessary to determine an economical transportation system. The transportation cost of a unit of cargo or passenger per route length is generally accepted as an indicator of economics. In the literature, many studies have been dedicated towards achieving this aim. For example, McCann (2001) deals with two interrelated questions, namely the optimum size of a vehicle or vessel, and the structure of transport costs with respect to haulage distance. Morten and Mazzenga (2004) evaluated the quantitative effects of introducing transportation costs into an international trade model. They modelled these costs through the introduction of international transportation services sector. Snaddon (2001) studied transportation parameters such as cost, quality, response, flexibility and dependability with respect to private and public firms. He found that the cost was over-emphasized in private firms as compared to public organizations. Arnold et al. (2004) dealt with the problem of optimally locating the rail/road terminals for freight transports in relation to the cost criterion. Dullaerta et al. (2005) suggested a new methodology for determining the optimal mixture of transport alternatives to minimize total logistics costs when goods are shipped from a supplier to a receiver. David et al. (2005) mentioned the external cost of emissions from vehicles. Pilot and Pilot (1999) and Prakash et al. (in press) focused on minimizing total cost for transportation problem, Al-Khayyal and Hwang (2007) formulated a model for finding a minimum cost routing in a network for a heterogeneous fleet of ships engaged in pickup and delivery of several liquid bulk products. Kutanoglu and Lohiya (in press) presented an optimization-based model and Ozbay et al. (2007) studied on transportation costs for passenger.

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In order to define total transportation costs more comprehensively, technical, economical and operational parameters for the transportation modes, such as road, rail and sea routes, should be set clearly as well as the effects of external costs, such as the costs of the accidents, emissions and noise. Moreover, a specifically designed cost method is necessary which takes into consideration the probable price escalations during the lifetime of a certain transportation system. For this purpose, a more realistic cost analysis method, called "the levelised cost analysis method", is used. By using this method the economic analysis for passenger transportation of seaway have been carried out (Sahin and Kesgin, 1991; Alkan et al., 1997). Recently, the method has been applied to Turkish transportation systems by Sahin et al. (2005) for the economic evaluation and comparison of alternative transportation modes. In this paper, the relation between the operational parameters and the cargo/passenger transportation costs is established by using the levelised cost method. Then, road, railroad and seaway transportation modes have been compared in terms of transportation costs. The proposed method in this study leads to determine the optimum capacity for cargo/passenger transportation and the appropriate transportation mode.

2. Modeling of transportation cost

The total transportation cost for a cargo or passengers can be broken down to its main components: capital, fuel, lubricants, and operational and maintenance costs. All expenses along the lifetime of a vehicle are calculated in certain intervals. Additionally, it is predicted that the amount of cargo or passengers carried annually will vary from one year to another. Therefore, cargo or passenger transportation cost can be determined utilizing the levelised cost analysis method. According to the presented method by Sahin et al. (2005) and Aybers and Sahin (1995), the cost of capital, fuel and lubricants as well as the operational and maintenance costs on a reference date, which is the date when the vehicle began its initial operation, can be formulated as follows:

$$C_{\mathrm{pw}} = \sum_{t=1}^{n} [C_{\mathrm{k}}(t) + C_{\mathrm{f}}(t) + C_{\mathrm{m}}(t) + C_{\mathrm{ex}}(t)](1+r)^{-t}, \tag{1}$$

where $C_{\mathrm{k}}(t)$ is the time dependent annual capital; $C_{\mathrm{f}}(t)$, the cost of fuel and lubricants; $C_{\mathrm{m}}(t)$, the operational and maintenance costs; and $C_{\mathrm{ex}}(t)$ the external costs. r stands for the discount ratio and n the economic lifetime of the vehicle.

The cost C_{pw} in Eq. (1) represents the net present value on the date of the vehicle's initial operation of all the costs incurred during the time interval $0 \leqslant t \leqslant n$ and can be expressed as equivalent and uniform annual cost series along the economic lifetime of the vehicle

$$C_{\mathrm{aw}} = \frac{\sum_{t=1}^{n} [C_{\mathrm{k}}(t) + C_{\mathrm{f}}(t) + C_{\mathrm{m}}(t) + C_{\mathrm{ex}}(t)](1+r)^{-t}}{\sum_{t=1}^{n} (1+r)^{-t}}. \tag{2}$$

If $Y_{\mathrm{s}}(t)$ and $A_{\mathrm{s}}(t)$ represent the number of annual cargoes and passengers or the number of cars that can be carried in a ferry respectively, the equivalent and uniform total cargo or passenger cost per unit, U_{T}, during the economic lifetime of the vehicle can be obtained as follows:

$$U_{\mathrm{T}} = \frac{\sum_{t=1}^{n} [C_{\mathrm{k}}(t) + C_{\mathrm{f}}(t) + C_{\mathrm{m}}(t) + C_{\mathrm{ex}}(t)](1+r)^{-t}}{\sum_{t=1}^{n} [Y_{\mathrm{s}}(t) + \alpha A_{\mathrm{s}}(t)](1+r)^{-t}}, \tag{3}$$

where α is an equivalent coefficient representing the ratio of the unit cost of car transportation to that of passenger transportation.

2.1. Annual capital costs

The methods of either constant or linearly declining annual capital or investment cost should preferably be used in the calculation of annual capital cost. In this study, the latter method is used. If the investment cost of the vehicle together with the infrastructure cost of the road or railroad transportation at the time of the initial operation is denoted by I_{c}, the linearly declining annual capital cost and its principle payments by a, and its interest components by f_{t}, can be calculated during the lifetime of vehicle, as follows:

$$C_{\mathrm{k}}(t) = I_{\mathrm{c}}\left[\left(1 - \frac{t-1}{n}\right)i + \frac{1}{n}\right], \tag{4}$$

$$a = \frac{I_{\mathrm{c}}}{n}, \quad f_t = I_{\mathrm{c}}\left[\left(1 - \frac{t-1}{n}\right)i\right], \tag{5}$$

where i is recovering interest rate.

2.2. Annual fuel and lubricant costs

If the annual fuel and lubricant costs at the time of the vehicle's initial operation is C_{fo} and the price escalation rate through the future years of the lifetime of the vehicle is denoted by e_f, then the annual fuel and lubricant costs can be defined as

$$C_f(t) = C_{fo}(1+e_f)^t. \tag{6}$$

If the real consumption values of fuel and lubricants are taken into consideration in working conditions, their annual costs at the time of the vehicle's initial operation can be expressed as

$$C_{fo} = 2LS_s(B_fP_f + B_oP_o), \tag{7}$$

where L is the route length; P_f and P_o are the fuel and lubricant prices; S_s is the number of annual trips; and B_f and B_o are the fuel and lubricant consumption per unit route length.

2.3. Annual operational and maintenance costs

If the annual operational and maintenance costs, excluding the insurance cost, is shown by C_{mo} at the initial operation of the vehicle and e_m is the escalation rate through future years of lifetime of the vehicle and $C_{mi}(t)$ is the time dependent annual insurance costs, then the time dependent cost of annual operational and maintenance cost can be found as follows:

$$C_m(t) = C_{mo}(1+e_m)^t + C_{mi}(t). \tag{8}$$

Considering that the initial investment cost of vehicle will decrease linearly during its economic lifetime, the annual insurance cost can be expressed as time dependent

$$C_{mi}(t) = sI_c\left(1-\frac{t}{n}\right)(1+e_s)^t, \tag{9}$$

where s is the percentage of insurance rate and e_s is the escalation rate of the future insurance cost.

2.4. The average amount of annual cargo/passengers or cars that can be transported

The amount of average annual transportable cargo or passengers, Y_s, becomes

$$Y_s = 2Y_kK_dS_s, \tag{10}$$

where Y_k is the cargo/passenger capacity of the vehicle, K_d is the annual average fullness ratio of the cargo/passenger and S_s is the annual number of trips of the vehicle.

The number of cars carried by a ferry, A_s, can be calculated as follows:

$$A_s = 2A_kA_dS_s, \tag{11}$$

where A_k is the car capacity of the vehicle and A_d is the annual average fullness ratio of the car. Here, S_s can be found below

$$S_s = \frac{8760 - Z_{bt} - Z_{bk}}{Z_d + Z_{sa}}, \tag{12}$$

where Z_{bt} is the annual time spent for maintenance-repair; Z_{bk} is the annual idle time; Z_d is the time elapsed for a given route length and Z_{sa} is the waiting time between sequential trips. Taking the service speed of the vehicle as V_s, the time spent in a trip is

$$Z_d = \frac{2L}{V_s}. \tag{13}$$

Substituting Eqs. (12) and (13) with Eqs. (10) and (11), the amount of cargoes or passengers carried annually will become

$$Y_s = \frac{2Y_kY_dV_s(8760 - Z_{bt} - Z_{bk})}{2L + V_sZ_{sa}}, \tag{14}$$

and the number of annual transportable cars for a ferry can be calculated as follows:

$$A_s = \frac{2A_kA_dV_s(8760 - Z_{bt} - Z_{bk})}{2L + V_sZ_{sa}}. \tag{15}$$

The annual average fullness ratio can be changed by systematically to compare the different transportation modes, but this parameter can be a constant value according to the modes for taking into consideration the country conditions and yearly statistical data.

2.5. Investment cost per unit of cargo or passenger

Levelised unit cargo or passenger investment cost, U_c, can be found as shown below

$$U_{\mathrm{c}} = \frac{\sum_{t=1}^{n} C_{\mathrm{k}}(t)(1+r)^{-t}}{(Y_{\mathrm{s}} + \alpha A_{\mathrm{s}})\sum_{t=1}^{n}(1+r)^{-t}}. \tag{16}$$

When the linear decreasing investment cost, Eq. (4), the amount of cargo or passengers, Eq. (14), and the number of cars carried by a ferry per year, Eq. (15), is substituted with Eq. (16), this will yield the unit cargo or passenger investment cost related to technical, economic and operational parameters

$$U_{\mathrm{c}} = \frac{\left\{\sum_{t=1}^{n} I_{\mathrm{c}}\left[\left(1-\frac{t-1}{n}\right)i+\frac{1}{n}\right](1+r)^{-t}\right\}[2L + V_{\mathrm{s}}Z_{\mathrm{sa}}]}{2(Y_{\mathrm{k}}Y_{\mathrm{d}} + \alpha A_{\mathrm{k}}A_{\mathrm{d}})V_{\mathrm{s}}(8760 - Z_{\mathrm{bt}} - Z_{\mathrm{bk}})\sum_{t=1}^{n}(1+r)^{-t}}. \tag{17}$$

2.6. Fuel and lubricant costs per unit of cargo or passenger

Levelised fuel and lubricant costs per unit of cargo or passenger, U_{f}, can be shown as

$$U_{\mathrm{f}} = \frac{\sum_{t=1}^{n} C_{\mathrm{f}}(t)(1+r)^{-t}}{(Y_{\mathrm{s}} + \alpha A_{\mathrm{s}})\sum_{t=1}^{n}(1+r)^{-t}}, \tag{18}$$

Again, when the Eqs. (6), (14) and (15), is substituted with Eq. (18), this will yield fuel and lubricant costs per unit of cargo or passenger

$$U_{\mathrm{f}} = \frac{(B_{\mathrm{f}}P_{\mathrm{f}} + B_{\mathrm{o}}P_{\mathrm{o}})L\sum_{t=1}^{n}\left[(1+e_{\mathrm{f}})^{t}(1+r)^{-t}\right]}{(Y_{\mathrm{k}}Y_{\mathrm{d}} + \alpha A_{\mathrm{k}}A_{\mathrm{d}})\left[\sum_{t=1}^{n}\left[(1+r)^{-t}\right]\right]}. \tag{19}$$

2.7. Operational and maintenance costs per unit of cargo or passenger

By applying the similar procedure for the levelised operational and maintenance costs per unit of cargo or passenger, U_{m}, we find

$$U_{\mathrm{m}} = \frac{\sum_{t=1}^{n} C_{\mathrm{m}}(t)(1+r)^{-t}}{(Y_{\mathrm{s}} + \alpha A_{\mathrm{s}})\sum_{t=1}^{n}(1+r)^{-t}}. \tag{20}$$

By substituting Eqs. (8), (14) and (15), in Eq. (20), the operational and maintenance costs per unit cargo or passenger can be obtained

$$U_{\mathrm{m}} = \frac{\left\{\sum_{t=1}^{n}\left[C_{\mathrm{mo}}(1+e_{\mathrm{m}})^{t} + \left(sI_{\mathrm{c}}\left(1-\frac{t}{n}\right)\right)(1+e_{\mathrm{s}})^{t}\right](1+r)^{-t}\right\}[2L + V_{\mathrm{s}}Z_{\mathrm{sa}}]}{2(Y_{\mathrm{k}}Y_{\mathrm{d}} + \alpha A_{\mathrm{k}}A_{\mathrm{d}})V_{\mathrm{s}}(8760 - Z_{\mathrm{bt}} - Z_{\mathrm{bk}})\sum_{t=1}^{n}(1+r)^{-t}}. \tag{21}$$

2.8. External costs per unit of cargo or passenger

The external costs per unit of cargo or passenger can be formulated as

$$U_{\mathrm{ex}} = \frac{(c_{\mathrm{ac}} + c_{\mathrm{p}} + c_{\mathrm{n}})L\sum_{t=1}^{n}\left(\frac{1+e_{\mathrm{x}}}{1+r}\right)^{t}}{(1+e_{\mathrm{x}})\sum_{t=1}^{n}[(1+r)^{-t}]}\left(\frac{Y_d^{*}}{Y_d}\right), \tag{22}$$

where c_{ac}, c_{p} and c_{n}, are specific cost of accidents, the specific cost of pollution caused by emission and the specific cost of pollution caused by noise, respectively. Y_{d}^{*} is reference fullness ratio used for the calculation of specific external costs, and e_{x} is the escalation rate in the external costs.

Finally, total transportation cost per cargo or passenger is found as shown below

$$U_{\mathrm{T}} = U_{\mathrm{c}} + U_{\mathrm{m}} + U_{\mathrm{f}} + U_{\mathrm{ex}}. \tag{23}$$

2.9. Equivalent infrastructure investment cost per vehicle in road transportation

The sharing of infrastructure investment costs per vehicle in road transportation according to vehicle types can be expressed as

$$(\mathrm{ICT})_j = \frac{\mathrm{IC_L}\sum_{i=1}^{K} L_i}{\sum_{j=1}^{M} N_j g_j} g_j. \tag{24}$$

Table 1
The number of vehicles, equivalent factor and wear and tear factor for road surface with respect to vehicle type

Vehicle type	Number of vehicle	Equivalent factor	Wear and tear factor
Automobile ($j = 1$)	$N_1 = 4{,}784{,}140$	$g_1 = 0.15$	$\lambda_1 = 0.00086$
Minibus ($j = 2$)	$N_2 = 249{,}041$	$g_2 = 0.25$	$\lambda_2 = 0.071$
Bus ($j = 3$)	$N_3 = 126{,}587$	$g_3 = 0.50$	$\lambda_3 = 0.143$
Light truck ($j = 4$)	$N_4 = 1{,}073{,}728$	$g_4 = 0.25$	$\lambda_4 = 0.071$
Truck ($j = 5$)	$N_5 = 412{,}881$	$g_5 = 1.00$	$\lambda_5 = 0.285$
Articulated lorry ($j = 6$)	$N_6 = 61{,}965$	$g_6 = 2.00$	$\lambda_6 = 0.428$

Table 2
Specific external costs (c_{ac}, c_p, c_n)

Environmental effects	Road		Railroad		Seaway	
	Cargo $/(ton km)	Passenger $/(pax km)	Cargo $/(ton km)	Passenger $/(pax km)	Cargo $/(ton km)	Passenger $/(pax km)
Accident (c_{ac})	3.3×10^{-3}	1.1×10^{-3}	4×10^{-4}	0.8×10^{-3}	6×10^{-5}	1.2×10^{-4}
Emission (c_p)	4.5×10^{-4}	1.5×10^{-4}	1.1×10^{-4}	1×10^{-4}	3.85×10^{-4}	6.5×10^{-4}
Noise (c_n)	2.2×10^{-4}	7.5×10^{-5}	1.5×10^{-4}	2×10^{-4}	–	–

Table 3
Technical and economical properties of the vehicles

Technical and economical properties of the vehicles			Transportation modes		
			Seaway	Railroad	Road
Description of vehicles	Symbol	Unit	General cargo ship	Freight train	Truck
Investment cost including infrastructure	I_c	$	5,875,619	6,440,000	85,000
Average economic lifetime	n	year	20	20	10
Insurance percentage (%Ic)	s	$	0.01702	0.00776	0.02706
Service speed of vehicle	V_s	km/h	22	35	50
Cargo capacity	Y_k	ton	2970	700	20
Annual maintenance-repair time	Z_{bt}	hours	300	1200	720
Annual idle time	Z_{bk}	hours	1095	1095	5110
Fuel consumption per km (main + aux.)	B_f	litre/km	16	7	0.3
Lubricant consumption per km (main + aux.)	B_o	litre/km	0.11	0.05	0.0036
Fuel price	P_f	$/litre	0.2	1.127	1.127
Lubricant price	P_o	$/litre	1.00	5.00	5.00
Annual operation and maintenance costs	C_{mo}	$/year	600,000	710,000	12 500
Interest rate	i		0.08	0.08	0.08
Discount rate	r		0.1	0.1	0.1
Escalation rate for future operational and maintenance costs	e_m		0.03	0.03	0.03
Escalation rate for future fuel cost	e_f		0.05	0.05	0.05
Escalation rate for future insurance cost	e_s		0.03	0.03	0.03
Escalation rate for future external costs	e_x		0.03	0.03	0.03
Route length	L	km	1000	1000	1000
Waiting time between sequential trips	Z_{sa}	hours	9.00	30	6.00
Specific cost of accident	c_{ac}	$/(ton km)	6.00E−05	4.00E−04	3.30E−03
Specific cost of pollution	c_p	$/(ton km)	3.85E−04	1.10E−04	4.50E−04
Specific cost of noise	c_n	$/(ton km)	0.00E+00	1.50E−04	2.20E−04
Reference fullness ratio for the specific external costs	Y_d^*		0.70	0.70	0.70

Note: For all values in the Tables are considered data of year 2005.

Equivalent infrastructure investment cost for a unit length of road, IC_L, is

$$\mathrm{IC}_L = \frac{\sum_{i=1}^{K} I_i L_i}{\sum_{i=1}^{K} L_i}, \tag{25}$$

where i is road type (highway, state way and province way); K the number of road types; I_i, infrastructure investment cost per unit length of related road type; L_i the length of related road/railroad type; j vehicle type; M the number of vehicle types; N_j the number of vehicle in related vehicle category and g_j sharing factor of infrastructure investment cost for the related vehicle types. Sharing annual cost of road maintenance and repair according to vehicle types is expressed below

$$(C_{\mathrm{B}})_j = \frac{C_{\mathrm{BT}}\lambda_j}{\sum_{j=1}^{M} N_j \lambda_j}, \tag{26}$$

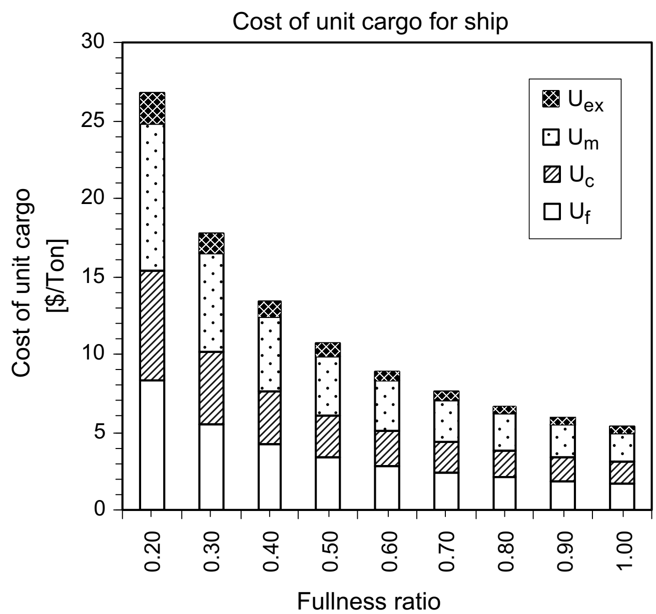

Fig. 1. The cost of each unit of cargo for a cargo ship ($L = 1000$ km).

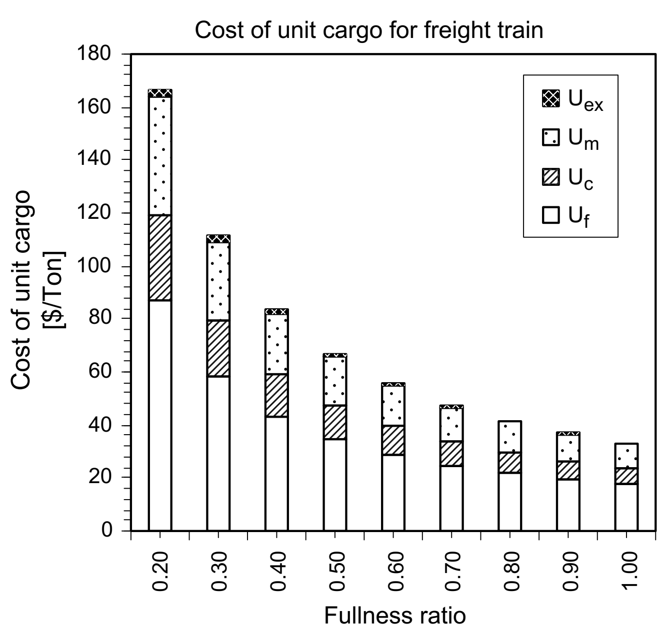

Fig. 2. The cost of each unit of cargo for a freight train ($L = 1000$ km).

where C_{BT} is annual maintenance and repair cost, and λ_j, the wear and tear factor for the road surface for the related vehicle type or the sharing percentage of the costs which are attributed to maintenance and repair. The vehicle types, the number of vehicles per vehicle type and equivalent factor in road transportation are given in Table 1. All calculations in this section are for road transportation. Similar applications can be made for railroad transportation.

3. A case study: An application of cost analyses for different transportation modes in Turkey

In this study, a cost analysis is conducted and costs are compared by using data concerning Turkey for different modes of transportation. Therefore, current data for investment costs, operational and maintenance costs, fuel and external costs for each transportation mode are collected for the proposed cost analysis method. The interest rate, i, is assumed to be 8%, the discount rate, r, 10%, the escalation rate for future fuel costs, e_f, 5%, the escalation rate for future operational and maintenance costs, e_m, 3% and the escalation rate for future external costs, e_x, 3% for all transportation modes. Studies

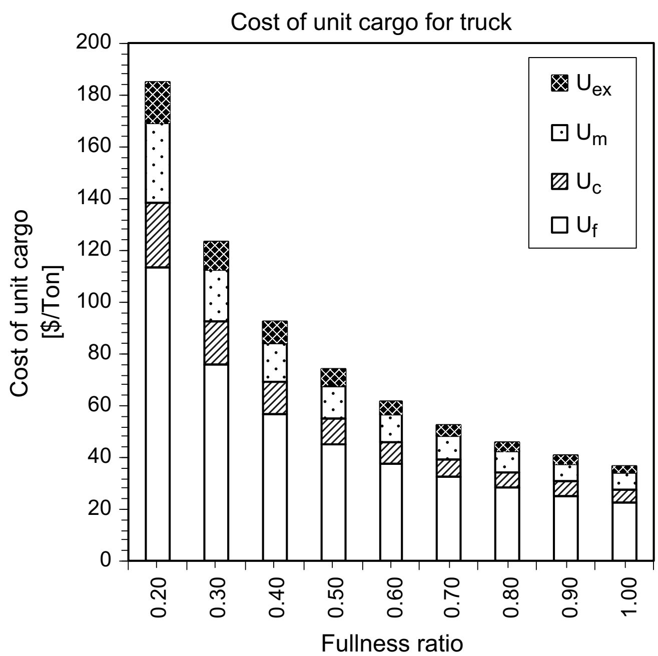

Fig. 3. The cost of each unit of cargo for a truck ($L = 1000$ km).

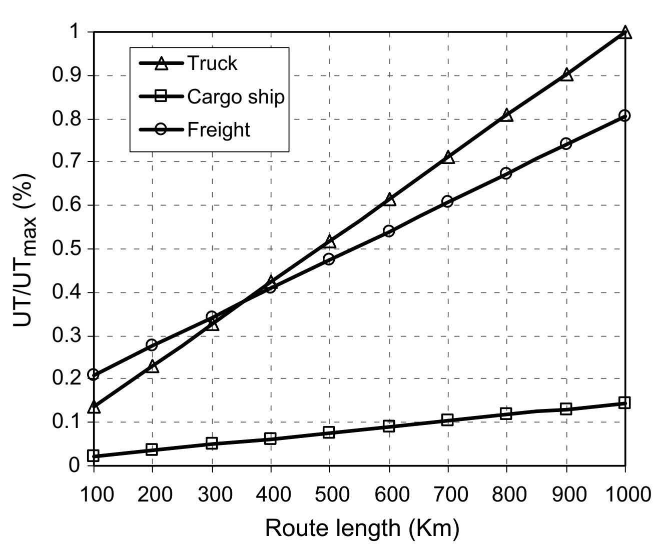

Fig. 4. Relative transportation cost for all modes.

and data on external cost estimations of different transportation modes on country basis are not satisfactory. Therefore, taking into consideration the available data for Turkey (Sahin et al., 2005) and the results of different international analyses such as those carried out by Forkenbrock (1999, 2001), Beuthe et al. (2002) and Quinet (1994, 2004), estimations are made for the specific external cost data shown in Table 2 for different transportation modes. Standard vehicle types that can suitably be used in this country are selected for different transportation modes. The selected vehicles are a general cargo ship with a capacity of 3300 DWT for the seaway, a freight train with a capacity of 700 tons for the railroad and a truck with a capacity of 20 tons for the road. All technical and economical parameters of these vehicles are summarized in Table 3.

4. Results and discussions

The variations in the total cost of a unit of cargo with the given fullness ratio and the proportion of the components of this cost are shown in Figs. 1–3 on the basis of transportation modes for a certain route length. It is seen in Fig. 1 that the total cost of a unit of cargo in sea transportation consists of 26% investment cost, 32% fuel cost, 35% operational and

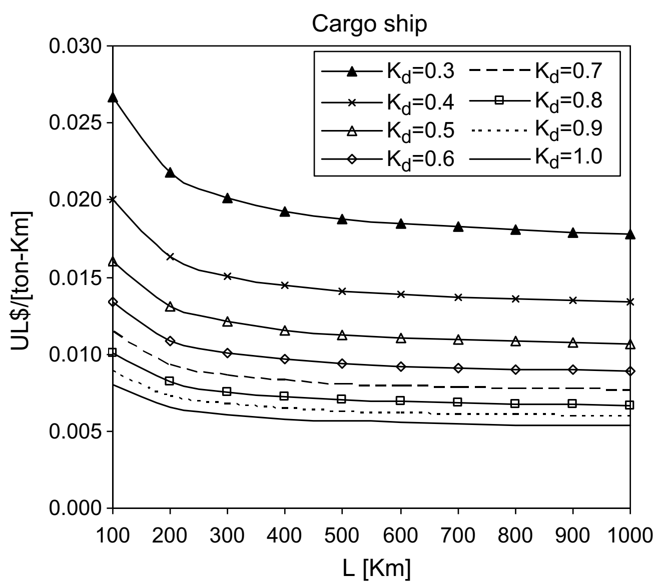

Fig. 5. Specific transport cost for cargo ship.

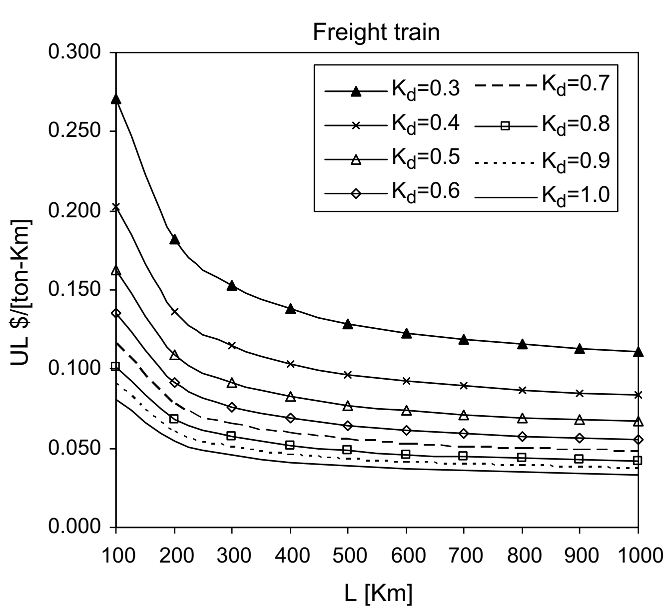

Fig. 6. Specific transport cost for freight train.

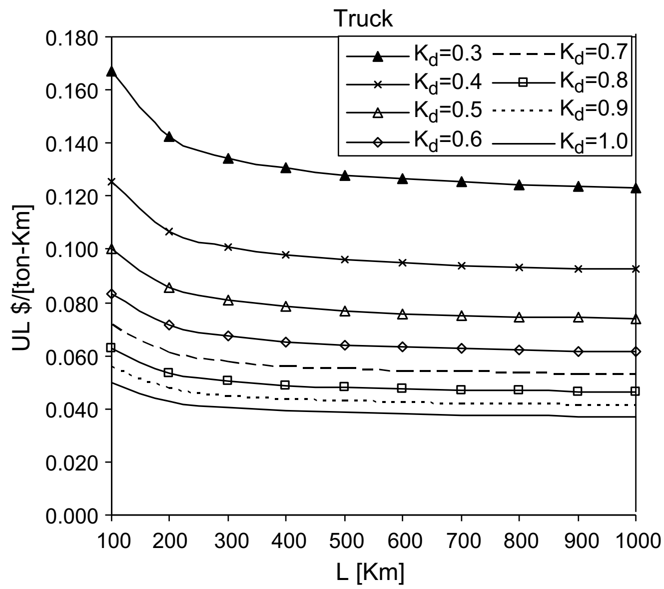

Fig. 7. Specific transport cost for truck.

maintenance cost and 7% external cost. As shown in Fig. 2, these percentages for railroad are 22% for investment, 46% for fuel, 30% for operational and maintenance and 2% external costs. For road transportation, these values are 14%, 60%, 17% and 9%, respectively. The relative transportation costs (U_T/U_{Tmax}) based on transportation modes and route lengths are shown in Fig. 4. The changes in specific transport costs, U_L, based on the route length and fullness ratio for standard transport vehicles are given in Figs. 5–7, respectively. In addition, the change in the total transportation cost per cargo based on the route length and fullness ratio for standard transport vehicles is given in Figs. 8–10, respectively.

An analysis of the figures for sea transportation revealed the following points: It is considered that a fullness ratio of 60% is the lower limit for sea cargo transportation, which may change according to route lengths. Thus, the fleet size and the optimal vessel capacity can be determined by taking into consideration the annual cargo potential on a given sea transportation route.

By looking at the figures for road transportation, it can be concluded that a fullness ratio of 80% was chosen as the lower limit for road cargo transportation. Determining the fleet size for this mode of transportation based on this fullness

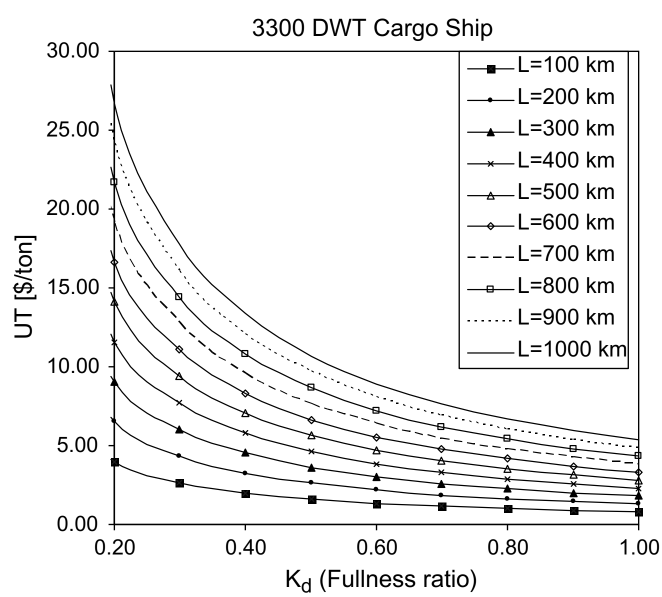

Fig. 8. Total transportation cost per unit of cargo for a cargo ship ($100 \leqslant L \leqslant 1000$ km).

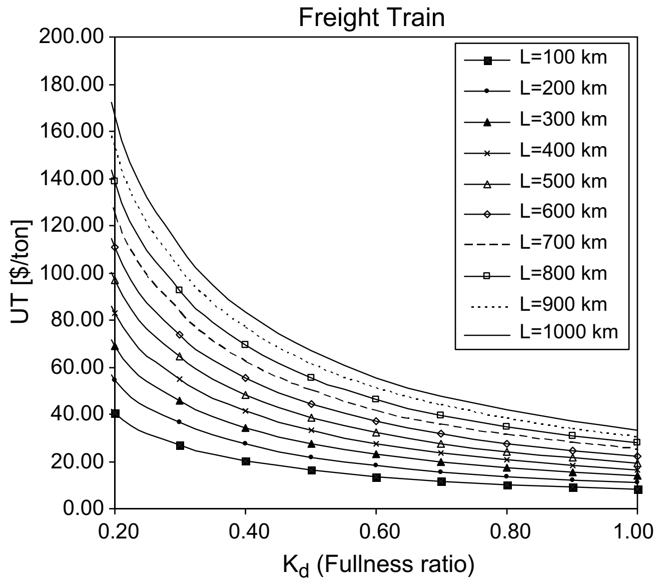

Fig. 9. Total transportation cost per unit of cargo for a freight train ($100 \leqslant L \leqslant 1000$ km).

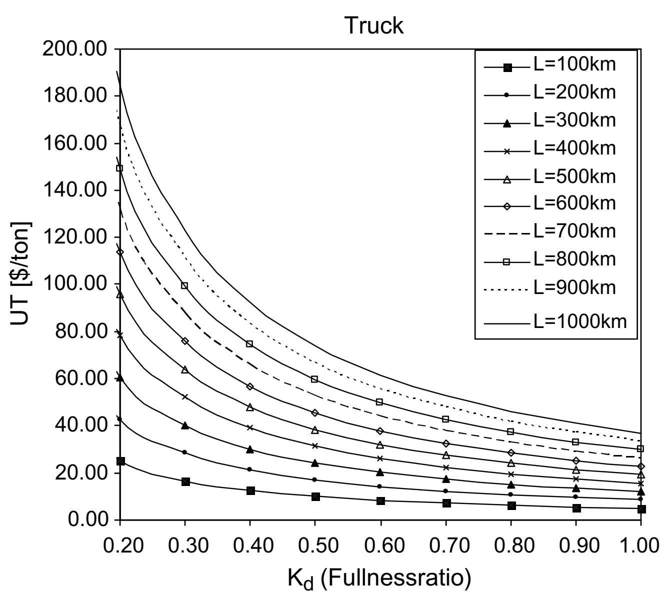

Fig. 10. Total transportation cost per unit of cargo for a truck ($100 \leqslant L \leqslant 1000$ km).

ratio may provide an important reduction in transport costs. It is seen that the proportion of road cargo transport costs to sea cargo transport costs is 7. And this ratio changes a little with route length.

The evaluation of the figures for railroad transportation reveals that if the route length becomes greater than 350 km, railroad transportation becomes more economical than road transport. Within the range of 350–1000 km, the economic advantage of the railroad transportation changes between 0% and 20%. This advantage does not change depending on the fullness ratio.

5. Conclusion

In this study, a different cost analysis model based on various technical, economical and operational parameters including external costs is suggested for cargo and passenger transportation for different modes of transportation, namely, sea, road and railroad. In addition, a case study of cargo transportation in Turkey has been carried out by using the presented model with general formulas covering all cost items. Here, the vehicle types are selected according to their suitability to the conditions of this country.

The results of the analysis based on the transportation modes show that as the fullness ratio increases, the transportation costs decline in a descending trend as expected. In sea transportation, the cost reduction effect caused by increasing fullness ratios becomes more obvious in long routes than in short ones. The costs of cargo transport on road are affected more by the fullness ratio and route lengths as compared to sea cargo transportation. The change in the fullness ratio has a greater effect on the transport cost at long distances in railroad transportation. Sea transportation is always more economical than other modes while road transportation is more advantageous than the railroad in short distances. However, preferring the road transportation in the short routes will be reduced its disadvantages.

In addition, this study has attempted to determine the optimal fleet size and suitable vehicle capacities for different transportation modes by taking into account the yearly cargo potential and the fullness ratio of the routes.

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