FREIGHT TRANSPORT PLANNING WITH GENETIC ALGORITHM BASED PROJECTED DEMAND

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Abstract- *Road freight transport needs to be estimated using the current status of the transport using the socio-economic and transport related indicators and then the planning may be carried out in order to achieve the goals of sustainable transport system. Estimation of road freight tone-km/year is carried out using population, gross domestic product and number of vehicles i.e. lorries using genetic algorithm (GA) approach. Based on Genetic Algorithm (GA) approach, four forms of the Freight Transport Demand Model (GAFTM) are proposed. Best fit model to historical data is selected for future estimation. The estimated road freight tone-km is transferred to railway freight. Transformations are made to obtain one equivalent value of lorry that carries how much freight and correspondingly one train. Net-tone/km for train and lorry is obtained. After that three scenarios are proposed to control road freight tone-km by transferring the 1%, 2% and 3% of the road freight to railway freight. Extra income that is obtained by diverting road freight traffic to railway is calculated. Results showed that about $180 million dollar can be gained and 84000 lorries may be saved from road in 2025 if scenario 3 is applied.*

Keywords- *Genetic algorithm, road freight tone-km, railway freight, freight transport planning*

INTRODUCTION

Road and rail freight transport provides transport and environmental policy with some of its most intractable problems. Lorries are visually very intrusive, noisy, polluting and responsible for much of the impetus behind road building strategies. They are the most visible component of a relatively new and sophisticated production and distribution system that has evolved in a way that weakens local production and consumption links and encourages longer distance supply lines. Over time the distances over which freight moves have lengthened and the amount of dependence on distant sources and complex road freighting operations has increased. In order to understand the forces that currently mould road freight operations we have to be aware of the importance of the spatial distribution of manufacturing and the geographical location of raw material and intermediate product inputs into a final manufactured product. Such awareness can reveal the beginnings of a new strategy that will move freight transport operations in the direction of sustainable development. Reference [1] has made these processes much more transparent and revealed the opportunities provided by substituting "near" for "far" in sourcing decisions.

Freight transport strategies have to be alive to a number of influences. They must recognize the importance and growing importance over time of emissions from this sector. These emissions have well recognized negative impacts on human health and even though lorries form a relatively small part of the total number of vehicles their impact on emission inventories is disproportionately large. Freight transport strategies must recognize the commercial importance of moving goods around and satisfying the transport demands from other economic sectors. This will require careful negotiation with interested parties and careful management of all transport modes and all possibilities for local sourcing. Freight transport strategies must reflect the importance of environmental and sustainable development objectives.

Forecasts of future levels of demand in road freight transport vary enormously. European Union (EU) documentation refers to a doubling of road freight [2]. More analytical studies with a well defined time framework have produced a percentage increase in tone kilometers of road freight of up to 149 [3].

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References [3]-[4] predicted a growth of 58% in tone kilometers over the period 1990-2010. In the same period fuel consumption will rise by 23-57% even taking into account improvements in energy efficiency.

Forecasts of heavy goods vehicle traffic in Great Britain [5] are based on a constant relationship between GDP and road tone kilometers. The forecast of vehicle kilometers (all heavy goods vehicles) for the period 1988-2025 is for a low growth rate of 67% and a high growth rate of 141%. Forecasting is a very inexact science and past forecasts have underestimated the size of the growth in both passenger kilometers and tone kilometers. Current transport policies are discriminating against rail, coastal shipping and waterways. There is no such thing as a level playing field and the mythology of a free market in transport could not be further from the truth. There is no market mechanism guiding the flow of funds into road building programmes.

Freight transport modelling and planning prevents traffic congestion in rural roads and reduces the resource allocation for building new highway network and improved safety. In order to make a good decision making for future prospects of road and rail freight transport, demand for freight in both highways and railways needs to be estimated with mathematical methods. One of the new methods, Genetic Algorithms (GA), first developed by [6]-[7] proposed in this study. It is a quite new method to estimate demand for freight in rural roads. Based on Genetic Algorithm (GA) approach, Freight Transport Demand Models (GAFTM) are developed that use the population, the Gross Domestic Product (GDP) and the Number of Vehicles (NoV) as inputs. One of the main reasons for choosing the GA approach is that the socio-economic and transport related indicators may affect the freight demand in non-linear behaviour.

MODEL DEVELOPMENT

The GAFTM models use the GA notion that has been developed by [6]. Reference [7] applied its notion to the engineering problems. It is a iterative process that involves *reproduction*, *crossover* and *mutation***.** The main advantage of GAs is their ability to use accumulating information about initially unknown search space in order to bias subsequent searches into useful subspaces. GAs differ from conventional nonlinear optimization techniques in that they search by maintaining a population (or data base) of solutions from which better solutions are created rather than making incremental changes to a single solution to the problem. Definition of the GA and its application to transport demand modelling may be obtained in [8]-[10].

The four forms of the GAFTM models are developed in the following way.

Exponential form of the $GAFTM_{exp}$ model is:

$$GAFTM_{\exp} = w_1 + w_2 X_1^{w_3} + w_4 X_2^{w_5} + w_6 X_3^{w_7} \quad (1)$$

Quadratic forms of the $GAFTM_{quad}$ models are:

$$GAFTM_{quad0} = w_1 + w_2 X_1 + w_3 X_2 + w_4 X_3 + w_5 X_1 X_2 + w_6 X_1 X_3 + w_7 X_2 X_3 + w_8 X_1 X_2 X_3 \quad (2)$$

$$GAFTM_{quad1} = w_1 + w_2 X_1^{w_3} + w_4 X_2^{w_5} + w_6 X_3^{w_7} + w_8 X_1 X_2 + w_9 X_1 X_3 + w_{10} X_2 X_3 + w_{11} X_1 X_2 X_3 \quad (3)$$

$$GAFTM_{quad2} = w_1 + (w_2 X_1 + w_3 X_2 + w_4 X_3)^{w_5} \quad (4)$$

where X_1 is the population (10^6), X_2 is the GDP (10^9\$) and X_3 is the NoV (10^5).

After applying the GAFTM models to estimate road freight transport using data on Table 1, the following weighting parameters are obtained.

$$GAFTM_{\exp} = 0.77 + 0.26 X_1^{0.44} + 0.00 X_2 + 0.31 X_3^{1.35} \qquad R^2 = 0.92 \quad (5)$$

$$GAFTM_{quad0} = 0.978 + 0.00 X_1 + 0.00 X_2 + 0.392 X_3 + 0 X_1 X_2 + 0.016 X_1 X_3 + 0 X_2 X_3 + 0 X_1 X_2 X_3 \qquad R^2 = 0.91 \quad (6)$$

$$GAFTM_{quad1} = 0 + 9.041 X_1^{0.001} + 0.00 X_2 + 0.0 X_3 + 0 X_1 X_2 + 0.0189 X_1 X_3 + 0 X_2 X_3 + 0 X_1 X_2 X_3 \qquad R^2 = 0.91 \quad (7)$$

$$GAFTM_{quad2} = 4.88 + (-1.47 X_1 - 0.16 X_2 + 3.34 X_3)^{0.98} \qquad R^2 = 0.91 \quad (8)$$

The validation of the four forms of the GAFTM models may be obtained in [8]. Tests were carried out based on the minimum relative error in testing period. The minimum error obtained in $GAFTM_{exp}$ model, thus it is selected for future freight transport demand estimation.

TABLE 1
Used data for road freight demand estimation

Years	Population (10^6)	GDP(10^9\$)	Goods transport	
			NoV(10^5)	tone-km (10^9)
	X_1	X_2	X_3	*GAFTM*
1980	44.74	69.75	33.07	37.51
1981	45.86	72.78	34.46	39.01
1982	47.00	65.94	35.95	40.57
1983	48.18	62.19	37.67	42.19
1984	49.38	60.76	39.58	43.88
1985	50.66	68.20	41.80	45.63
1986	51.78	76.46	44.19	54.02
1987	52.92	87.73	45.94	58.83
1988	54.08	90.97	47.49	65.46
1989	55.27	108.68	49.00	68.24
1990	56.47	152.39	52.08	65.71
1991	57.50	152.35	55.43	61.97
1992	58.55	160.75	59.53	67.70
1993	59.61	181.99	65.98	97.84
1994	60.70	131.14	68.82	95.02
1995	61.81	171.98	71.92	112.52
1996	62.93	184.72	77.61	123.67
1997	64.08	194.36	88.34	124.34
1998	65.24	205.98	99.72	135.27
1999	66.43	187.66	107.19	134.41
2000	67.64	201.48	118.87	141.82
2001	68.59	144.00	122.97	151.42
2002	69.82	181.00	127.44	150.91
2003	69.93	238.53	137.85	152.16
2004	70.85	301.53	190.73	156.85
2005	71.76	359.97	215.20	166.83
2006	72.67	380.62	240.52	177.40

Sources: General Directorate of Turkish Highways [11], State Planning Organization [12]

ROAD FREIGHT TRANSPORT DEMAND IN FUTURE

When road and railway freights are analyzed, the road freight is increased about 4 times, but railway freight is not considerably changed within last 21 years for the period of 1985-2006. These trends will continue if efficient freight plan is not made. Figure 1 shows the general trend of road and railway freight between 1985 and 2006 indexed at 1985 as 1. Road freight transport demand is forecasted under different scenarios using these values in this study.

Estimation of road tone-km is carried out after forecasting the socio-economic and transport related indicators. The estimation of population, GDP and NoV is carried out in the following way.

1. Population: State Planning Organization (SPO) [12] plans and controls the population growth rate in Turkey according to the 5 years National Development Plans (NDP). This plans show that the growth rate of population is separated into two categories. One is the real growth and the second is the targeted growth rate. It indicates that the population growth rate increase with a decreasing trend especially within last 15 years. Therefore, it may be better to estimate the population of Turkey in 2025 according to the two-case: One is the current population growth rate that can be obtained from

the observations and it is named as Case I, and the second is the targeted growth rate according to the NDP named as Case II.

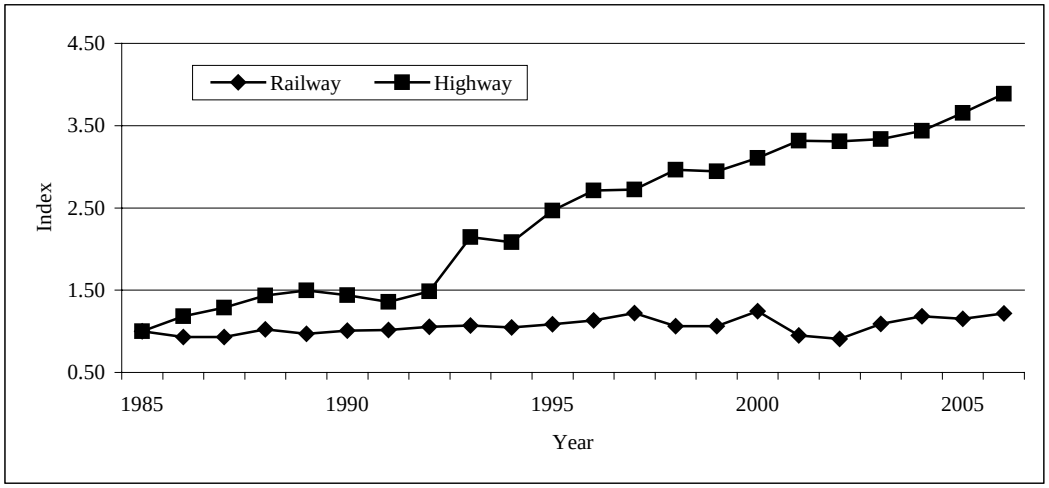

FIGURE 1
The trend of road and railway freights for the period of 1985-2006 (fixed at 1985=1) [11]-[13]

2. GDP: The observed GDP is in the fluctuating trend. Therefore, it could be better to take the average growth rate of the GDP under various cases. The cases can be explained as:
   Case I: Take the average growth rate of the observed period for the GDP as a future growth rate (i.e. annual average growth rate is 4% within last 20 years),
   Case II: Assume that the GDP of Turkey by means of per capita will meet the EU average in 2025 (i.e. 6% annual growth rate).

The projected GDP can be obtained in [9] based on the Case I and Case II.

3. NoV: Number of light goods vehicles (LGV) and trucks show linear increase within the last 30 years. Therefore, the following linear equations are used to predict NoV in the future.

$y = 55667x + 173990$ $R^2 = 0.94$ (9)
$y = 11657x + 139389$ $R^2 = 0.99$ (10)

where y is number of lorries and x is the time series where 1985=1, 1986=2….

Projected number of vehicles (NoV) is given in Table 2. The NoV for goods transport is $2.8*10^6$ and the total NoV is $22.5*10^5$ in 2025.

TABLE 2
Projected NoV

Years	2010	2015	2020	2025
NoV (10^5)	178.81	212.47	246.13	279.79

Expected road freight tone-km may be analyzed under four combinations as:

	Population	**GDP**	**NoV**
I. Combination	Case I	Case I	Table 2
II. Combination	Case I	Case II	Table 2
III. Combination	Case II	Case I	Table 2
IV. Combination	Case II	Case II	Table 2

Application of $GAFTM_{exp}$ model for road freight tone-km under four combinations can be seen in Figure 2 for the period of 2007-2025. The lowest and highest estimated road freight tone-km is about between 530 and

$575*10^9$ tone-km/year for combinations I and II. Therefore, combination I and II is selected for future analysis.

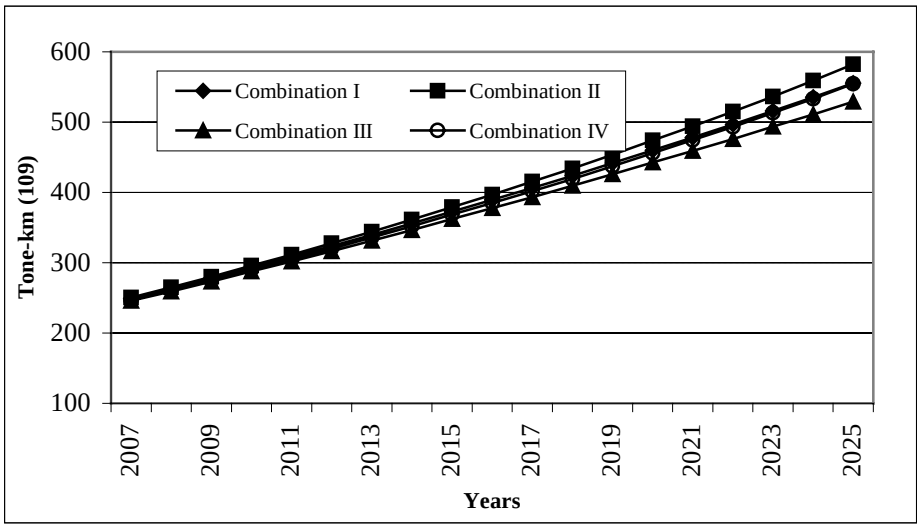

FIGURE 2
Estimated road freight tone-km under four combinations

SCENARIOS AND FREIGHT DEMAND ANALYSIS

The forecasted road freight transport is transferred to the railways under three scenarios. It is assumed that until 2010 there are no policy changes for all scenarios. All the analyses are carried out after 2010. If some part of the road freight is transferred to a railway, then it requires some extra time to plan its coming extra demand from road freight.

Scenario 1: Each year 1% of the road freight is transferred to railway and it steadily increases, meaning that 15% decrease on road tone-km in 2025.

Scenario 2: Each year 2% of the road freight is transferred to railway and it steadily increases, means that 30% decrease on road tone-km in 2025.

Scenario 3: Each year 3% of the road freight is transferred to railway meaning that and 45% decrease on road tone-km in 2025.

TABLE 3
Transferred road freight tone-km to railway for the period of 2011 to 2025

Year	Expected road freight demand (10^6 tone-km)	Transferred road freight (10^6 tone-km) to railway freight		
		Scenario 1	Scenario 2	Scenario 3
2011	303.53	3.04	6.07	9.11
2012	319.02	6.38	12.76	19.14
2013	334.92	10.05	20.10	30.14
2014	351.26	14.05	28.10	42.15
2015	368.03	18.40	36.80	55.20
2016	385.00	23.10	46.20	69.30
2017	402.41	28.17	56.34	84.51
2018	420.26	33.62	67.24	100.86
2019	438.57	39.47	78.94	118.41
2020	457.33	45.73	91.47	137.20
2021	476.33	52.40	104.79	157.19
2022	495.80	59.50	118.99	178.49
2023	515.75	67.05	134.09	201.14
2024	536.19	75.07	150.13	225.20
2025	557.13	83.57	167.14	250.71

Forecasted road freight tone-km and transformations to railway freight can be seen in Table 3. As can be seen, the minimum values of $84*10^6$ tone-km and $250*10^6$ tone-km can be transported by train according to scenario 1 and 3, respectively.

After transferring the road freight tone-km to railway will lead to change the railway freight net-ton-km and it creates some extra income. Current level of railway revenues for only freight transport can be seen in Figure 3. Figure indicates that there is a floating trend in observed revenues between 1985 and 2000. After 2001 observed revenues slightly increased. It is expected that increasing trend of freight income will continue in future years.

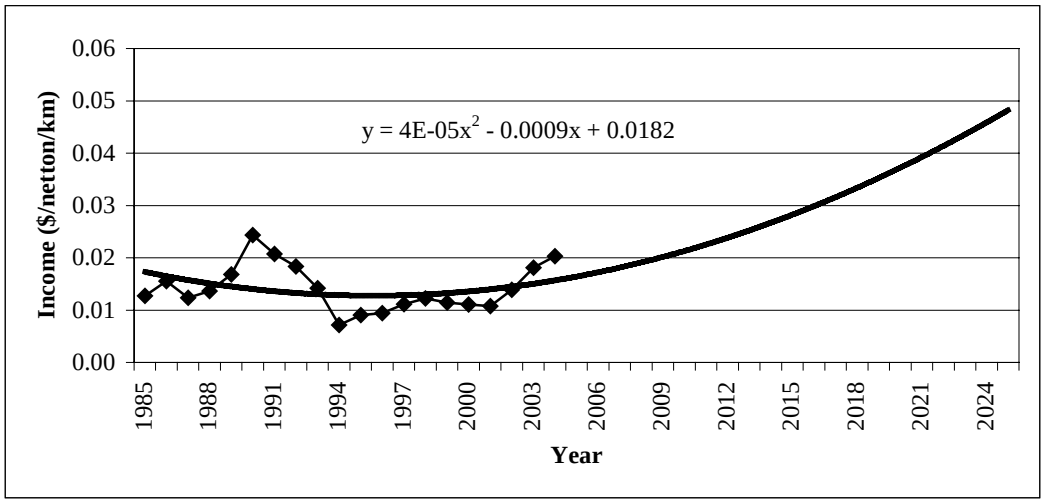

FIGURE 3
Observed and expected revenues for railway freight net-tone/km.

In order to calculate the equivalent unit value of road freight tone-km, there is a need to estimate how much the average value of one lorry that moves with a goods and similarly one train. It is obtained that one lorry carried 3 tones and one train carries 170 tones. Using these values, transformations from road freight to railway freight are made. Results can be seen in Table 4. Expected extra revenues from rail transport are about $\$60*10^6$ to $\$180*10^6$ in 2025 for scenario 1 and 3, respectively.

TABLE 4
Divided railway freight demand and extra revenue for railways

Year	Net-tone/train-km (10^6)			Extra revenues ($\$10^6$) for railways		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
2011	55	110	166	1.03	2.06	3.09
2012	116	232	348	2.28	4.56	6.84
2014	255	511	766	5.58	11.16	16.74
2015	335	669	1004	7.72	15.43	23.15
2016	420	840	1260	10.23	20.46	30.69
2017	512	1024	1536	13.18	26.37	39.55
2018	611	1223	1834	16.63	33.25	49.88
2019	718	1435	2153	20.63	41.25	61.88
2020	832	1663	2495	25.24	50.49	75.73
2021	953	1905	2858	30.54	61.08	91.63
2022	1082	2163	3245	36.61	73.21	109.82
2023	1219	2438	3657	43.52	87.04	130.56
2024	1365	2730	4095	51.37	102.75	154.12
2025	1519	3039	4558	60.26	120.52	180.78

CONCLUSIONS

This study deals with estimation of road freight transport demand indicators in Turkish rural roads and analysis the railway extra revenues if some part of the road freight is transferred to railways. The GAFTM models are developed using population, GDP and number of vehicles. The road freight demand is projected with four cases under four combinations of the cases. GA approach is selected as a methodology so that road freight tone-km may be better estimated by the non-linear form of the mathematical expressions. Among the four forms of the GAFTM models, the best of the GAFTM model is selected in terms of minimum total average relative errors in testing period. The following results can be drawn from this study.

The analysis has shown that the potential for reducing the number of lorry movements in Turkey is very large and much larger than previously recognized. This reduction can be achieved in part by transferring freight from road to rail It is clear, however that a transfer of this kind cannot represent a fundamental solution to the problems of rising ton-km of road freight. Freight transport offers a number of attractive options for building alternatives. Establishing the importance of regional and local production/consumption links and reducing the basic demand for freight transport is one of these alternatives.

The case for fundamental demand reduction in road freight transport is a strong one and the time has arrived when continuing to develop along the same path as the last 20 years is no longer acceptable and is in clear conflict with sustainable development objectives. There is a way forward and sustainable development is a stimulus to innovation and experimentation that will chart a new course.

Analysis showed that minimum of 1000 lorries discarded from road traffic according to scenario 1 in 2011 and 83570 lorry will be discarded from road traffic if scenario 3 is applied in 2025. This means that improved road safety and environmental pollution and extra revenue for railways.

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REFERENCES

[1] Böge, S. 1994. The Well Travelled Yoghurt Pot: Lessons for new freight transport policies and regional production. In World Transport Policy and Practice, MCB, Bradford.

[2] CEC, 1994. Road Freight Transport: the single European Market. Report of the Committee of Enquiry, July 1994, DGVII, Commisson of the European Communities, Brussels.

[3] Hey, C, Hickmann, G, Geisendorf, S., Schleicher-Tappeser, R., 1992. Dead End Road: Freiburg, Germany.

[4] Bleijenberg, A., 1993. Fiscal measures as part of a European Transport Policy in ECMT, Transport Policy and Global Warming, OECD, Paris, 141-154.

[5] HMSO, 1989. National Road Traffic Forecasts (Great Britain), Department of Transport.

[6] Holland, J. H, 1975. *Adaptations in Natural Artificial Systems.* University of Michigan Press, MI.

[7] Goldberg. D.E., 1989. Genetic Algorithms in Search, Optimization and Machine learning. Addison-Wesley, Harlow, England.

[8] Haldenbilen, S. and Ceylan H., 2005. "The development of a policy for road tax in Turkey, using a genetic algorithm approach for demand estimation". *Transportation Research 39A, 861-87.*

[9] Haldenbilen, S. and Ceylan H., 2005. "Transport Demand Estimation based on Genetic Algorithm Approach" *Transportation Planning and Technology*, V(28), No:6, 403-426.

[10] Haldenbilen, S., 2003. Investigation of indicators of sustainable transportation systems using genetic algorithm approach: a case study of Turkey". PhD Thesis, Pamukkale University, Turkey.

[11] GDTH, General Directorate of Turkish Highways, 2008. *Statistical Yearbook on Turkish Highways 1990-2006.* The Republic of Turkey, Ministry of Public Works and Settlement General Directorate of Highways, Planning division, Ankara, Turkey.

[12] SPO, State Planning Organization, 2008. Available at http//.www.dpt.gov.tr.

[13] TR, Turkish Railways, 2008. Available at http//.www. tcdd.gov.tr.