Presenting the model of inter-region freight transportation in Iran Road transportation network

Gholam Ali Shafabakhsh[1*], Mohsen Sadeghi[2], Ehsan Kashi[3*]

1 Semnan University, Faculty of Civil Engineering Assistant Professor, Semnan, I. R. of Iran
2 Semnan University, PHD student, Faculty of Civil Engineering, Semnan, I. R. of Iran
[3] Semnan University, PHD student, Faculty of Civil Engineering, Semnan, I. R. of Iran
shafabakhsh@semnan.ac.ir

Abstract : Interregional trips include passenger and freight trips. To predict passenger trips, four- stage method is used including trip production, trip distribution, modal split and assignment. Four-stage model is not more efficient for freight transportation. In this paper, mathematical modeling is presented based on entropy and reduction of intervals and freight transportation time. For this model input-output relationships between the regions and road transportation network flows were considered. To solve this model, the data from the Iran's transportation master plan has been used. Finally, the results of solving model were compared with the observations and the model was evaluated. The results showed that the presented model had good accuracy in estimating the percent of different kinds of transported freight and the accuracy of the model in estimation of freight transportation matrix between the regions and with the separation of different freight were suitable.
[Gholam Ali Shafabakhsh, Mohsen Sadeghi, Ehsan Kashi**. Presenting the model of inter-region freight transportation in Iran Road transportation network.** *Life Sci J* 2012; 9(3):763-769]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 108

Keywords: Freight transportation, distribution model, Entropy, math modeling

1. Introduction

Transportation is the basis of a linking bridge that various parts of societies by passing from it move toward permanent development. Today, transportation is infrastructure section of economy affecting economical development process and is the basis of trade exchanges and economical and social development key. It is obvious that there is a direct relationship between the efficiency in transportation and public efficiency of economy and economical growth and transportation is a mediator between agricultural, industrial, trade and service activities at national and international level. Another group considered transportation the heart of development and believed that transportation has effective role in distribution of incomes and reduction of social and economical inequalities and reduction of poverty and difference of income between the rural and urban people. The studies carried out at macro economical level of some of the countries showed that investment in transportation increased economical growth of the countries and by increasing the social output in private investment provided investment in transportation infrastructures. Transportation industry in Iran during various periods had some problems and its main aim was the attempt to achieve a better position and considering the special position of the country in the region, creating an efficient transportation system had special position in socio-economic development. Now, about 500 million tons freight are transported between the provinces in Iran annually and this subject shows the economical exchanges between the provinces of Iran.

Among all the freight exchanges done in Iran between the regions, about 95% are done by road transportation and 5% are done by rail transportation. Although this is due to the lack of incomplete railway network in Iran, irregular planning and the lack of considering combinational transportation. Finally, in Iran considering the existing condition, more inclination is toward road transportation of freight and the holders of freight due to some reasons as trip time, costs and comfort prefer to use this method to transport their freight.

Thus, modeling the distribution of different kinds of freight between some regions in Iran can be an interesting subject being investigated in this study.

2. Literature review

Modeling freight transportation as a subset of transportation comprehensive plans in terms of progress, importance and planning to the modeling in urban trips is very slow. However, Izard (1960) was the starter of freight transportation modeling and had a good progress[8] but Leontief and Strout (1963) and Wilson (1970) didn't have good progress in the execution and estimation of the issues with great scales [11,14].

Maybe, the main reason is the shortage of the models being used, the lack of access of good data about freight in transportation network and freight loading between the regions. Since 2002, there were some statistics in the form of bill of lading about

freight transportation in Iran but the data is not published with some details and they are not used compared to the existing data about urban trips for estimation of the model. The road network data were not completely available to be used for modeling freight transportation network.

In the plans presented during 1980s regarding the construction of freight transportation models Boyce and Hewings (1981), Batten and Boyce (1986), Kim et al (1983) it is attempted to consider the data of freight[2,1,9]. The structure of the presented plan Kim et al (2002) was regarding the effect of earthquake on inter regional freight transportation[10] while, Fernandez et al (2003) presented a comprehensive model in which the balance of supply and demand was shown in intercity freight transportation[4]. Lin and Kockelman (2002) followed the discussion of freight transportation and land use [12]. DeJong et al (2004) reviewed different kinds of freight transportation [3]. Ham et al (2005) presented a comprehensive model for freight transportation as multidimensional and by Lagrange algorithm solved it [6]. Vigan, Southworth (2005) dealt with the problems and errors of different kinds of freight transportation [15].

Considering the previous studies, such models are evident. The regions with low budget assignment had structural progress (provinces, metropolis, countries, etc) should predict which of the parts of inter regional road network are faced with more freight transportation issues. Better predications enter the market on the behalf of freight transportation companies with considerable money. Answering the questions of the priority of the development of infrastructures and other kinds of development require a better attitude to the increase of network dimensions.

3. Methodology

A country can be divided into some economical divisions each consisting of one or more small regions and agricultural, industrial and mineral activities. There is a region for each region of economical models covering economical relations and entrance-exit relations of freight from the region. In this study, the aim was to predict the transportation of inter regional freight based on the type of freight. To achieve the mentioned aim, a model should be made and used requiring some criteria, to make exchange model of the freight inter regional, the following criteria are considered:

- Forming a coherent model of transportation network and transporting various freight inter regional as the effect of network disturbance is observed.
- Estimation of model parameters of the existing data in special time

In this study, the conditions and data of the model were explained. Iran zoning for freight transportation, classification of different kinds of freight and definition of road arterial network are initial actions that should be done. In the next stage, the related model is presented and its characteristics are analyzed. Then, the estimation of the variables and results was explained and finally the results of the model were displayed briefly and the general predications of the model were compared with the data being used in estimation process to show the conformity of this model.

3.1. Zoning

Normally, the following criteria are used for the definition of the regions.

The regions system should be in conformity with the country divisions namely regarding the statistics of population and production. Thus, the regions are defined as: A set of smaller units that can be collected by various ways as the results of these studies are compared with each other.

- The regions should be homogenous as possible. This case is easily about urban regions. Because the regions are bigger and each one were including different kinds of installations or residents. Thus, homogeneity should be balanced in terms of the aims of the study and based on two variables of the region size and country divisions.

Fig 1: Zoning freight transportation based on gravity centers in Iran

- The regions should show the natural zone of influence and influence zone of its centrality and interior networks of the region. This case should be

observed in appearance of the regions as it shows the interior characteristics of the region.

- The regions shouldn't be the same and their sizes should be in conformity with the trip time units. Thus, more compressed regions should have smaller dimensions.

Each region is determined by a equilibrium or gravity center. In urban studies, gravity centers are virtual determining the average trip cost to another place in each region. Normally, these places are related to a specific location but it is not necessarily the same. These places are linked to the network by a channel showing the average cost of link to a node is in the real network (road). In intercity studies, bigger regions are used and this process is vice versa, it means that the central point shows the production and absorption trip centers and it is determined first. Then, the region boundary is determined based on influence zone of central point considering the influence zone of central points of the neighboring regions. Figure 1 shows the zoning including 56 zones.

3.2.Freight classification

Freight classification can be done by various methods and the classification shouldn't be not very big or small. The freight classification in this paper is based on classification in bill of lading of road maintenance and road transportation. This classification is in accordance with Table 1. This classification is including 27 types of freight.

3.3. Road transportation network

Transportation network in this study is including arterial roads. The data of transportation networks including arterial paths are relate to arterial paths based on the data of road maintenance and road transportation. To analyze the freight transportation with heavy vehicles, a road network with 61 nodes and 227 links are made. The nodes and links were defined based on the intersection of the roads and the interval between these intersections.

The capacity of road links for highways and freeways in which the going and coming path are separate, 10000 trucks/passing line and for the rest of roads including major and minor ways 7000 trucks, passing lines, day are assumed. Fig. 2 shows the arterial network of Iran roads in 2007.

Table 1: The classification of different kinds of transported freight with road transportation

No.	Freight type	No.	Freight type	No.	Freight type
1	Grains	10	Cotton	19	Construction materials
2	Rice	11	Sugar	20	Mineral
3	Cereals	12	Edible oil	21	Fuel
4	Vegetables	13	Flour	22	Chemical
5	Fruit	14	Fast food	23	Textile
6	Live stock	15	Steel	24	Detergent
7	Poultry	16	Metals	25	Car and machineries
8	Fertilizer	17	Coal	26	Paper and wood
9	Tea	18	Cement	27	Durable freight

Fig 2: Arterial road network in Iran in 2007

3.4. The recommended model for freight distribution and solution

In this stage, we deal with the needs of the model, its construction and its limitations. The recommended math model is based on non-linear objective function and five limitations and in the following their design is mentioned.

3.4.1. Model requirements and preparing the data

Freight transportation is based on economical relations and the volume of entrance and exit freight of the regions; m shows the type of freight moving between r regions. This model of freight transportation based on enter-exit of freight of regions can predict the costs of freight exchange between the regions and freight transportation in the network by various transportation methods. The

predicted freight are attributed for exchange between the regions in accordance with a simple criterion of the minimum distance of the methods, paths and links. This model is formulated as an optimization issue with the limitation and is solved by Matlab software.

3.4.2. Objective function

The math relations of freight transportation model between the regions were obtained of the combination of Leontief, Strout, Wilson and Ham. The exit and entrance of the freight for each region is considered by entrance-exist regional models in analysis duration as one year. The existing issue is the predication of the exchanges between each pair of region in accordance with the section-freight and transportation networks.

The first assumption is that all the authorities in transporting in case of not having the information about transportation costs are inclined to make the distances and transportation time to the minimum and the second assumption is that there are some factors that cause the dispersion of freight transportation on origins and destinations. Thus, transportation methods can be depicted by Entropy functions. Thus, objective function is defined as:

$$\min z = \sum_a \int_0^{f_a} d_a(\varphi) d\varphi - \sum_m \frac{1}{\lambda^m} \sum_{ij} x_{ij}^m \ln\left(\frac{x_i^m}{x_{ij}^m}\right) - \sum_{im} \frac{x_i^m}{\theta_i^m} \ln\left(\frac{x_i}{x_i^m}\right) \quad (1)$$

In equation 1, the parameters are defined as:

f_a^w : Flow in Ton on link a

$d_a(f_a)$: The distance of freight transportation (km) on link a

x_{ij}^m : Freight exchange (Ton), type m from region i to region j

λ^m : Sensitivity parameter in regions for type m freight

x_i^m : Total freight exit of type m from region i(Ton)in a year

x_i : Total exit freight of region i (Ton) in a year

θ_i^m : Sensitivity parameter of production or storing the type m freight in region i

3.4.3. Limitations

After defining the objective function, the limitations should be defined as following. For this initial model, the distances of links are considered fixed or in case of the presence of linkhes with more traffic, the length is considered bigger than the real length effectively to show the extra operational costs of traffic density. To show this effective distance, the old function of trip time-volume (BPR) was used that by increasing the ratio of the flow to the capacity and as it reaches 1, positive power of trip time is increased. This function is investigated of power zero, 3, 6 and sensitivity analysis is done for it. During the use of this model, it is possible that to show critical events as earthquake, etc some of the links are deleted from the network completely or some of the paths are reduced. The limitations of the objective function defined in the previous item can be defined as:

The first limitation shows that the flow of each link is equal to the sum of the path flows on all the paths between all the regions by link a

$$\sum_m \sum_{ijr} s_{ijr}^m \delta_{ijr}^m = f_a$$

For all a links (2)

s_{ijr}^m : It denotes exit flow (Ton) of type m freight from region i to region j on path r

δ_{ijr}^m : If path r uses a link from i to j path, this parameter is 1, otherwise it is 0.

f_a : Flow in Ton on link a

The second limitation shows that the amount of exit and entered freight of type m and to region i should be equal to the sum of the freight exchange between region i and all the regions j.

$\sum_j x_{ij}^m = x_i^m$ For each freight type m and all regions i (3) The third limitation showed that total exit freight from a region and entered to a region is equal to the sum of different kinds of exit and entrance freight to region i.

$\sum_m x_i^m = x_i$ For all the regions i (4)

The final limitation showed that the path flows should be non negative and this means that the flows of links should be non-negative.

$s_{ijr}^m \geq 0$ For each freight m and all regions i,j and all paths r (5)

3.4.4. Solution algorithm

Innovative searching methods are methods presenting an answer close to optimized answer at optimal time for a problem by searching among the possible answers. Normally, there is no reason that

the obtained answer is the best answer and we can not even compare the closeness of the optimized answer with the real optimized answer.

One of the super innovative methods being used in recent years for solving math planning and the problems with integer numbers is genetic algorithm method. The researchers by observing the conformity, resistance, self-repair, guide, production and other characteristics of natural systems and reflecting in the point that how the nature solves the problems and they were thinking about imitating natural methods for solving complex problems and the design of systems. The main idea of genetic algorithm is formed based on Darwin evolution theory. Rechenberg (1973) by presenting evolutionary calculation methods being inspired by nature to solve the hard problems took the first step [13]. But the initial principles of genetics algorithm were presented by Holland et al. They were inclined to the conformity of natural systems for modeling artificial systems. These studies formed genetics algorithm. Holland (1975) indicated the math basics of genetic algorithm in his famous book [7]. Goldberg (1989) showed that genetic algorithms are research methods based on genetic mechanic and natural selection [5].

These methods rapidly after a small part of searching space is converged to optimized answers and are used successfully for complex optimization problems in engineering. Algorithm is an artificial resistance of a good test method with genetic process such as production, mutation and crossover for forming a better answer from one repetition to another repetition and reaching an optimized answer.

Considering the presence of some tools such as Matlab software with the capability of solving these issues by various algorithms, to solve this problem, this software and genetic algorithm module were used.

4. Results

The results of solving model can be summarized in three sections. The first section is about the determining the share of each of different kinds of freight based on the model and its comparison with the observations.

In this section, R^2 between the observations and estimations is 0.89. Table 2 shows the percent of each of different kinds of freight in two cases of observation and estimation.

Table 2: The difference of the percent of observed and estimated for different kinds of freight

Freight type	Observed percent	Estimated percent
Grains	5.6	9.14
Rice	0.9	0.81
Cereals	0.2	0.19
Vegetables	3	3.68
Fruit	2.5	2.28
Live stock	3.4	2.78
Poultry	0.6	0.42
Fertilizer	2.9	3.23
Tea	0.1	0.12
Cotton	0.4	0.32
Sugar	1	0.85
Edible oil	1.2	0.81
Flour	0.7	0.82
Fast food	3.1	3.58
Steel	11.8	7.81
Metals	1.6	1.30
Coal	0.7	0.50
Cement	10.9	13.89
Construction materials	12.2	10.26
Mineral	4.7	5.21
Fuel	12.3	11.36
Chemical	2.8	2.08
Textile	1.1	1.35
Detergent	0.6	0.62
Car and machineries	4.5	5.56
Paper and wood	2.3	2.38

Durable freight	8.8	8.66

As is shown in Table 2, the estimated values for the percent of the transported freight are acceptable considerably, only in some of the freight consisting of a great part of transportation in Iran such as grains and steel, the difference is considerable.

Second section of the results is the comparison of the flow of heavy vehicles on the links. In this section considering the presented model and BPR function with the equation $d_a^t = d_a(1+0.15(f_a/C_a)^p)$, in which p is parameter of link function, f_a: The observed volume on the link, Ca: link capacity, d_a free trip time and d_a^t:The final trip time. The investigation was done for three powers of 0, 3, 6 and the observed and calculated results were compared. For three cases R^2, 0.73, 0.51 and 0.81 were observed. Fig. 3 showed the dispersion between the observations and estimations for function parameter of link equal 6.

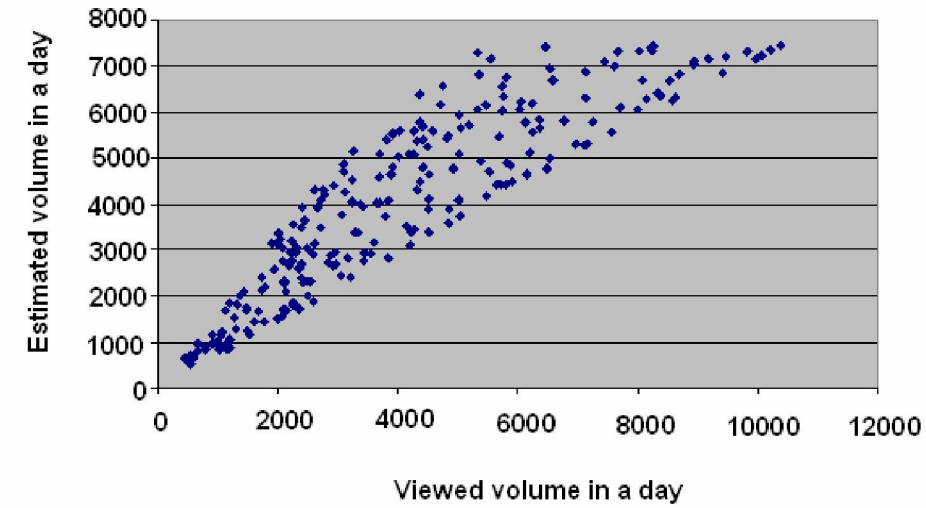

Fig 3: The comparison of the trip time of the links for two cases of observed and estimation with function parameter of link6

. The third section of the results of the presented model in this study is the comparison between the origin and destination matrix of each freight separately. As it was presented in the model, x_{ij}^m is the amount of transported freight of type m between two regions i, j. This matrix had 84672 members in this study. In the comparison of the observations and estimations for this variable, R^2 was 0.63. Although correlation coefficient is not very suitable in this case, it can be acceptable.

5. Conclusion

A mathematical model based on entropy objective function and reduction of flow in links was executed to predict the transportation of inter regional freight and transportation network flows based on the type of freight. Thus, this model is an alternative for the stages of trip distribution and traffic assignment of four-stage model of transportation planning. This model is done for transportation of freight with 27 type's freight and 56 regions and for simplified road network of Iran. This model was successfully solved by genetic algorithm in Matlab software. The required model was executed to estimate the transportation of the inter regional freight based on the type of freight, the links flow. It seems that this model kept the general nature of regions and different types of freight and the predicted transportation was in line with the observed transportations.

According to the results of model, the percent of different kinds of transported freight can be done and the elements of origin and destination matrix for each of the freight mentioned that regarding the first case, the results were rather acceptable but in the second case, the correlation coefficient of the estimated results was considerably different from the observed results.

References:

[1] Batten, D.F., Boyce, D.E.: Spatial interaction, transportation, and interregional commodity shipment models. In: Nijkamp, P. (Ed.), Handbook of Regional and Urban Economics, vol. 1. ,1986, pp.357–406.

[2] Boyce, D.E., Hewings, G.J.D.: Interregional commodity flow, input–output and transportation modeling: an entropy formulation. Presented at the Conference on Interregional Models, First World Regional Science Congress, Cambridge, MA, 1981.

[3] DeJong, G., Gunn, H. and Walker, W.: National and international freight transport models: an overview and ideas for future development, Transport Reviews, vol.24, no.1,2004,pp.103-124.

[4] Fernandez, J.E., de Cea, J., Soto, A.: A multi-modal supply-demand equilibrium model for predicting intercity freight flows. Transportation Research 37B, 2003, pp.595–614.

[5] Goldberg, D.E.: Genetic Algorithms in Search, Optimization and Machine Learning, Addison-Wesley,1989.

[6] Ham, H., Kim, T. H., Boyce, D.E.: Implementation and estimation of a combined model of interregional, multimodal commodity shipments and transportation network flows. Transportation Research Part B 39,2005, pp.65–79

[7] Holland, J.H.: Adaptation in Natural and Artificial Systems, The University of Michigan Press,1975.

[8] Isard, W.: Methods of Regional Analysis. MIT Press, Cambridge,1960.

[9] Kim, T.J., Boyce, D.E., Hewings, G.J.D.: Combined input–output and commodity .flow models for interregional development planning: insights from a Korean application. Geographical Analysis 15,1983, pp.330–342.

[10] Kim, T.J., Ham, H., Boyce, D.E.: Economic impacts of transportation network changes: implementation of a combined transportation and input–output model. Papers in Regional Science 81, 2002,pp. 223–246.

[11] Leontief, W.W., Strout, A.: Multiregional input–output analysis. In: Barna, T. (Ed.), Structural Interdependence and Economic Development. Macmillan, London,1963.

[12] Lin, J., Kockelman, K., Zhao, Y.: Tracking land use, transport, and industrial production using random-utility based multizonal input–output models: applications for Texas trade. Working Paper, Department of Civil Engineering, University of Texas, Austin,2002.

[13] Rechenberg, I.: Evolution strategie: Optimierung Technisher Systeme nach Prinzipien des Biologischen Evolution. Fromman-Hozlboog Verlag, Stuttgart, 1973.

[14] Wilson, A.G.: Interregional commodity flows: entropy maximizing procedures. Geographical Analysis 2, 1970,pp.255–282.

[15] Wigan, M.R., Southworth, F.: What's Wrong with Freight Models and What Should We Do About It?, Paper prepared for the European Transport Conference, Strasbourg, France, October 2005.

07/2/2012