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Optimization and easement of highway traffic by using DEA logic

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Accepted: September 31, 2015

ABSTRACT

One of the phenomena that Tehran inhabitants encounter everyday is the traffic. The destructive effects of this phenomenon are dawdling of vehicle passengers, air pollution, waste of fuels and etc. Several solutions have been proposed up to now to overcome this problem. Unfortunately, this most of these solutions are theoretical and are not on the basis of the traffic reality. In this paper, by considering humans' behavior theory and using the data envelopment analysis technique, an effort is made to solve this problem. Moreover, the proposed suggestions are able to control the highway traffic and allocate an emergency lane to emergency vehicles. As a result, the highways' traffic will be optimized and relaxed practically.

KEYWORDS: traffic, relaxation, data envelopment analysis.

1. INTRODUCTION

Traffic is one of the harmful events which its destructive effects not only affects the time, but also they have an influence on fuel and air pollution. Based on the statistics obtained from the national(Statistical Center of Iran) statistics organization in 2009, the fuel cost and also the costs related to the inappropriate use of the traffic and vehicles in cities are about 30000 billion Tomans(1Toman=10Rial (Rial:Iran's currency)) a year. During a year, about 4 billion hours of people's lifetime is wasted in big cities traffic. If Rial value of a single hour is assumed to be 1000Tomans, the cost of annual time waste imposed to the country will be about 4000 billion Tomans. It is obvious that traffic and its related problems impose huge costs to megacities in a country. Therefore, presence of an appropriate schedule based on the facts can decrease a big part of these costs.

There are several methods in order to estimate the traffic and slow it down. Most of these methods are theoretical and their information and inputs are based on the assumptions and simplifying the facts. As an example, in dynamic freeway traffic management method, based on limited factors such density, access and volume, the traffic is evaluated. This will make the study unreal. Among other methods used for traffic control, there is a method called cellular transmission which evaluates the performance based on a single unit and therefore, the effects of other units are omitted and as a results, the model can't be close enough to the reality. Considering the aforementioned facts, the presence and definition of a method which can evaluate the traffic conditions effectively, will be necessary. So in this paper, some efforts has been made in order to optimize and solve the traffic problem effectively by using data envelopment analysis method.

The data envelopment analysis method is a mathematical Programming method for evaluating the performance of decision maker units that have several inputs and outputs and are based on the output to input ratio. Hence, this method is used for performance evaluation especially for state commercial companies, hospital organizations, educational centers and etc. [1].

Charnes[2] developed the Farrell viewpoints and proposed a pattern that could measure the performance with several inputs and outputs. This pattern was named as Data Envelopment Analysis and was used for the first time in the Phd thesis of Edward Rods with Cupper as the supervisor and the title 'Educational Development of US National Schools students in 1976 and in Karnegi university'.

The next sections of the paper are organized as follows: in section II, a summary of the previous studies on the control and decreasing the traffic is given. In Section III, the problem definition is done and the considered assumptions in both normal and critical conditions have been expressed. In section IV, the proposed Data Envelopment Analysis method has been introduced and defined. In section V, by considering a simple numerical example, the proposed model is explained and finally, in the last section, the results of using the Data Envelopment Analysis are analyzed and some suggestions are made for the further research.

2. Previous Studies

Yang[3] showed that there are systems which can inform the variable speeds to the driver. Such systems transmit speeds to the drivers based on the simulation of some parts of the highway and statistical works (i.e. getting information and statistics in different hours and holidays using different sensors).

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Based on the shields and Greenberg's equation, Ardekani[4] revealed that the density and amount of the vehicle transportation in a certain time interval and determining their relationship can be modeled based on the related statistical works and the traffic flow relationships based on the aforesaid indexes.

Shamsinezhad[5]Showed that the traffic control of an isolated intersection using smart fuzzy method and considering the traffic volume and conditions results in making the traffic control system smart and improving the switching performance of traffic lights. Finally, the average delay time of the vehicles passing the cross-section during the control process, is calculated and is compared to the average delay time of the vehicles from the constant scheduling method.

Another method used in order to solve the traffic issue is using the estimated speeds for the traffic. In this method, traffic speed estimation is done based on the volume and average speed of some vehicles in each line for a 5-minute time interval. This model is analyzed based on the Bayesian and dynamic line models.

3. Problem Definition

As discussed in the previous sections, the main purpose of this model is traffic relaxation by making the traffic issue real. Earlier, the traffic issue was studied without considering the humans' behavior theory. Therefore, it was analyzed far from the real area. In this paper, the highways are divided into three models named A, B, C. model A presents a highway with only one input. An example for this case is the West-East second floor of SADR highway from Imam Ali cross-section to Niyayesh Tunnelin Tehran. Model B presents a highway which has an output in addition to an input. An example for this model is Hemmat highway from south to northern Tehran. The model C highway has a U-turn in addition to the input and the output like the Chamran highway from south to north in Tehran. By using simulation for the peak hour and considering certain time intervals, we determine the number of vehicles passing the input and output of each DMU. Employing the data envelopment analysis method, the optimal inputs of each DMU are calculated. Based on the optimal inputs for each unit, if the summation of outputs of the previous units plus one, is less than the optimal value calculated from the data envelopment analysis method in each certain time interval, the ramp light would be green. Otherwise, the ramp light before entering the new unit should be red. In the other words, in each input, output and U-turn, a detector is installed which calculates the passing vehicles in a certain time interval in each unit input, unit output, U-turn and ramp input.

The placement methods of units in the models A to C are pictured in the following figures.



Fig. 3.Model C

One of the methods for decreasing the traffic is the demand control and decrease. It is known that demand decrease is done by subjective and uncertain methods like using public transportation. In this paper, some efforts has been made in order to control and relax the traffic.

Primary inputs decrease can be done by dynamic road sign and variable speeds. It should be noted that in order to decrease the demand, the number of vehicles in a certain time interval is considered which was analyzed by simulation earlier.

In the next section, the drivers are informed of the paths with lower traffic by using dynamic panels. Despite this method doesn't decrease the traffic impressively, but it is one of the methods that eliminates or decreases the unnecessary demands.

If we want to make the model closer to reality, it should be noted that traffic doesn't have a decisive condition. It means that if a model is proposed that considers all the vehicles with the same values, in the emergency cases which the emergency vehicles should reach the destination in the least time, these vehicles have the same value with the other vehicles and there is no superiority for them. This would be a problem with these methods. Therefore, the model proposed in the next sections, considers this fact and gives the emergency vehicles weight and value superiority by the ramp traffic lights based on the aforesaid fact and the stop and movement strategy.

For the critical times, the input ramp light of emergency or firefighting can be made green so that they enter the emergency lane. It should be noted that if the emergency vehicles enter the highway from the main path, they enter the emergency path from the beginning. This fact is shown in the next figure.

4. Mathematical model

Variables and parameters:

DMU (o): unit under analysis;

x(o): The input numbers in a certain time interval of the index line

q(o): The optimal input numbers in a certain time interval of the index line

y(o): The output numbers in a certain time interval of the index line

y(SS): initial input for the DMU N.O. 1

 $\theta(o)$: Efficiency of DMU N.O. o

Z: The color of the ramp light in a certain time interval of normal condition

 Δt : The time period for passing of q(o)-y(s-1,o-1) vehicles.

 Δt : The time period that the emergency vehicle reaches the last from the y(o) DMU announced by the TOC and the ramp light should be red

 $\mathbf{\Phi}$: The time period that the ramp light should be red due to emergency.

Y: If the light color is green, this parameter is one. Otherwise, it is zero.

T: If TOC announces the emergency is located before ramp o, its value is one. Otherwise, it is zero.

 δ : In the normal condition, its value is one. Otherwise, it is zero.

•: The time period of light color

 $Max \theta_o = \alpha_o y_o$

S.T

$$v_o x_o = 1$$

$$\alpha_s y_s \leq v_s x_s$$

$$v_1, v_2, \dots, v_m \geq 0$$

$$\alpha_1, \alpha_2, \dots, \alpha_s \geq 0$$

o=1,...,n s=1,...,m $q(o)=\theta_o \times x_o$ And for the TOC expecters in the aritical as

And for the TOC operators in the critical condition:

$$z = ((1 - \beta)\gamma_{Green} + \beta\gamma_{Red})) \times \Delta t$$
$$\varphi = \tau \times \Delta t$$
$$\sigma = \delta z + (1 - \delta) \times \varphi$$

5. Numerical Example

Consider a highway with 7 inputs, 4 outputs and 4 U-turns. Based on model C, the DMUs are determined and there will be 8 units with the following specifications:

|--|

DMU	А	В	C	Ď	Е	F	G	Н
input	6	8	10	18	35	37	40	42
output	4	5	7	10	11	14	16	18

Based on this model:

θ	DMU				
0.6667	A*				
0.625	В				
0.7	С				
0.5556	D				
0.3143	Е				
0.3784	F				
0.4	G				
0.4286	Н				

T-LL 2 Fff. f. ... I DMU

For DMU A:

 $Max\theta=4u$ St. 6v=1 $4u \le 6v$ $5u \le 8v$ $7u \le 10v$ $10u \le 18v$ $11u \le 35v$ $14u \le 37v$ $16u \le 40v$ $18u \le 42v$ $u, v \ge 0$

Table 3. Optimal inputs for each DMU

The number of vehicles entering the ramp in a certain time interval	DMU
-	А
1	В
2	С
3	D
1	E
3	F
2	G
2	Н

6. Conclusion and Suggestions for the Future Work

Undoubtedly, in order to eliminate the traffic problem which is the final goal of this paper, all the proposed solutions should be considered simultaneously. This will finally result in economical use of fuel, decrease of the air pollution and mental relaxation for the vehicle passengers. This paper showed that based on the data envelopment analysis technique, the performance of the determined units in a highway can be evaluated and the optimal inputs for each unit can be determined based on the movement and stop policy of the ramps and the variable speed in the primary input. In order to realize this goal, the humans' behavior theory in driving and their movement model in traffic based on the simulations was considered to make the model closer to the facts. Also, to study the reality of the traffic flow, the supplementary crisis model is used.

Finally, for the future work and further research, these suggestions can be considered:

The balancing method of the ramps by considering the vehicle flow that enters the ramps in a way the demand for entering the highways due to the ramps is balanced and the entering focus in a specific input ramp is not far more than the other ramps.

The feasibility studies of designing a suitable strategy in order to decrease the demand for input of each unit and finally the highway by creating the culture of using public transportation.

Considering an informant as a parameter given to the driver with a better reliability than the dynamic signs so that the drivers are able to choose their destination based on these information and the conditions.

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