MODEL FOR LOCATING SPEED CONTROL STATIONS TO REDUCE ROAD ACCIDENTS: A GOAL PROGRAMMING APPROACH

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ABSTRACT

The high speed is a very serious cause of accidents in the suburban traffic and both the financial and life damage is quite considerable. An approach to reduce speed is to install cameras to record the road traffic violations. Locating appropriate installation points can have a great role in the effectiveness of these systems. To this end, using the expert system, a model has been developed to locate cameras to record road traffic violations. It selects and introduces the best points from among the candidate points for the system installation considering all the desired items and considerations. In this model, first the qualitative information of the candidate points is converted into quantitative data and then the points are ranked based on the issues considered for each of them using the TOPSIS method. Lastly, the final highest ranking points are finalized and selected for the system installation at susceptible road sections including important entries/exits, distance from origin/destination, proper distance between two systems, and so on using the Goal Programming Approach.

Keywords: *Locating, Traffic Violation Recording Cameras, Intelligent Violation Recording System, ITS, Goal Programming, TOPSIS.*

1. INTRODUCTION

People believe the high speed is an important factor in reducing time to arrive at their destinations while it is a very serious cause of road accidents; the most serious problem with the high speed is the need to increase the Decision Sight Distance and Stopping Sight Distance (Żak & Węgliński, 2014).

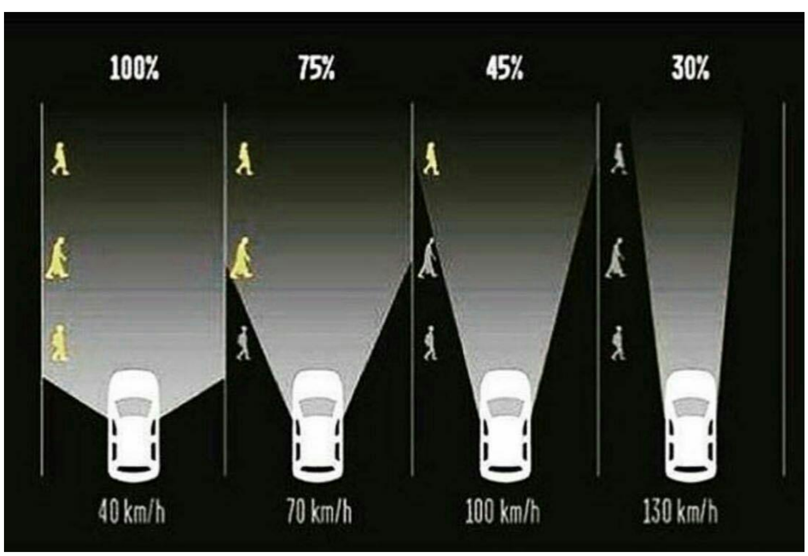

Fig. 1: Relationship between speed and driver visibility

The best way to decrease the number of the high speed-caused accidents is to reduce the speed of the passing vehicles and bring it close to the safe speed; this is possible through cameras that record violations. Such factors as dispersion of cameras, their non-existence at some key points, large distance between them, and their inadequate performance can inversely affect their functioning. Therefore, it was decided, in the national plan to equip Iran's artillery roads with traffic violation recording systems, to install 1887 cameras so that their presence in all roads was highlighted and reduced road accidents.

Locating studies began in the 1910s, but they were addressed seriously and extensively in the 1960s. In the beginning, mostly its economic application was considered, but its widespread use was gradually considered in other cases too.(Nickel et al., 2005; Kewley , 1998)

In a paper entitled "Criteria for Locating Speed Violation Recording Cameras", Ameri et al. (2016) addressed the determination of the camera locating-related criteria (geometric, physical, safety, and traffic) using Delphi's questionnaire distribution and expert surveys. In another study, Hajhashemi et al. (2015) used budget, manpower, and passing vehicle constraints and presented a model based on integer programming and accident distribution curves. They claimed their model was a scientific-executive solution to determine points to install speed control cameras.

Regarding the locating of intelligent transportation equipment, Brimicombe et al. (2009) presented a linear integer programming model for selecting their optimal locations wherein the accident rate was the only used safety index. The ARRB project team presented the criteria for locating speed control cameras for roads, highways, and freeways separately based on two main indices, i.e. speed and accident rate (Brucker, 2004).

In a paper entitled "An Optimization Model for Locating Speed Control Cameras in Suburban Roads for Maximum Accident Coverage", Fazelifar et al. (2014) presented a camera locating model to enhance the efficiency of cameras and the allocated resources.

In a paper entitled "A Locating Model for the Installation of Speed Control Cameras Based on the Hierarchical Analysis Process (Case Study: 3rd Ring of Hamedan City)", Eliassi et al. proposed a model based on the hierarchical analysis process. It finds the results using the history of accidents, the police presence, and criteria coefficients based on paired comparisons and experts' opinions.

The current study aims at explaining the locating model of these systems using the TOPSIS decision making tool and goal programming.

2. PROCESS OF SELECTING POINTS TO INSTALL THE SPEED CONTROL SYSTEM

The point selection is done in two phases: 1) determining points that have the potential for system installation and 2) ranking the points specified in phase 1.

Phase 1 involves the following:

- *Classifying the related axes.*
- *Studying based on budget.*
- *Providing communication information*.
- *Providing traffic statistics (traffic and speed).*
- *Providing the list of accident-prone points of each axis (police-provided tables).*

The points with system installation potentials are determined after phase 1 is complete and the project-related representatives have visited the site; they are then ranked in phase 2 using the TOPSIS and the Goal Programming.

3. AXIS SELECTED FOR RESEARCH

To do this research, the 135 km long Jolfa-Tabriz **highway** departure route was considered and 12 points were selected and their information gathered for the initial locating of the system installation.

Considering the axis type and the need for a 30 km distance between the points, the number of points needed for the system installation is found from the following relation (Salman & Shafiqur, 2012; Safarzade, 2016):

No. of points = 1 + axis length/30 = 1 + 135/30 ≅ 6

12 points have been specified by experts as candidate points for system installation in the studied axis and ranked by the TOPSIS method based on 10 evaluation criteria (Table 1).

Table 1- Ranking of the 12 candidate points

Point	Cost of purchasing electricity	Theft probability	Accident probability	Thunder strike probability	Destruction probability	Police priority	Transportation priority	Radio communication	Vertical arc	Horizontal arc
X_1	4	1	1	1	1	10	4	10	3	3
X_2	4	1	1	1	1	10	8	10	10	3
X_3	10	1	1	1	1	5	1	10	3	3
X_4	10	1	1	1	1	10	4	10	10	3
X_5	4	1	1	1	1	2	4	10	3	3
X_6	10	1	1	1	1	5	4	10	3	3
X_7	10	1	1	1	1	5	4	10	3	3
X_8	10	1	1	1	1	10	4	10	3	3
X_9	4	1	1	1	1	10	4	10	3	3
X_{10}	10	1	1	1	1	10	4	10	10	10
X_{11}	10	1	1	1	1	2	1	10	3	3
X_{12}	10	1	1	1	1	10	4	10	3	3

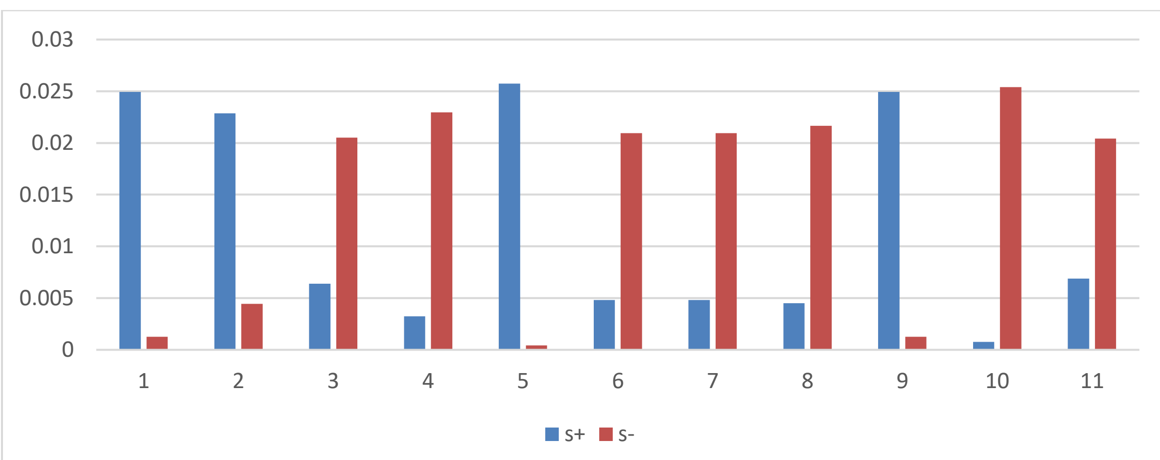

Fig. 2- Positive and negative ideal alternatives

Table 2- Final Scores of the points

X1	0.047611933
X2	0.162451304
X3	0.762294654
X4	0.876790931
X5	0.016377278
X6	0.812701447
X7	0.812701447
X8	0.827644768
X9	0.047611933
X10	0.970884839
X11	0.74739217
X12	0.827644768

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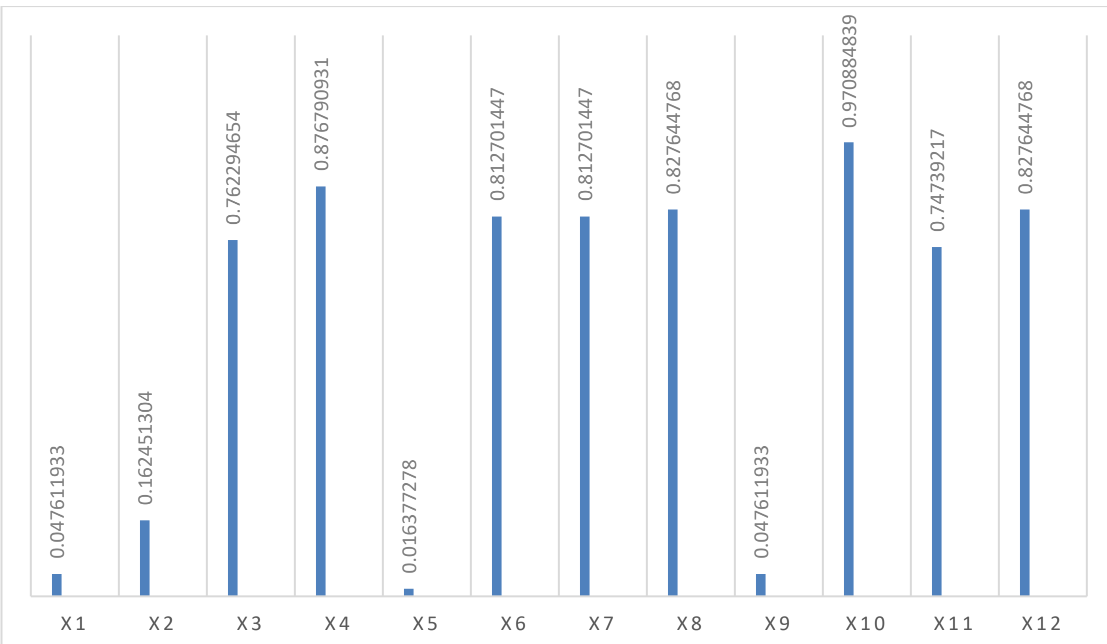

Fig. 3- Final Scores of the points

After each point's final score has been found, use can be made of the Goal Programming to specify the number of points and select them considering the fact that its score can be considerably increased or decreased depending on whether its prior or next points are selected.

The final points will be selected from among those with the highest scores found by TOPSIS considering the objective of the Goal Programming (selecting the most suitable system), the distance between two systems, the distance from the important city, and the entries and exits existing in the axis (the desired or acceptability level for a point selection).

The objective function in this research is as follows:

Max $Z=0.047611933x_1+0.162451304\ x_2 + 0.762294654\ x_3+ 0.876790931\ x_4 + 0.016377278\ x_5 + 0.812701447\ x_6 + 0.812701447\ x_7 + 0.827644768\ x_8 +0.047611933\ x_9 +0.970884839\ x_{10} + 0.74739217\ x_{11} +0.827644768\ x_{12}$

To determine the number of the selected systems considering the length of the axis, use is made of the following relation

$$\text{No. of selected systems} = x_i + x_j + d_1^- - d_1^+$$

For the case being studied, the relationship can be rewritten as follows:

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + d_1^- - d_1^+ = 5$$

Next, the distance between the systems is determined based on the axis type by subtracting the km from origin of each system from that of its previous one. Since the ideal distance on this axis is 30 km, the relationship for the selecting each proposed point, considering its prior and next points and the distance between them, is as follows (selecting one of the x_1 and x_2 consecutive systems):

$$x_1 + x_2 + d^{3-} - d^{3+} = 1$$

Such a constraint is written for other successive points too.

To determine the selected points with proper distance from cities, use is made of the following relation:

$$x_i + x_j = 1$$

And, to determine the selected points with proper distance from important city entries and exits, use is made of the following relation:

$$x_i + x_j + d_i^- - d_i^+ = 1$$

The numbers obtained are as in Table 4.

Table 4- Applying the opinion of the Co. representative in the scores

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}
0.005893	0.02	0.157	0.181	0.0007	0.034	0.168	0.171	0.01	0.12	0.031	0.102

Now, a 1-10 goal deviation range is considered for each point selection criterion; the closer is the number to 1, the easier is neglecting the criterion and the closer it is to 10, the more difficult it is to neglect it. For instance, considering 6 and 2 for respectively d_1^- and d_1^+ means that reducing the number of the systems required by the axis (considering the route length and the service level) is quite difficult and the probability of increasing the number of systems is low; this way the goal deviation probability is specified for each point selection criterion.

The above information entered the MATLAB Software and 5 points were selected to install the intelligent violation recording system (Table 5):

Table 5- Selected final points

X_2	X_5	X_7	X_9	X_{10}

4. CONCLUSIONS

This paper addresses how to select the best points in an axis to install speed control systems. In the studied axis, each candidate point was evaluated based on 10 criteria considering the information collected by experts. Then, using the TOPSIS method, the desired evaluation was summed up and a score was found for each proposed point. To select the final points from among the proposed ones, use was made of the goal programming method considering such priorities as the distance from an important city, the distance from important entries and exits, and distance between two systems; the selected points were then obtained by the expert system using the MATLAB Software after specifying the ideals for each of the mentioned cases and the permissible deviation from them.

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