An ANP-Based Model for Location of Fixed Speed Cameras

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Abstract

Speeding is a major cause of traffic accidents and is estimated to be the cause of about 40% of fatalities in road accidents. Speed is a major accident risk factor and affects both rate and severity of traffic accidents. This importance has led to universal use of intelligent control systems for maintaining road safety by enforcing speed regulations. In this study, a modeling is carried out by the use of Analytic Network Process (ANP) based on the expert opinion to determine the importance of several criteria for location of speed cameras. Modeling was carried out using the opinions expressed in a meeting with an expert group consisting of two credible experts on traffic and transportation, one traffic officer, and one expert on traffic accident. Criteria, alternatives, and the relation between factors were discussed in meeting and the results were recorded only after reaching a consensus. The basic model was developed, and then quantified by introducing the numbers and relations suggested by experts. Camera location criteria considered in this study are police presence, effect of traffic control equipment, lighting conditions, history of accidents (in the last three years), and land use adjacent to the studied road segment. Accident statistics was used as the measure of road segment's recent safety. For this purpose, history of accidents in each segment in the last three years was collected. The accidents resulting no injury or fatality were given a weight of 1, accidents leading to injury were given a weight of 3, and fatal accidents were given a weight of 9. Hamedan's third ring road is then used as a case study to evaluate the model. The results show that Ahmadi Roshan Blvd. is the top priority for installation of speed cameras.

Keywords: Accident, speeding, speed camera, Analytical Network Process

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1. Introduction

Reports of Iran's Legal Medicine Organization suggests that traffic accidents have been the cause of 20,349 deaths and 297,980 injuries in 2011, 19,089 deaths and 318,802 injuries in 2012, and 17,994 deaths and 315,719 injuries in 2013 [Legal Medicine Organization of Iran, 2014]. According to these figures, traffic accident is the second leading cause of death in Iran. According to the reports of World Health Organization, in 2009, road accidents has caused one million and three hundred thousand deaths and about twenty to fifty million injuries or disabilities with significant psychological and economic effects on survivors and their families. Besides, every single human being is unique and irreplaceable, and death of about 20,000 and injury of about 700,000 Iranians every year is deplorable [Bariri and Esmaeili, 2010].

The worldwide population growth and economic development of the past decades have led to a substantially increased demand for transportation. The results of this increased demand have been the increased car ownership, growing use of vehicles and consequently more traffic congestion, increased rate of accidents, reduced reliability of travel time estimations, reduced safety of passenger and cargo transport, increased energy consumption, and faster environmental degradation. For a long time, the main strategy to address this increasing demand was to increase the capacity of transport networks and develop infrastructures such as freeways, highways, and interchanges. But experience has shown that when adopted alone, this strategy is expensive, environmentally destructive, and ineffectual as it cannot keep up with the demand and handle the consequent problems. As a result, supplementary strategies aimed at more efficient use of current capacities in line with ultimate objective of sustainable transportation and thereby sustainable development has recently received increasing attention. The notable strategies with this approach include the travel demand management, public transport development, and pedestrian and bicycler centered design. Another remarkable approach that has piqued the interest of many countries especially in the developed world is the use of intelligent transportation systems (ITS) [Afandizadeh, Dehghani and Moraveji, 2014].

Intelligent transportation refers to the use of new technologies such as data processing, electronics, control systems, and other communication technologies and management strategies in an integrated framework to create an efficient and safe transportation system [Sheikholeslami et al. 2014].

Every year, 1.2 million people die in road accidents, many of them caused by speeding. It is estimated that 40% of road fatalities are because of speeding. Speed is a major risk factor for road accident and is correlated with both the probability of accident and the probability of more severe injuries. Studies and experience have shown that speeding is one of the major causes of accidents leading to severe injuries or death. However, drivers often do not realize the dangers of speeding. At higher speeds, vehicle is more difficult to control and maneuver and this increases the probability of errors that are unlikely to occur at lower speeds. Thus, a monitoring system capable of providing a safe road network by preventing speeding would be ideal. This goal can be achieved by effective use of intelligent speed control systems for targeted enhancement of road safety. This paper concerns the location of speed cameras in road networks with the city of Hamedan considered as a case study. Hamadan has a roughly circular layout, courtesy of its first master plan adopted in 1928. This layout consists of concentric circles connected with belt roads as well as six main streets leading to the central square, dividing the layout into sectors of a circle. Hamadan is the city of grand squares, which have been designed not by traffic engineering principles but based on its historical origins. Hamadan's urban transport layout is strongly influenced by the city's first master plan. In this layout, a large central square (Imam Sq.) and 6 main streets have extended radially out of this square have been designed to provide access to the

Bazaar and city center. Failure of authorities to develop and implement adequate traffic organization plans and hasty and unprincipled decisions in regard to traffic issues have led to a complex and confusing traffic situation in this city [Goharpur, 2010].
The radial design leads to traffic concentration and emergence of major congestion points, especially in the main conjunctions and squares such as Imam Sq. and tomb of Avicenna, mainly because of their commercial and touristic nature. The third (outer) ring road has therefore been constructed as a high speed pathway to reduce such congestions and facilitate urban transportation within the city. Given the steady growth in the number of private cars passing or visiting the city, the current road network needs to be modified to keep up with the increasing size of traffic. For example, some passages, such as the city's third ring road may need to be fully converted into a large highway and some of the roads may need to be turned into one-way streets. As mentioned, the city's third ring road acts as a major high speed pathway to reduce travel time and delays in urban travels. With the steady growth of city population and consequently steady increase in the number of private cars, this arterial road has partly developed and is still developing into a highway. With an efficient third ring road at their disposal, all vehicles, especially the heavy ones, can avoid the inner roads unless strictly needed. The figure 1, shows general route of Hamadan’s third ring road is highlighted in red.

The city of Hamedan is constructed radial pattern, so the volume of traffic passing to the city center and the first ring is driven. The city’s transport policies are based on the fact that day trips lead to the third ring of the city. Therefore, the third ring of the city was chosen as an influence area and should be immunized in terms of speed.

According to pervious traffic studies and a brief field survey conducted by the authors, the city can be divided into 20 traffic zones, out of which 19 fall within the area of influence of the city’s third ring road. This extent of influence shows the importance of this ring road for elimination of traffic congestions and gridlocks in the inner parts of the city. The figure 2 shows a schematic diagram of this ring road’s segments and the zones served by each segment.

In this study, the goal is to examine the location of speed camera in the segments of Hamadan’s third ring road as a high-speed arterial thoroughfare. Considering the high price and maintenance costs of speed camera equipment, the number of cameras that can be installed is limited by the budget, so they must be assigned to the segments where they would be most effective, and the rest of the segments can be equipped after and if more funds are available. In this study, this location problem is modeled with the help of the software Super Decisions. The Super Decisions is decision support software that implements the AHP and ANP. Super Decisions is decision-making software which works based on two multi-criteria decision making methods. Super Decisions implements the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP). It has been used in many research and practical fields such as manufacturing, environmental management, aviation, small hydropower plants and agriculture.

The Analytic Hierarchical Process (AHP) and the Analytic Network Process (ANP) make it possible to include intangibles in decision making. AHP/ANP are the most powerful synthesis methodologies for combining judgment and data to effectively rank options and predict outcomes. It should be noted that the study is focused on the criteria with greatest effect on the effectiveness of fixed speed cameras, and factors and criteria of minor importance are disregarded.

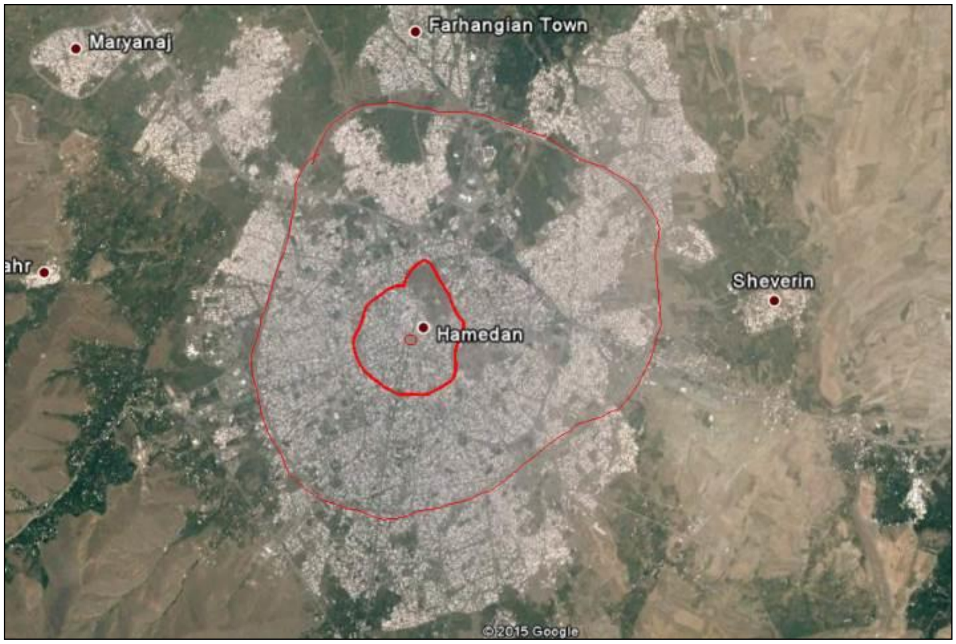

Figure 1. A view of the study area and Hamadan's third ring road

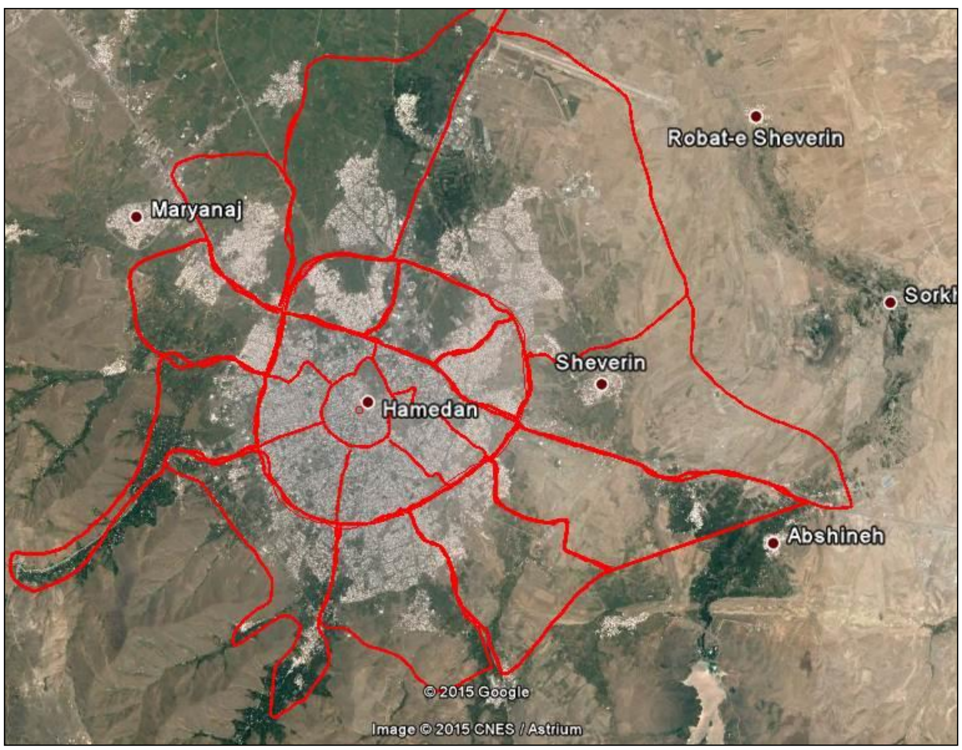

Figure 2. The third ring's segments and access from peripheral zones

In this study used all the crashes. Speed is a factor that directly and indirectly contributes to the causes of accidents. So all types of crashes were studied. In any case, if the vehicles had an accident at a lower speed, the risk was much lower.

2. Research Literature

In a study by Elyasi et al. location of speed cameras on Hamadan’s third ring road was ranked and prioritized by an approach based on Analytic Hierarchy Process (AHP) (Figure 3).
The model developed in this study by the use of AHP technique based on expert opinions yielded the following conclusion [Elyasi et al. 2014].
As shown in the above figure, Yadgar blvd. was identified, with a significant lead, as the top ranking choice for installation of speed camera. Note that the mentioned study was conducted using the data available in 2014. In a study by Mountain, he investigated the effectiveness of speed cameras in comparison with other speed control and management systems by assessing different management schemes of 38 highways. His results showed that all types of speed control schemes have similar effects on the rate of accidents and have caused a moderate decrease in the number of individual accidents [Mountain, Hirst and Maher, 2005]. Andrew et al. studied the effects of mobile speed camera on road accidents in England. They investigated the cause and severity of graphically recorded accidents and compared the rate of accidents before and after the installation of speed cameras. Their results showed that installation of camera reduced the total rate of accidents by 5% and the rate of fatal accidents by 9%. They concluded that speed cameras can be used as effective tools to reduce the roots of traffic in areas where the average speed is high [Andrew, Violet and Robin 2008].
In a study by Garber, he investigated the road safety effects of speed cameras by examining and comparing the accidents before and after their installation, and found that the presence of speed cameras significantly reduced the severity and thus consequences of accidents [Garber and Gadiraju 2013]. Samii and Mohsen in studied the effect of speed cameras on highways of Mashhad, Iran and reported a significant difference in the speed and volume of traffic in different bands of highways. They suggested that with the development of image processing systems, speed on each particular band can be controlled and enforced separately according to the speed limit defined for that band [Ghavidel and Afandizadeh, 2016; Samii and Mohsenin, 2014]. Review of the literature of this field suggests that installation of speed cameras can lead to 2% to 51% decrease in the rate of accidents and up to 80% decrease in the rate of fatal accidents [Thierry, 2010].

Multi-criteria decision-making methods used for assessing the safety of road surfaces, accidental parts [Horrace and Keane, 2004; Coll et al., 2013, Boroujerdian et al, 2014; Rassafi et al, 2012], select transportation policies [Najafi et al. 2016], Identification of parts with the same characteristics [Sadeghi et al. 2012].
The method of network analysis with the advantages of the hierarchical analysis method is not within the framework of this method and, considering the network relations, has a higher advantage than AHP [Saaty, 2001]. In other words, hierarchical analysis method is a special case of network analysis method, which is why in the process of analyzing the hierarchy of relations is either going back or forth [Saaty, 1980, 1990].

Compared to other decision models, it is possible to consider all criteria with the same unit and most of the MADM techniques are capable of analyzing the assessment criteria in both quantitative and qualitative modes. In this research, network analysis has been used as a multi-criteria decision-making method. The main objective of the research is to prioritize factors affecting crashes based on network analysis.

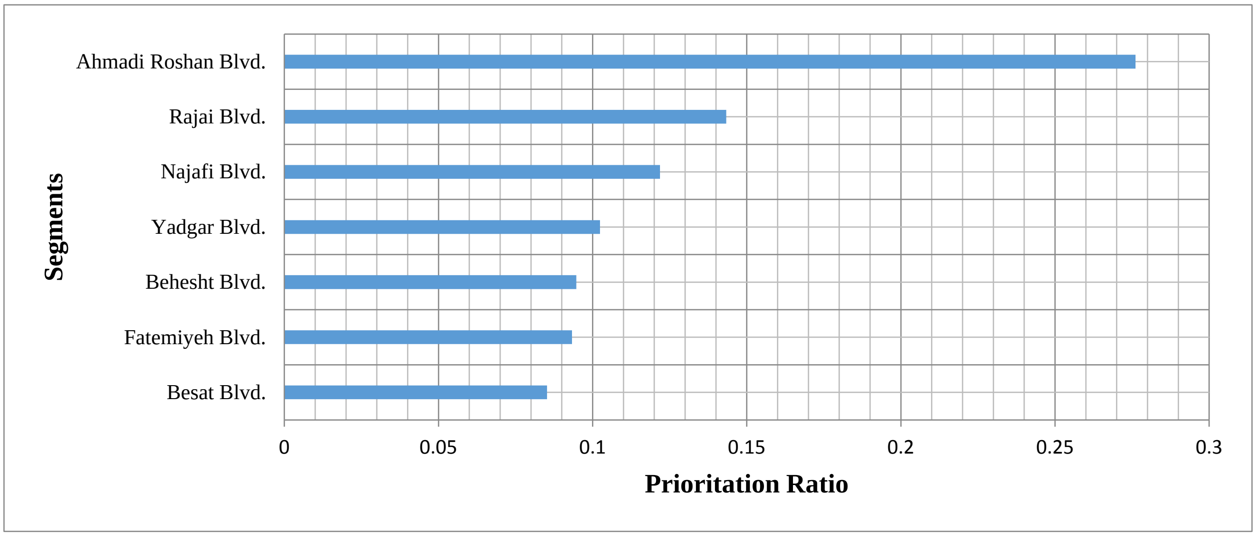

Figure 3. Final ranking of road segments in the study of [Elyasi et al., 2014]

Research has been conducted on the impact of fixed speed and safety cameras [Ghavidel and Afandizadeh, 2016]. In these studies, it was found that by installing speed control cameras, low-impact crashes were reduced by about 8%, but high-intensity crashes of about 30% showed a dramatic impact on safety improvements (Ellen et al., 2014). However, speed control cameras did not affect the arterial pathways. Of course, these studies have been conducted in the arterial corridors of Barcelona (Novoa and et al., 2010).

3. Research Method

In this research, we use a network model to prioritize the installation of a speed control camera. In this regard, the purpose of selecting a segment with the potential for an accident is to install the camera. Selection criteria based on police presence, crash history, usage and lighting conditions of each piece. Therefore, every piece that has a higher rating than the others in the above criteria will prioritize installation of fixed speed cameras. Selectable options are the third ring of Hamadan, which was prioritized in the nonlinear network. In the output of this research, the order of the components was determined in the installation of the speed control camera.

In this study, the relative importance of speed camera location criteria is determined by the use of Analytic Network Process (ANP) based on opinions of experts. The analytic network process (ANP) is a form of the analytic hierarchy process (AHP) used in multi-criteria decision analysis. AHP structures a decision problem into a hierarchy with a goal, decision criteria, and alternatives, while the ANP structures it as a network. Both then use a system of pairwise comparisons to measure the weights of the components of the structure, and finally to rank the alternatives in the decision. In the AHP, each element in the hierarchy is considered to be independent of all the others the decision criteria are considered to be independent of one another and the alternatives are considered to be independent of the decision criteria and of each other. But in many real-world cases, there is interdependence among the items and the alternatives. ANP does not require independence among elements, so it can be used as an effective tool in these cases.

Experts and elites were selected among traffic engineers involved in traffic issues in the study area as well as officials in traffic management and traffic engineering in Hamedan. Finally, expert opinions were monitored by the incidence of accidents. Camera location criteria considered in this study are police presence, effect of traffic control equipment, lighting conditions, history of accidents, and land use around the studied road segment. Afterwards, Hamedan's third ring road is used as a case study to evaluate the model. Statistical test for the variables were conducted in this research. Using the Cronbach alpha test, the validity of the data has been measured.

Note that the history of accidents is incorporated according to the number of accidents occurred in the last three years. The priority of each of the abovementioned criteria is determined by the use of ANP method in five following stages:

Step 1: pairwise comparison of criteria with respect to problem objective

Each of the criteria to be used for comparison of alternative has a particular degree of importance for the objective. In other words, different criteria have different amounts of effect (weights) in the objective. Weights for different severity levels of crashes, Based on advice on road safety, the frequency of crashes over a specified period of time in a specific segment of a uniform route can be selected as an indicator for accident risk assessment. Therefore, the Frequency Index of Accidents was used as an effective indicator in choosing a higher risk segment for installing speed control cameras.

The first step will be to conduct pairwise comparisons between criteria in terms of their importance for the objective. After forming the matrix of pairwise comparison of criteria with respect to the objective, weight of each criterion with respect to the problem objective (W1) will be obtained by geometric averaging:

$$W_1=(C_1, \ldots\ldots, C_n) \quad (1)$$

Step 2: pairwise comparison of criteria with respect to each individual criterion

In most cases, the criteria to be used for comparison of alternative have some degrees of interdependency, meaning that a change in one criterion has an increasing or decreasing effect on other criteria. In this step, importance of criteria with respect to each other (according to their interdependency) will be determined. Each criterion will be individually compared with other criteria and its weight for each pairwise comparison matrix will be determined by geometric averaging. Finally, the criteria weights obtained in this step will be placed in the matrix W2, that is, the matrix representing the criteria weights with respect to other criteria. For example, entries in the column W2 represent the weights of criteria with respect to the first criterion.

$$W_2=(W_{21}, \ldots\ldots, W_{2n}) \quad (2)$$

Having the results of comparisons made in previous steps, criteria can now be ranked accordingly. For this purpose, Matrix W2 (where the number of rows and columns equals the number of criteria) will be multiplied by the matrix W1 (where there is a single column and the number of rows equals the number of criteria), and criteria will be ranked based on the resulting weights. For example, weight of the first criterion will be obtained by multiplying the first row in the column vector W_1.

$$W_c = W_2 * W_1 \quad (3)$$

Step 3: pairwise comparison of alternatives with respect to criteria

Assuming that there is no interdependence between alternatives, in this step, pairwise comparisons will be made between alternatives with respect to each individual criterion to determine their weights (importance) in this respect. After forming the pairwise comparison matrix of alternatives with respect to each criterion, weight of alternatives of each matrix will be obtained by geometric averaging. For example, W31 represents the weight of alternatives with respect to the first criterion [Saatyand Vargas 2010].

Step 4: pairwise comparison of alternatives with respect to each other

Occasionally, the alternatives to be compared also have some degrees of interdependency, meaning that they can affect each other. Such interdependency may have a significant effect on the choice of alternatives. In this step, alternative will compared with respect to each other to account for the effects of their interdependency. For this purpose, the effect of alternatives on each other with respect to each particular criterion will be measured. For example, W41 represents the weight of alternatives according to their interdependence with respect to the first criterion, or in other words, W41 represents the effect of alternatives on each other when only the first criterion is taken into account. Weighting of the alternatives according to their interdependence will be carried out for every criterion.

To determine the ranking of alternatives with respect to criteria, matrices of pairwise comparison of alternatives with respect to alternatives will be normalized and then multiplied by the column vector of pairwise comparison of alternatives with respect to criteria (calculated in the previous step). The same procedure will be repeated for every criterion. For example, to calculate WA1, normalized matrix W41 (matrix of pairwise comparison of alternatives with respect to the first criterion) will be multiplied by the column vector W31 (weight of alternatives with respect to the first criterion) in order to determine the final importance weight of alternatives with respect to criteria. This procedure will be repeated for every criterion and the matrix WA will be formed accordingly (in WA, the number of rows equals the number of alternatives and the number of columns equals the number of criteria).

$$W_{A1} = W_{41} * W_{31} \quad (4)$$

$$W_{A2} = W_{42} * W_{32} \quad (5)$$

$$W_{Am} = W_{4m} * W_{3n} \quad (6)$$

$$W_{A} = (W_{A1}, \ldots\ldots\ldots\ldots\ldots\ldots W_{Am}) \quad (7)$$

Step 5: Ranking the alternatives

In the final step, alternatives will be ranked. In this step, the matrix of weights of alternatives with respect to criteria (WA) will be multiplied by the matrix of criteria weights (WC), and the resulting weights will be used to rank the alternatives [Saatyand Vargas, 2010].

$$W_{ANP} = W_{A} * W_{C} \quad (8)$$

4. Results

Model was developed by identifying the factors and linking them to each other based on the criteria discussed in the next subsection. Histories of accidents, Police presence, Traffic control equipment, adjacent land use and Lighting conditions Criteria, as well as the relationship between criteria, have been identified using expert opinions as well as previous studies.

Modeling was carried out using the opinions expressed in a meeting with an expert group consisting of two credible experts on traffic and transportation, one traffic officer, and one expert on traffic accident. Criteria, alternatives, and the relation between factors were discussed in meeting and the results were recorded only after reaching a consensus. The basic model was developed, and then quantified by introducing the numbers and relations suggested by experts. The basic model is presented in figure 4.

4.1 Criteria used in the Model

4.1.1 History of Accidents

Accident statistics was used as the measure of road segment’s recent safety. For this purpose, history of accidents in each segment in the last three years was collected. The accidents resulting no injury or fatality were given a weight of 1, accidents leading to injury were given a weight of 3, and fatal accidents were given a weight of 9. Segment of Hamedan's third ring road and their accident statistics are shown in Table 1. In this table, columns show the span of each segment, the total number of accidents, and the number of accidents leading to financial damage, injury, and death. As mentioned, weighted sum of these figures was used as the segment's accident statistic.

Table 1 show the frequency of accidents in the studied parts in the third ring of Hamedan city, which is obtained by available statistics (sources of accident statistics data). Prioritization of parts is determined by the number of accidents and compared with other parts.

4.1.2 Police Presence

Police presence has a significant impact on the rate of speeding offenses. Regular presence of the police will result in compliance with the law and, as a result, the reduction of speeding accidents. Conversely, in the event of an occasional presence and sometimes of a police officer, it may result in a reduction in law and discipline in keeping track of speed.

As mentioned, speed is the most important factor affecting the rate and severity of road accidents. Police presence on the streets and firm control of offences by the use of mobile speed cameras reduces the occurrence of offences and thus the number of accidents. As a result, police presence can effectively influence the location of fixed speed cameras. The sub-criteria considered for this criterion are:

- Absence of police
- Occasional presence of police
- Continuous presence of police

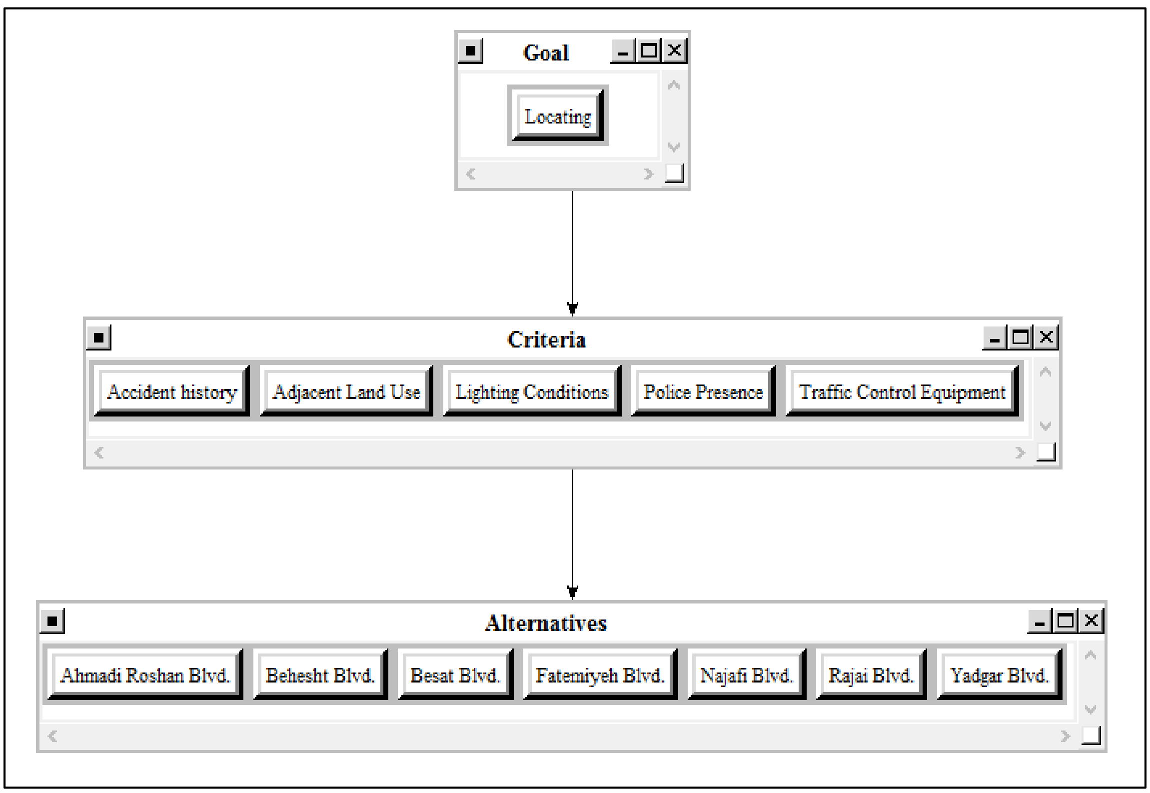

Figure 4. Basic model developed in Super Decisions software

Table 1. Segment of Hamedan's third ring road and their accident statistics

	Segment name	Segment area	Number of accidents	Accidents with property damage only	Accidents leading to injury	Accidents leading to fatality
1	Besat Blvd.	From Pajuhesh Sq./underpass to Besat Sq.	32	17	14	1
2	Fatemiyeh Blvd.	From Besat Sq. to Resalat bridge	35	8	24	3
3	Behesht Blvd.	From Resalat bridge to Babak bridge	43	0	39	4
4	Yadgar Blvd.	From Babak bridge/intersection to Ghadir bridge	84	2	80	2
5	Najafi Blvd.	From Ghadir bridge to Najafi intersection	49	7	40	2
6	Rajai Blvd.	From Rajai intersection to Modarres Sq.	41	5	35	1
7	Ahmadi Roshan Blvd.	From Modarres Sq. to Pajuhesh Sq./underpass	27	2	25	0
		TOTAL	311			

4.1.3 Traffic Control Equipment

Traffic control equipment can be divided into two groups of physical such as speed bumps and non-physical such as traffic warning signs. With the effective use of such equipment, there would be a reduced need for speed camera. The sub-criteria considered for this criterion are:

- Absence of traffic control equipment
- Presence of sufficient traffic control equipment
- Presence of insufficient/substandard traffic control equipment

4.1.4 Adjacent Land Use

The land use in each of the parts can be different. For example, in the block of Shahid Ahmadi Roshan Blvd, the educational application has a larger share than other parts due to Bu-Ali Sina University and other educational centers. Accordingly to experts, there is a higher risk of accidents due to speed.

The sub-criteria considered for this criterion are:

- Educational
- Residential
- Commercial
- Administrative

4.1.5 Lighting Conditions

According to previous studies that have been mentioned in the literature review, lighting has had an important impact on accidents in residential areas, especially in urban highways. The sub-criteria considered for lighting conditions are as follows:

- Day
- Night with sufficient lighting
- Night with insufficient lighting

4.2 Identified Relations and Dependencies

The dependencies and relations identified between the studied criteria are shown in Table 2. Each asterisk represents the relationship or effect that the horizontal element represents on the vertical element of the table. This relationship can be two-way or one-way. For example, in cell 1-2, the asterisk means that the cause of the crashes affects the presence of the police, and in the cell 2-1, is not an asterisk. This means that the cause of the crashes has no effect on the presence of the police.

The identified relations were defined in the software as shown in Figure 5, and then applied to the rest of pairwise comparisons and calculations accordingly.

Table 2. Relations between criteria

Criterion	Accident history	Police presence	Traffic control equipment	Adjacent land use	Lighting conditions
Accident history		*			*
Police presence			*	*	
Traffic control equipment		*		*	
Adjacent land use		*	*		
Lighting conditions					

In this study, the goal was to quantify the contribution of each criterion and sub-criterion to the location of speed cameras on the studied road segments and then rank these segments in terms of their suitability for this purpose. Pairwise comparisons were discussed in the meetings with experts and for each comparison, discussion continued until reaching consensus on a number. It should be noted that this step of solution did not require any specific software and was carried out by simply multiplying the matrices according to the steps described in the previous section. The steps followed for this purpose are explained in the following. The model used in this study is presented in Figure 6.

Weights of criteria were determined using ANP process based on pairwise comparison made by experts. Once approved by experts, criteria and sub-criteria were discussed in a meeting and results of comparisons were recorded after reaching a consensus. Accordingly, each criterion and sub-criterion was weighted based on its importance for and impact on the probability of accident due to speeding. The overall weight of each road segment was calculated according to the relation of criteria and sub-criteria and their importance for the probability of accident in each segment. After calculating the normalized matrix and consistency ratio, the results of final weighting were obtained as shown in Table 3. Having the weight of each road segment and using the final normalized weights, the values were replaced into the weight matrix without considering the impact of other criteria.

Using the consistency coefficient, the degree of coherence of the comparisons is measured. The Compatibility Index (CI) and Compatibility Ratio (CR) can be used to determine the degree of compatibility of the judgment. In order for judgment to be acceptable, the hour recommends that the compliance rate be less than 0/1- 0/2. Otherwise, the reassessment of the dual comparison matrix is suggested.

B_1 was calculated based on the weighted sum of number of accidents in each road segment in the last three years. The studied case was Hamadan’s third ring road, starting from Pajuhesh Sq., circling the entire city, and ending at the same square. The initial results obtained for each segment of this road are shown in Tables 4 and 5. For example, B1 values were obtained based on the history of traffic accident as explained above. Other results were calculated similarly for police presence, traffic control equipment, and adjacent land use criteria.

After comparing the criteria, sub-criteria were also subjected to pairwise comparison, and then scored and normalized. Tables 6 to 8 show the results of pairwise comparisons made between sub-criteria in the software environment and the obtained inconsistency ratios.

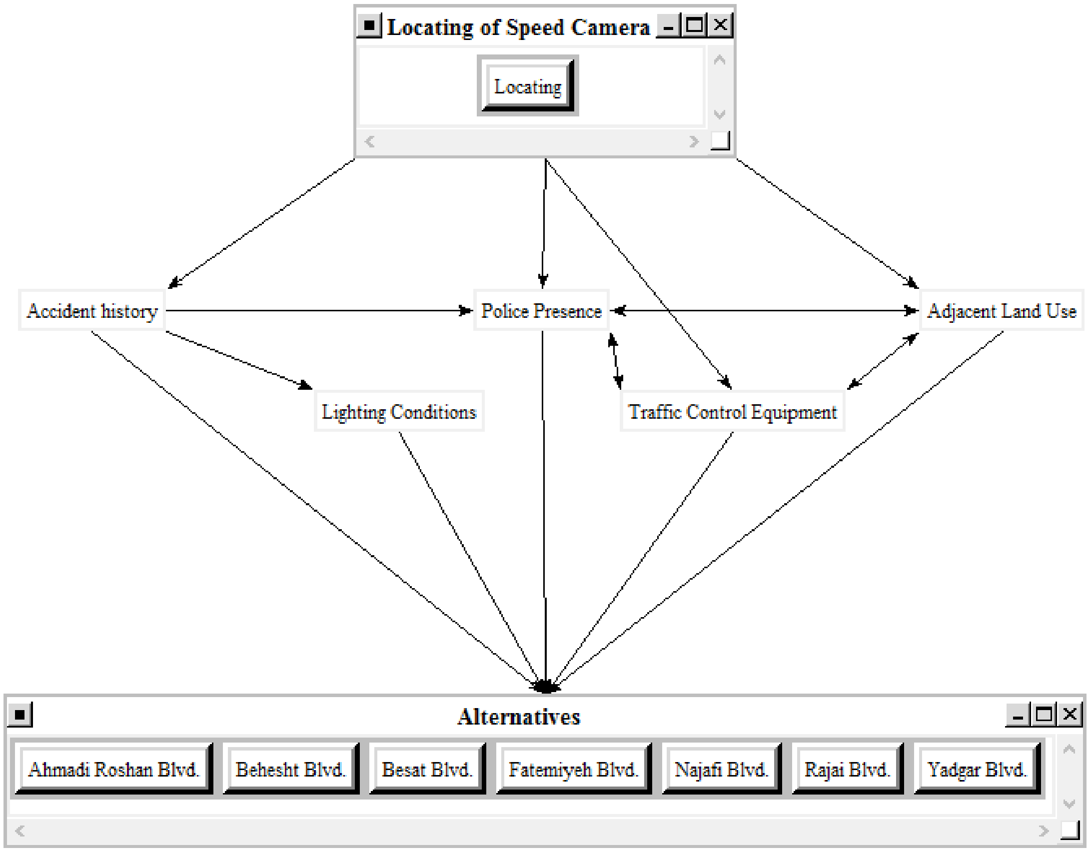

Figure 5. Schematic diagram of relations between criteria

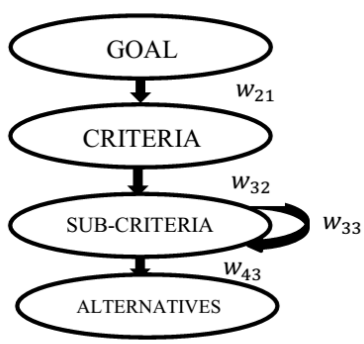

Figure 6. Model of the study

Table 3. Calculation of criteria and sub-criteria factors and final weights

Criterion	final weight of criterion	factor	sub-criterion		final weight of sub criterion
Accident history	**0.509**	B_1	65	87	0.081
			87	109	0.025
			109	131	0.035
			131	153	0.051
			153	175	0.074
			175	197	0.108
			197	219	0.155
			219	241	0.222
			241	263	0.312
Police presence	**0.202**	B_2	Absence		0.693
			Occasional presence		0.239
			Continuous presence		0.068
Traffic control equipment	**0.091**	B_3	Absence		0.75
			Standard and sufficient		0.099
			Non-standard		0.151
Adjacent land use	**0.102**	B_4	educational		0.629
			residential		0.168
			commercial		0.144
			administrative		0.059
Lighting conditions	**0.096**	B_5	Day		0.090
			Night with sufficient lighting		0.664
			Night with insufficient lighting		0.244

Table 4. B_1 values calculated for the studied road segments

	Segment name	Segment area	Weighted sum	Score	B_1
1	Besat Blvd.	From Pajuhesh Sq./underpass to Besat Sq.	68	1	0.081
2	Fatemiyeh Blvd.	From Besat Sq. to Resalat bridge	107	2	0.025
3	Behesht Blvd.	From Resalat bridge to Babak bridge	153	3	0.035
4	Yadgar Blvd.	From Babak bridge/intersection to Ghadir bridge	260	9	0.312
5	Najafi Blvd.	From Ghadir bridge to Najafi intersection	145	4	0.051
6	Rajai Blvd.	From Rajai intersection to Modarres Sq.	119	3	0.035
7	Ahmadi Roshan Blvd.	From Modarres Sq. to Pajuhesh Sq./underpass	77	1	0.081

Table 5. B_3 and B_4 values calculated for the studied road segments

	Segment name	Segment area	B_3	B_4
1	Besat Blvd.	From Pajuhesh Sq./underpass to Besat Sq.	0.099	0.168
2	Fatemiyeh Blvd.	From Besat Sq. to Resalat bridge	0.099	0.168
3	Behesht Blvd.	From Resalat bridge to Babak bridge	0.151	0.156
4	Yadgar Blvd.	From Babak bridge/intersection to Ghadir bridge	0.151	0.156
5	Najafi Blvd.	From Ghadir bridge to Najafi intersection	0.120	0.144
6	Rajai Blvd.	From Rajai intersection to Modarres Sq.	0.135	0.150
7	Ahmadi Roshan Blvd.	From Modarres Sq. to Pajuhesh Sq./underpass	0.269	0.345

Table 6. Pairwise comparisons between the sub-criteria of adjacent land use with respect to the objective

sub-criterion	administrative	commercial	educational	residential	Normalized	Inconsistency ratio
administrative	1.00	0.25	0.20	0.17	0.06	
commercial	4.00	1.00	3.00	2.00	0.44	0.079
educational	5.00	0.33	1.00	0.50	0.19	
residential	5.99	0.50	2.00	1.00	0.31	

Table 7. Pairwise comparisons between the sub-criteria of police presence with respect to the objective

sub-criterion	Absence	Continuous presence	Occasional presence	Normalized	Inconsistency ratio
Absence	1.00	0.25	3.00	0.62	
Continuous presence	0.20	1.00	0.25	0.09	0.08
Occasional presence	0.33	4.00	1.00	0.27	

Table 8. Pairwise comparisons between the sub-criteria of lighting conditions with respect to the objective

sub-criterion	Day	Night with sufficient lighting	Night with insufficient lighting	Normalized	Inconsistency ratio
Day	1.00	0.33	0.25	0.12	
Night with sufficient lighting	3.00	1.00	0.50	0.31	0.02
Night with insufficient lighting	4.00	2.00	1.00	0.56	

results of pairwise comparisons made between sub-criteria in the software environment and the obtained inconsistency ratios.

4.3 Final Calculations and Ranking

After calculating the inconsistency ratios and verifying the process, the results of pairwise comparisons were used in the network. The

After comparing the criteria, sub-criteria were also subjected to pairwise comparison, and then scored and normalized. Tables 6 to 8 show the comparisons were carried out using the statistical results with zero inconsistency to reduce the inconsistency of the entire network assumed in the model. The final ranking of the studied road

segments is presented in Table 9.
In this table, each row provides three values for the respective segment: the third column (Raw) shows the raw value obtained from the super matrix, the second column (Normals) shows the normalized value of the result obtained from the super matrix, and values of the first column (Ideal) have been obtained by dividing the value of each alternative by the value of top ranking alternative. It should be noted that the presented figures are the direct outputs of the software. In this research, the software of the Super Decisions software version 2 has been used.

Figure 7 show that the results of the network model have very little sensitivity to the criteria. If there is a change in the share of each of the criteria, there will be no new prioritization indicating the sustainability of the results of the model. Therefore, the results can be used to install the speed control cameras.

Table 9. Final ranking of road segments for installation of speed camera

Name	Graphic	Ideals	Normals	Raw
ahmadi roshan		1.000000	0.196264	0.107075
besat		0.919479	0.180461	0.098453
bolvar behesht		0.687754	0.134982	0.073641
fatemie		0.682347	0.133920	0.073062
najafi		0.459616	0.090206	0.049213
rajayi		0.757846	0.148738	0.081146
yadegar emam		0.588131	0.115429	0.062974

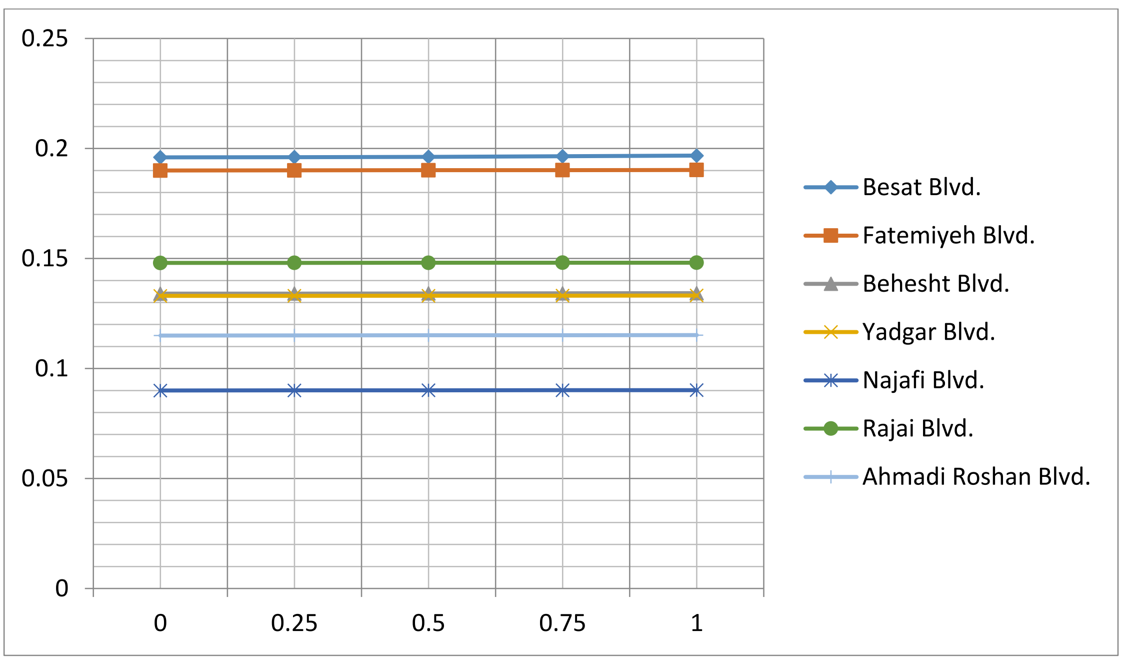

Figure 7. Sensitivity analysis of selected options

5. Conclusion

Studies and experience have shown that speeding is one of the major causes of accidents leading to injuries or death. However, drivers often do not realize the dangers of speeding. At higher speeds, vehicle is more difficult to maneuver and this increases the probability of errors that are unlikely to occur at lower speeds. When used effectively, speed cameras enables the police to fine the speeding vehicles appropriately, and this ability acts as a great deterrent against such violations and gradually leads to internalizing of respect for traffic rules.

The results obtained in this study clearly show that Ahmadi Roshan Blvd. has gained the highest from the perspective of selected criteria and is therefore the top priority for installation of speed cameras. In fact, this segment is the only part in the entire ring road where speed cameras are being installed.

It is notable that, at first, Yadgar Blvd. with its significantly high rate of accident seemed to be the top priority for installation of speed cameras, and the study of Elyasi et al. also identified this boulevard as the top priority for this effort. This inconsistency between our result and the result of that study could be due to shortcomings of analytic hierarchy process, because in AHP, relations are unidirectional, but in ANP, all criteria, sub-criteria and alternatives may have bidirectional relationship and their interdependencies could be taken into account.

6. Discussion

In this research, Data did not consider various levels of injury severity. Unfortunately, there are no levels in the number of injuries in each accident in the form of crash imaging. While those accidents injured at the site by the emergency department are reported as injury accidents. There are a total number of mistakes in the crash data in the relevant forms that should be referred to the police as a proposal for immunization.

At second level, Besat Blvd and Shahid Rajaee Blvd, with a very small difference, are located in the Ahmadi Roshan Blvd, which are capable of installing speed control cameras. Of course, it is recommended to install the camera according to the research results so that the corridor can be more secure during installation. Figure 8 provide a map showing geographical location of the suggested Location of Fixed Speed Cameras.

Practical benefits of this paper using the results of the research show, it is possible to indirectly reduce accidents involving unacceptable speeds and other accidents indirectly, and in order to be safe the parts of the area under study, priority should be given. Also speed control cameras can be cost effective in the first place. Firstly, reducing crashes and crafting will keep track of speed, and the huge cost of crashes will be reduced. Secondly, proceeds from offender fines can be used to secure passages and help safety on both sides.

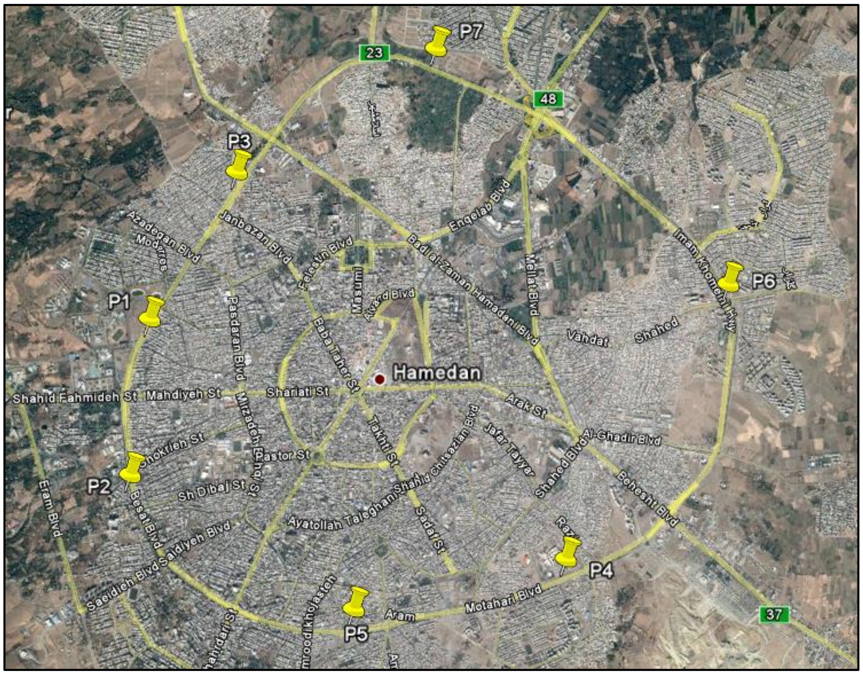

Figure 8. Suggested Location of Fixed Speed Cameras

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