Determining and evaluating the requirements of ITS (Intelligent Transportation System) implementation in Iran road transport

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Abstract: Intelligent Transportation System (ITS) is a collection of amazing achievement of information technology in transportation which has transformed quality of people's lives as well as transportation management. Its use is essential given the increasing population and traffic increase. To take advantage of it is necessary to identify the main requirements of this system as its first architecture level given the area and location of its implementation and then the implementation conditions of next architecture levels is provided by determining the importance of each requirement and their components. This paper aims to determine and prioritize the requirements of architecture deployment of intelligent Transportation System in Iran and from the perspective of exports of this system in organizations in charge; thus, the statistical population is all export and specialists of ITS in seven organizations and companies involved and responsible in this field. For this purpose, 3 types of requirements have been introduced according to the research model: 1. the managerial structure; 2. Necessary contexts; 3. Technological requirements, and several indices have been proposed for each factor. The research method is descriptive-applied; and questionnaire and paired comparisons matrix have been used for collecting the required data, and SPSS software has been used for statistical analysis of information. The indices weights have been obtained using AHP method. In this study five research hypotheses have been proposed to investigate the existing and optimal conditions for deploying it; after the investigation, it was indicated that among the three introduced requirements in the model, the first and important priority in its implementation is managerial structure. It is worth mentioning that all three types of requirements are needed for implementing this project.
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Introduction

Demand for travel is increasing every day, transportation becomes more widespread, and this leads to important issues such as congestion, increasing costs, accidents, wasting time and resources especially in roads and highways inside and around the cities [1]. Solving these issues is possible using this technology. Intelligent transportation system is a system that uses information and communication technologies to help handling the transport network. Tools of this intelligent system are used to avoid wasting time and sustaining lives of people besides improving the performance of the transport network [2]. These systems and services have been implemented worldwide. For example, navigation systems for vehicles are widely used in Japan while such system are not much common in the U.S.A tools of this system has three basic and central features including: information, communication, integration and cohesion that these three features help the transport executors to take more coordinated decisions. Transport policies and measures are trying to adapt endless demands, more mobility with less traffic congestion, protect the environment and ensure safe and efficient operation of transportation system which requires more efforts in a wider area. One of these ideas is the use of intelligent transportation systems that can create a new horizon for achieving sustainable and safe mobility in the communication and transport network. Its advantages include the following: 1. Reducing accidents; 2. Helping to reduce traffic congestion; 3. Environmental monitoring and protecting; 4. Operating efficiency and productivity; 5. Comfort factors; 6. Increasing safety; 7. Customer satisfaction; 8. Saving energy (3).

Achieving these advantages is an important necessity in Iran; therefore, it is necessary to apply it and its basic requirements of its architecture must be determined. Determining the requirements in the architecture model of intelligent transportation system causes creating an analysis on the strengths

and weaknesses of facilities and existing resources in order to evaluate the existing opportunities for its deployment and provide a solution for dealing with threats and facilitate the codification of the strategy necessary to achieve the system objectives. To use it, first, basic requirements of its architecture must be determined and prioritized which has been discussed in this paper. In studies conducted in this field in Iran, the researcher only faced on sample by investigating numerous theses and articles, which only defined intelligent transportation system and its indices, while this article has been dealt with its implementation part in Iran road transport and how we can be benefited from its advantages in our country, and what factors must be noted more.

Literature review

A: applying intelligent transportation system

Intelligent transportation system covers a wide range of new tools of administrating the transport network and servicing passengers. Tools of this system which are known as telemetric transport rest on three main features of information, communication and integration. Collecting, processing, aggregating and supplying information are its basis. In recent years, a number of countries have created these national plans and have designed and supported many of these projects. The experiences of these countries have been used for those who are ready to launch new plans and its projects.

At the national level, many countries have started this plan by establishing a collection of interested groups in public and private sector. Forming and maintaining this plan can greatly be facilitated by legislating or administrative orders at high governmental level [4].

Countries such as America, Canada, England, Australia, Japan and Netherlands are pioneering in the science and technology of transportation and traffic engineering, and have started initial studies on intelligent transport systems from 60s and 70s. in fact, these measures have been started after a few years of the need to perform management practices in the field of transportation. In these countries (and later in development countries such as south east Asia and smaller countries of Europe) the focus on infrastructural and hardware measure about traffic has come to an end long ago, and today the main emphasis is on performing projects and plans of system management improvement [5].

The important reference in evaluating this project for estimating costs and planning about implementing its programs is the U.S architecture documentation of intelligent transportation system which was presented in 1996 in order to provide the benefits than costs spent on its implementation. The activities performed in selected and world's leading regions have been presented in table 1:

Table 1: activities performed in the field of IT'S in selected and world's leading regions

location	year	activity	row
U.S	1967	Compilation of the first program of intelligent transportation system	1
U.S	1972	Implementation of intelligent control in five intersections	2
Europe	1985	Euro-K 4 transnational institution with the aim of developing IT in transportation	3
Europe	1991	Establishment of Ertiko 5 transnational institution with the aim of compiling European standards and architecture of intelligent transportation system and determining Ertico goals for 2010	4
U.S	1992	Compiling architecture of intelligent transportation system	5
Japan	1995	Developing principles of intelligent transportation system	6
Japan	1996	Compilation of comprehensive plan of intelligent transportation system	7
U.S	1996	Compilation of twenty-year strategy of the intelligent transportation systems	8
Canada	2000	Comprehensive intelligent transportation system design and architecture	9
China	2001	intelligent transportation system design and architecture	10
Japan	from2004	Realization of the intelligent way	11

B: intelligent transportation architecture levels

In the past, traffic control systems were used to provide one or two services and these services were usually provided independently from each other; while multiple services that are provided to users simultaneously, there is a risk that a number of sub-components of the system does not work in opposition to each other. Intelligent transportation architecture is needed to integrate system components and their cooperation and synergy which provide a framework for its design and implementation based on conditions and requirements.

As shown in the multilevel model of figure 1, its architecture is divided into different levels. It's essential that traffic and transport managers

concentrate their attention on the system architecture in levels order [6]; these levels are considered a range for detailed engineering and design.

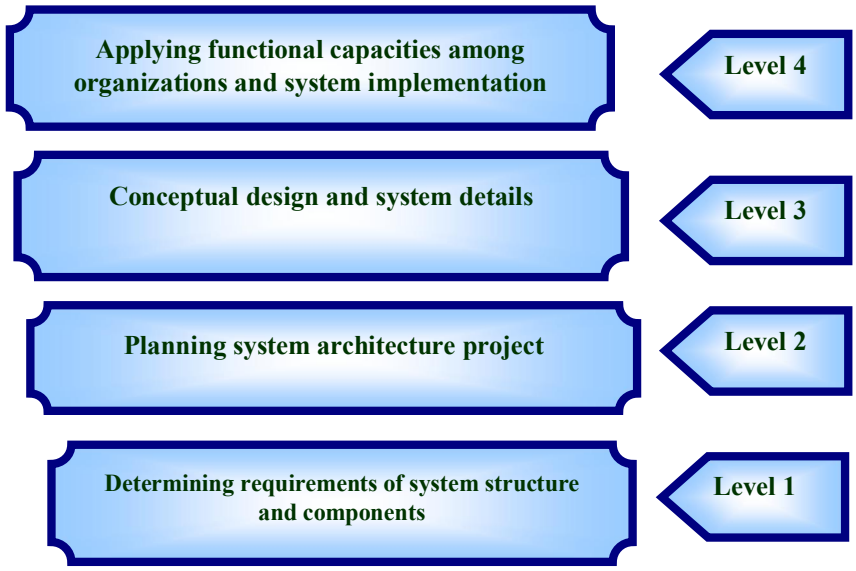

Figure 1: architecture levels of intelligent transportation [6]

According to researchers' opinions, it's essential that the first level of intelligent transportation architecture be started by determining and evaluating its criteria and indices from exports point of view [7].

C: the research model

To deploy and implement intelligent transport for using its advantages it's essential that main requirements of this system be identified as the first level of system architecture given the area and location of its implementation, and then the strategies for implementing next level of architecture be introduced given the importance of each requirement and their components. Figure 2 shows the research model including the requirements and their components in the deployment of this method.

Research hypotheses

Its implementation has caused new studies and consequently its development; its development has been concentrated in two areas of system management and tool and equipment [8].

The main issue of this study is to prioritize and determine the provided components in the analytical model and the two areas which will be implemented for roads and highways in Iran considering executive centers like Transportation Ministry, police and information centers. Given the condition of roads and traffic of highways in Iran and high waste of time and volume of accidents and also the need to implement intelligent transportation system; thus, the first hypothesis is:

Hypothesis 1. In the existing and optimal situation, the most requirements in deploying intelligent transportation system are the factor of managerial structure.

Since management is an integral part of human life today and has had significant effects on various organizations and systems and enhanced the efficiency of using new technologies, accordingly the second hypothesis is:

Hypothesis 2. In the existing and optimal situation, the most important index of managerial structure indices is creating cooperation between executive units in the intelligent transportation system.

Today, countries using intelligent transportation system emphasize on creating the necessary conditions for optimal use of it. For example a country like Japan has established an independent telecommunication unit from public telecom for the optimum use of its services. According, the third hypothesis is as follows:

Hypothesis 3: in the existing and optimal situation, the most important index of necessary conditions is the condition of highways and roads in intelligent transportation system.

In developed countries massive investments are used for using intelligent transportation and the

latest technologies are used; and the have prevent accidents and wastes of time as much as possible, because which service has an efficiency and effectiveness compatible with its equipment. Accordingly, the fourth hypothesis is as follows:

Hypothesis 4. In the existing and optimal situation the most important index of technological requirements is receptors and stabilizers in intelligent transportation system.

Given that the four hypotheses above are considered from an overall view, it seams like asking you what your idea about the football team is. You'll answer it's a good team with tactic, and all lines have plan. But another question is raised, what features must a forward have? This is the personal opinion which has been asked separately from organizations, accordingly, the fifth hypothesis is as follows:

Hypothesis 5. What is the priority of each requirements of intelligent transportation deployment in Iran roads for every organization?

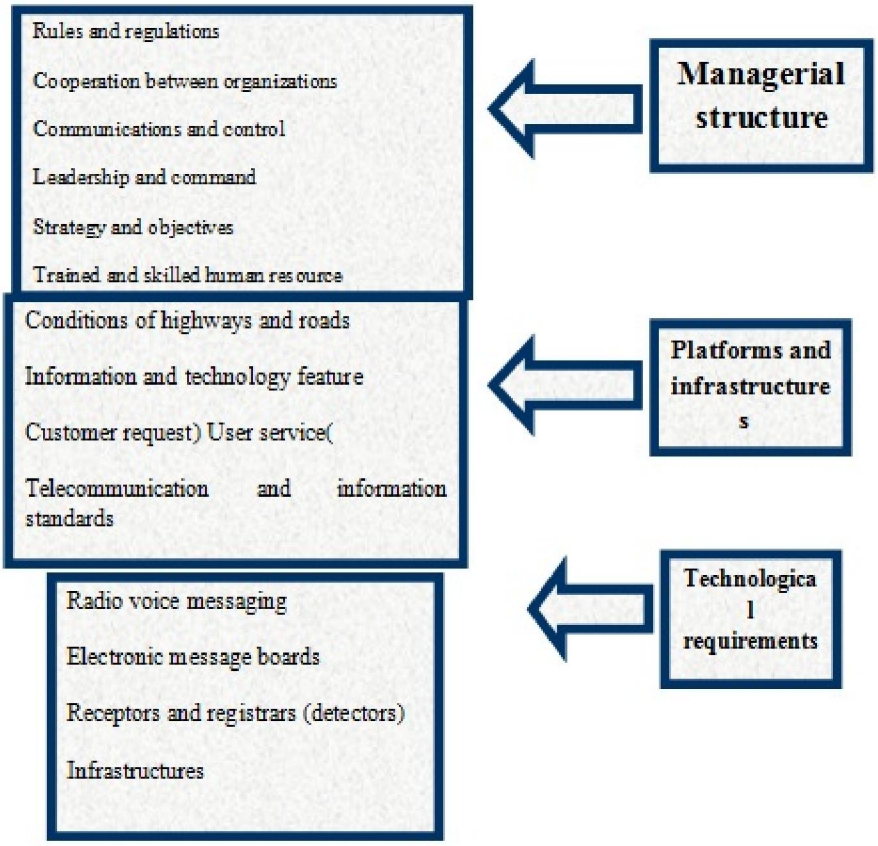

Figure 2. Analytical model of research, ITS implementation requirements [2] [9]

Answering the questions lead to achieve the research objectives as follows:

1. Determining implementation and deployment requirements of intelligent transportation system in Iran road transport
2. Determining and prioritizing deployment requirements of road intelligent transportation system for changed organizations

Research methodology

This is a descriptive-applied study. Descriptive method has been used for describing its factors and indices in the statistical population; and the applied method has been selected since the research objective is applying the results in the statistical population.

The statistical population of this study is all organizations and companies involved and responsible in its field. The number of organizations and companies is seven which has been listed in table 1. All related experts and specialists are considered as statistical samples. Detecting exports and specialists of this system has been performed in by person visiting and the study by the researcher in desired organizations and companies; in each organization, available experts and specialists have been identified through organizational chart and the opinion of the organization managers; and after initial interview the researcher has found that they have been skilled in

the field of transportation and traffic in Iran besides having the knowledge of this system. Details and their number have been provided in table 2.

Since this is an attitude survey study, the research based his work on questionnaire technique which has been used for collecting the required data. In order to identify important factors affecting the implementation of this system, by studying authentic and related books and articles and also obtaining the views of experts, the questionnaire was made with closed questions with five options (very much (5), much (4), medium (3), low (2), very low (1)) by the researcher. The five-opinion questionnaire was designed for evaluating indices of this system implementation in the existing and optimal situation in Iran using the perspective of selected organizations and companies. Also, questionnaire 2 was prepared and arranged for performing paired comparisons and prioritizing influential factors from specialized perspective for each organization and company. To determine the validity of questionnaires along time was spent on interviewing and contacting with the experts in the statistical population.

Table 2: statistics of export/specialist in intelligent transportation in organizations and companies of statistical population

Number of specialist/ expert of intelligent transportation	**Name of company/organization**
12	Road maintenance organization
10	Transport institute
14	police
10	Traffic control
4	Arman Company
3	Metra Cmpany
3	Tehran Arg Company
56	Total

After ensuring the validity, the final questionnaire was given to 10 employees of statistical population and completed in order to determine its reliability. Then, its reliability was calculated by Cronbach's alpha method using SPSS software. Its results are summarized in table 3.

Table 3: the value of Cronbach's alpha for each of key factors using SPSS software

Chronbch's Alpha	**Main factors**	**Number of factors**
0.85	Managerial structure factor	1
0.89	Platforms and infrastructures factor	2
0.88	Technological requirements factor	3

Since the obtained coefficients are higher 75%, the reliability of the questionnaire is acceptable.

A: the mode of information analysis stages of the research

In order to simply introduce how information has been analyzed, the model of information analysis stages of the research has been presented in figure 2.

To determine implementation requirements of this system in road traffic, data were evaluated in the two required conditions (ideal) and existing condition. To this end, a questionnaire was designed qualitatively and prepared for analysis by ranking the options, 1 for very low to 5 for very much.

The statistical sample has been divided into 5 groups including road maintenance organization, companies, traffic control organization, transport research organization and the police. The questionnaire was distributed among those who had a complete or partial recognition to intelligent transport and its performance. 12 questionnaires were delivered for the road maintenance organization, 7 for companies, 6 for transport institute, 7 for Tehran control traffic organization and finally for police authorities. By testing the mean difference between groups, it was indicated that there was no significant difference between them. Thus, the groups were converted to one sample for ease in reviewing the statistical questions.

B: statistical analysis

Each of the questions 1 to 4 was tested for the situation in Iran using descriptive statistic method. Question 5 has been evaluated using AHP method. Question 5 is to determine the priority of requirements from the perspective of decision makers of each organization for that organization; actually it is ranking indices relative to each other that AHP method is suited for this purpose. This method wants the decision maker to compare indices with each other through paired comparisons matrix; and the final W vector in which the weight of each index is from 0 to 1 is obtained with a simple averaging process. In this method, a natural measure of adjustment degree of the decision maker comparison is calculated [10].

Results

1. B: evaluating the first question

A. 1-B: evaluating the first question in optimal situation

To test the first hypothesis, the calculated mean of optimal or required situation of factors for implementing this system is desired. The acceptable mean number is 3. Now considering that groups'

mean is larger than the acceptable mean, therefore, the factor of managerial structure is a requirement for its implementation. Table 4 lists a summary of evaluating factors affecting implementation of intelligent transportation.

Table 4: the results of evaluating the first question is the optimal situation

Factor rank	Optimal mean	Acceptance mean	factors
1	4.71	3	The first factor of managerial structure
3	4.29	3	The second factor of conditions and infrastructures
2	4.45	3	The second factor of technological requirements

By comparing factors' means, it was indicated that managerial structure factor with the mean of 4.71is the most important factor, next technological requirements factor with the mean of 4.45 and the third one infrastructures factor with the mean of 4.29 for the implementation of intelligent transportation.

B. 1-B: evaluating the first question, comparing the existing situation with optimal

The evaluation of the first question has been performed for each factor by comparing the existing situation with optimal. The obtained difference represents the most requirements for that factor.

Evaluating the mean of the first factor in the existing and optimal situation.

Table 5: the first factor mean in the existing and optimal situation

mean	Acceptance mean	
1.74	3	**Existing situation**
4.71	3	**Optimal situation**

To deploy this system, the first factor must be at least as much as 4.71 from 5 while in the existing situation it is less than the average of 1.74 from 5. Evaluating the second factor mean in the existing and optimal situation

Table 6: the second factor mean in the existing and optimal situation

mean	Acceptance mean	
2.61	3	**Existing situation**
4.29	3	**Optimal situation**

To deploy this system, the second factor must exists at least as much as 4.29 while it is less than the average of 2.61 in the existing situation. Evaluating the third factor mean in the existing and optimal situation.

Table 7: third factor mean in the existing and optimal situation

mean	Acceptance mean	
2.11	<3	**Existing situation**
4.45	>3	**Optimal situation**

To deploy this system, the third factor must be as much as 4.45 while it less than the average of 2.11 in the existing situation. Diagram 1 shows the results of evaluating the three factors simply.

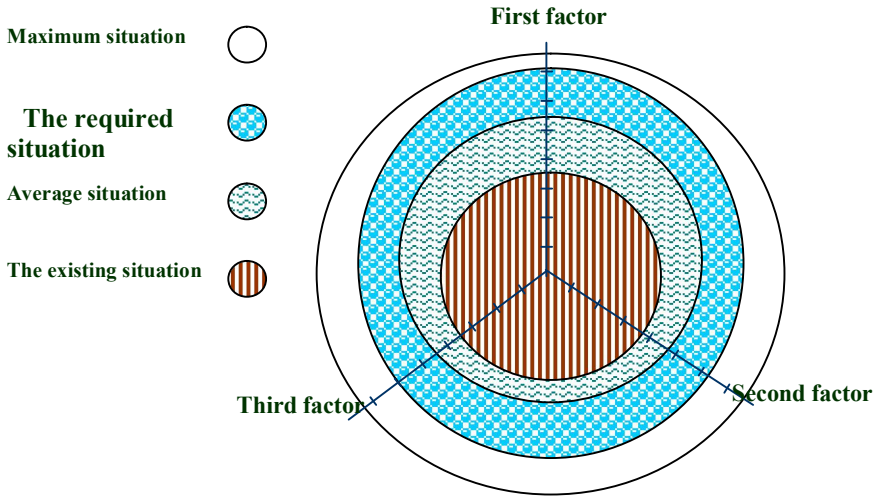

Diagram 1. The existing and optimal situation of the triple factors in the implementation of intelligent transportation

The result is that in terms of statistical population in the existing situation, none of the factors have the required conditions for implementing this system.

C – B: evaluating the second question

The most important requirement of managerial structure indices is the index of creating cooperation between executive units in intelligent transportation system.

A – the evaluation of the second question in optimal and existing situation and comparing the existing situation with optimal one for each index of the first factor have been done using SPSS software and listed in table 7.

The most important index in its implementation is an index which requires the most need in the necessary conditions and has the worst condition in the existing situation; because the research objective is attracting those who interested in the weakest indices in the current condition of Iran transportation which require the most attention. For an overall conclusion the distance of the existing situation with the required situation (optimal) is considered and the most distance suggests the most important index which must be taken into consideration. Table has been prepared to this end.

Table 8: determining the distance between the existing and optimal situation in the first factor indices

Attention priority	distance	rank	Existing situation	rank	Optimal situation	index
4	2/38	2	2/42	2	4/8	**Rules and regulations**
2	2/47	6	1/93	6	4/4	**Communications and control**
1	2/6	5	2/2	1	4/8	**Creating cooperation between organizations**
3	2/44	4	2/21	5	4/65	**Leading and commanding**
5	2/3	3	2/4	4	4/7	**Strategy and objectives**
6	2/28	1	2/52	3	4/8	**Trained human resource**

Based on the information in table 8 in optimal situation, the most important index of the managerial structure is creating cooperation among organizations. The most distance to reach the optimal situation is the third index, i.e. creating cooperation between units in the managerial structure factor.

D –B: evaluating the third question

What is the most important index of the second factor, i.e. platforms and infrastructures in intelligent transportation system?

Descriptive statistics of the third questions in the existing situation has been presented in table 9.

Table 9: the distance between the existing and optimal situation in the second factor indices

Attention priority	distance	rank	Existing situation	rank	Optimal situation	index
3	1.37	3	2.62	2	3.99	**First index**
1	2.38	4	**2**	3	4.38	**Second index**
4	1.115	1	3.2	4	4.315	**Third index**
2	1.96	2	2.7	1	4.66	**Fourth index**

Among the second factor indices, providing financial condition and compiling standards have the most requirements.

E – B: evaluating the fourth question

What is the most important requirement of technological requirement in intelligent transportation system?

Table 10: the distance between the existing and optimal situation in the third factor indices

rank	distance	rank	Existing situation	rank	Optimal situation	index
4	1.25	1	3	4	4.25	**First index**
3	2.15	2	**2.4**	3	4.55	**Second index**
1	3.05	4	**1.7**	1	4.75	**Third index**
2	2.8	3	**1.8**	2	4.6	**Fourth index**

Therefore, the most important index of technological requirements which must be taken into consideration is the index of receptors and registrars in intelligent transportation.

C: determining the indices weights from the specialized perspective of each organization

In designing this system besides identifying the impact of factors, the priorities of the involved and responsible organizations for the implementation of intelligent transportation must also be determined; so that targeting is done with a comprehensive view to provide the compatibility of units and their synergy besides their integrity. They also must prioritize executive indices based on their own requirements and use them as primary planning inputs [11]. Moreover, the required cooperation and integrity does not exist between related organization and their status in the system is not specified; and private sector must be used for designing this system [12]. For this reason, a survey was performed from specialists of each organization using paired comparisons matrix and the weights of indices have been determined with AHP method. Because of the lengthy calculations, the calculation process for the first factor indices of the Road Maintenance Organization has been presented; and for other factors and organizations, only results have been listed in table 14.

Determining weights of the first factor indices from the perspective of Iran Road Maintenance Organization. First, the geometric mean of the corresponding entries to the paired comparisons matrices has been obtained for factor indices in table 11.

Table 11: the geometric mean of paired comparisons matrices for the first factor indices

	1	2	3	4	5	6
1	1	1.54	1.46	1.34	1.7	1.87
2	0.67	1	1.52	1.58	2.09	2.09
3	0.66	0.65	1	2.07	2.008	1.86
4	0.74	0.64	0.56	1	1.61	1.4
5	0.58	0.47	0.49	0.61	1	1.2
6	0.55	0.47	0.53	0.7	0.58	1

Then weight of indices was obtained using geometric mean.

$$\xrightarrow{\text{LinesGeome tricalAver age}} \begin{vmatrix} 1.43 \\ 1.38 \\ 1.22 \\ 0.91 \\ 0.97 \\ 0.61 \end{vmatrix}_{6.2} \xrightarrow{\text{Normalizat ion}} \begin{vmatrix} 0.23 \\ 0.22 \\ 0.19 \\ 0.14 \\ 0.12 \\ 0.10 \end{vmatrix} = \omega$$

Now, the priorities obtained from judgments of group members must be trusted. To this end, the consistency rate has been obtained for the comparisons. The studies have shown that if consistency rate (CR) is less than 10 percent, the consistency of comparisons can be accepted [10], otherwise, the comparisons should be done again. The consistency rate has been calculated through a special vector method as follows:

$$A\omega = \lambda\omega \Rightarrow \begin{vmatrix} 1.39 \\ 1.34 \\ 1.20 \\ 0.88 \\ 0.65 \\ 0.59 \end{vmatrix} = \lambda \begin{vmatrix} 0.23 \\ 0.22 \\ 0.19 \\ 0.14 \\ 0.12 \\ 0.10 \end{vmatrix} \Rightarrow \begin{matrix} \lambda_1 = 6.04 \\ \lambda_2 = 6.09 \\ \lambda_3 = 6.31 \\ \lambda_4 = 6.2 \\ \lambda_5 = 5.90 \\ \lambda_6 = 6.5 \end{matrix} \rightarrow \overline{\lambda} = 6.18$$

$$IR = \frac{II}{IIR}$$

$$\lambda = \frac{\sum_j a_{ij} w_j}{w_i} \qquad II = \frac{\overline{\lambda} - n}{n-1} = \frac{6.18 - 6}{5} = 0.036$$

IIR is a random index which has been calculated in resources for n from 1 to …; the number in this study is 6 so IIR=1.24.

n	2	3	4	5	6	7	8	9
IIR	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

$IR = \frac{0.036}{24.1} = 0.02$ $IR = \frac{II}{IIR}$.

Therefore, with 0.02 consistency rate in the judgment of specialists, thus, the priority of indices for Iran Road Maintenance Organization is as follows:

1. Determining strategies and objectives
2. Creating rules and regulations
3. Cooperation among the necessary organizations
4. Communication and control
5. 5. Determining leadership and command

Table 12 shows weights of intelligent transportation indices in every organization or company.

Table 12: weights of intelligent transportation system in each organization or country

Results and priorities			Name of organization/company	row
Requirements factor	**Platforms factor**	**Managerial structure**		
-message radio -message boards -detectors -Telecom infrastructures	-infrastructures -information feature -Customer request -standards	-strategy and objectives -rules and regulations -cooperation among organizations -communication and control -leadership and command -Human resource	Road maintenance organization	1
- message radio -message boards -detectors -Telecom infrastructures	-infrastructures -information feature -Customer request -standards	-strategy and objectives -rules and regulations -cooperation among organizations -communication and control -leadership and command -Human resource	Transport institute	2
-detectors - message radio -Telecom infrastructures -message boards	-infrastructures -information feature -Customer request -standards	-strategy and objectives -rules and regulations -cooperation among organizations -communication and control -leadership and command -Human resource	Traffic control organization	3
-detectors -Telecom infrastructures - -message boards - message radio	-infrastructures -information feature -Customer request -standards	-strategy and objectives -rules and regulations -cooperation among organizations -communication and control -leadership and command -Human resource	Tehran Arg company	4
-detectors -Telecom infrastructures - -message boards - message radio	-infrastructures -information feature -Customer request -standards	-strategy and objectives -rules and regulations -cooperation among organizations -communication and control -leadership and commanding -Human resource	Metra consultation company	5
-message radio -message boards -detectors -Telecom infrastructures	-infrastructures -information feature -Customer request -standards	-strategy and objectives -rules and regulations -cooperation among organizations -communication and control -leadership and commanding -Human resource	The police	6
-detectors -Telecom infrastructures - -message boards - message radio	-infrastructures -information feature -Customer request -standards	-strategy and objectives -rules and regulations -cooperation among organizations -communication and control -leadership and commanding -Human resource	**Arman Company**	7

Discussion and conclusion

Given that intelligent transportation is a technology that its implementation depends on environmental conditions and facilities; thus, in connection with its implementation, the opinions of in charge and executive organizations must be considered; and regarding the overall summary of the views of organizations involved in this system, cases and indices are considered for its implementation [13], this research has been conducted with this view and the following results have been presented.

In the present study, four questions have been considered for evaluating factors and indices in the existing and optimal situation for its deployment in Iran; and AHP has been used for determining the importance and weights of important indices in the deployment of this system from the perspective of each organization. To select the most important among the three factors affecting its architecture in the situation in Iran by comparing the existing and optimal situation, it was indicated that managerial structure factor is more important than physical requirements and platforms, i.e. among the three proposed factors, the factor of managerial structure must be taken into consideration more than other factors. Therefore, by using efficient methods between involved and in charge organizations for its implementation, the required connection must be created to be able to coordinate other activities for implementing among organizations. Because by implementing this factor, other factors can be implemented as well. It should be noted that for the implementation of this system, all three factors in the provided model have been known as requirements of its implementation.

The purpose of second, third and fourth questions is identifying the most important indices of factors; the result is

1. Managerial structure factor as the most important factor for intelligent transportation is the index of creating cooperation and coordination between involved units in its implementation such as police, road maintenance, etc.
2. The most important index in the second factor of this system has been the compilation of standards, and this result seems logical after an analytical evaluation, because the base of platforms is the presence of executive standards, and receptors and registrars must be designed and deployed considering these standards.
3. The most important index of the third factor, i.e. technological requirements of intelligent transportation is receptors and registrars.

The priority and importance of indices for each organization have been determined using AHP method which has been presented in table 12. According to results of this table in the dimension of managerial structure among the proposed indices for all organizations, the most attention must be paid to the index of creating cooperation between groups and organizations involved in intelligent transportation; thus for creating the ground for its implementation, the compilation of telecommunication and information standards must be considered, because other indices in the factor of grounds are related to this index.

Because in the factor of physical requirements, the index of deploying electronic message boards has been more important. Therefore, the ground of the required planning and budgeting must be done for preparing the appropriate equipment.

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