IJTE, Vol. 9, No. 3, Winter 2022, pp. 735-747

Research Paper

Novel Index of Budget Allocation to Practical Projects of Intelligent Transportation Systems in a Transit Corridor

Morteza Asadamraji [1,*]

Received: 2021.10.09 *Accepted: 2021.12.20*

Abstract

One of the new ways to improve the performance of roads is to make them smarter. To use intelligent transportation systems(ITS), various measures have been taken in different countries, and Iran has also been pushed in this direction. One of the problems regarding needs assessment, installation, and implementation of intelligent transportation systems is the priority of their purchase and implementation. This is especially evident in the main corridors of the country, which include several main roads. The prioritization of practical projects of intelligent transportation systems is considered in budget shortfall and is the basis for decision-making of those involved. To prioritize intelligent transportation systems projects, the selection of criteria and ranking techniques are very important. The purpose of this study is to prioritize ITS projects in one of the main corridors of the country (Tehran-Bandar Imam) The reason for choosing the corridor was its long length, the existence of different hierarchies of roads, as well as the needs of different intelligences. In this regard, the intelligent projects defined in this corridor have been prioritized using the criteria of execution time, benefit/cost, and ease of implementation, proposing a new index. The new prioritization index is designed according to the average of solutions. The results showed that among the proposed intelligent system projects, the use of versatile video surveillance cameras, new speed cameras, variable message boards, and automatic accident detection system, respectively, had a higher priority than other projects. The research results are used to select practical projects in budget constraints.

Keywords: Intelligent transportation system (ITS), smart corridor, prioritization index, budget allocation

[*] Corresponding author. E-mail: m_asadamraji@sbu.ac.ir

[1] Assistant Professor, Department of Geotechnics and Transportation, Faculty of Civil Engineering, Water and Environment, Shahid Beheshti University, Tehran, Iran

.

1. Introduction

Many managers in various organizations still know the key to the survival and success of the collection under their management in today's rapidly evolving period, adopting the most appropriate strategies. However, the most important issue in the strategic management process is the implementation of strategies. The process of implementing a strategy is much more difficult than the process of formulating it because it involves far more variables and constraints. In the implementation phase, there is a parametric strategy called budget and related constraints that always exist in any situation. On the other hand, by allocating a specific budget to a project, receiving the maximum and most appropriate performance that can meet many needs and demands affects the implementation process as another parameter. However, as the costs of implementing a project increase, so do the sensitivities about how to prioritize different parts of the project. How a project should proceed to achieve the maximum performance expected in a given period of time, given the budget constraints, is a management skill in the execution process. On the other hand, intelligent transportation systems are one of the achievements of information and communication technology in transportation. The use of intelligent systems in transportation as one of the most important human needs in the country's macro-planning is of particular interest. Intelligent transportation systems offer many solutions to some of the most complex transportation problems. The use of ITS provides the possibility of improving traffic flow by reducing congestion, improving air quality, reducing travel delays, and increasing safety (Mousavi, 2010)

Different technologies of intelligent transportation systems are used in different cases, including primary systems such as car navigation and traffic light control systems, traffic signs, speed cameras, and automatic vehicle number identification systems and more advanced and sophisticated systems that simultaneously integrate different information from different sources, such as weather conditions, traffic conditions, road conditions, etc. (Guerrero-Ibáñez et al, 2018). In addition to the existing technologies of these systems, the need for communication between them and also how they are communicated are very important, and this is taken into account in the intelligent transportation systems. The first signals and technologies to be implemented and the maintenance of intelligent transportation systems have regular programs in different countries (Shladover, 2018).

Given the tremendous global progress in the field of smart alarms and control equipment and their effectiveness, the need to install and operate this equipment is essential in Iran. Intelligent transportation systems, in addition to operating safely and efficiently for all users of road transportation systems, generate simultaneous traffic information that many other traffic management systems use. Associations and institutes related to ITS in different countries have reached different classifications regarding these systems. Considering the conditions of Iran and the appropriateness of projects and relations with safety discussions, environment, and reducing fuel consumption, a number of systems are proposed as smartification of the main roads of the country, some of the most important of which are:

- Electronic toll collection system
- Speed control and license plate recognition cameras
- Video surveillance cameras
- Variable speed boards
- Variable message boards
- Frost prevention systems
- Road weather information systems
- Vehicle tracking system
- Traffic counting system
- Weigh-in-motion systems and automatic accident detection system

One of the main problems in using the mentioned systems and other intelligent transportation systems is their purchase and competitive implementation in the roads of different provinces of the country; each province that has more systems it is in a higher rank in terms of transportation parameters. The main research question is which projects of intelligent transportation systems should be given priority in the context of budget constraints? Therefore, this study set to make optimal decisions regarding the selection of practical priorities for intelligent transportation systems projects in the country's corridors. Considering the needs of smartification of an important corridor of the country and using the criteria according to the conditions of the country and the prioritization index obtained from the average solution technique, the practical projects of intelligent transportation systems are ranked.

2. Literature Review

With the rapid increase of technology and the increasing growth of countries' economies, transportation is also on the path of development. One of the requirements for transportation development is the use of intelligent transportation systems (An et al, 2011). Intelligent Transport Systems (ITS) is a general term for the combined application of communication, control, and information processing technologies for the transportation system. Using it saves lives, saves time, money, energy, and environmental benefits. The ITS covers all modes of transportation and examines all elements of the transport system, such as the vehicle, infrastructure, and the driver or user. The overall task of ITS is to improve decision-making, often in a timely manner, for transport network controllers and other users, and thus to improve the overall performance of the transport system. Piarc (2004) noted the efficiency of the transportation system. For this purpose, these systems are classified into three general categories, including vehicle systems, traffic management systems, and travel information systems. User services provided by ITS include demand and access management, traffic control and management, traffic and travel information, driver assistance systems, fleet management, and emergency and safety systems (Tian et al, 2017).

In the method used by Jason et al., ITS services are prioritized based on the scoring of each service; the services with the highest score will have the highest priority in execution. In this study, 20 ITS services are prioritized for Mongolia as a developing country (Zhang et al, 2018).

According to the US Intelligent Systems Document, suburban ITS is looking for programs to satisfy people and other users in other sectors to improve security facilities and access to transportation services in suburban areas. Significant challenges in providing transportation services in suburban or state areas are related to differences in suburban travel conditions and class differences between travelers and their needs. Intelligent systems projects have been implemented extensively in different US states (Figueiredo et al, 2001).

One of the major ITS projects was the Michigan's Vehicle Infrastructure Integration (VII) Strategic and Business Plan, which provided the basis for the Michigan Department of Transportation's activities in the field of automotive wireless communications systems, one of the most important and evolving applications of ITS. It includes the perspective, mission, and goals that the state pursues to work with key organizations in this area and provides management at the state and national levels for research, implementation, and development of vehicle infrastructure integration (VII) (Biswas et al, 2006).

Intercity transportation is one of the important applications of ITS used in both urban and suburban areas. In recent years, with the development of wi-fi systems, spatial information, and GPRS, the project planning has been further developed (Naboulsi et al, 2015)

One of the most prestigious projects and technologies of intelligent transportation systems that have a long history is the use of various types of functional speed cameras as well as average speed cameras. In addition to use of these cameras from dynamic warning systems and also taking advantage of variable speed limits, speed warning to prevent exceeding the speed limit, warning about deceleration due to speed differences in downstream areas, and other facilities are used in different countries (Montella, 2014)

In the research conducted by Aulin et al., 24 economic, social, environmental, and flexibility performance criteria were introduced for the use of ITS in transportation, and then the options for developing these criteria were prioritized based on the GAHP (Group Analytic Hierarchy Process) method (Krmac & Djordjević, 2018).

Numerous studies have also been conducted in the field of multi-criteria decision making for the implementation of other transportation projects. Novak et al. presented an innovative way in 2015 to develop and implement multi-criteria analysis (MCA). In this study, the project prioritization process is presented before and after multi-criteria analysis for the State of Vermont in the United States and is done using a combined approach to prioritize transportation project (Novak et al., 2015).

Shelton et al. prioritized transportation projects based on budget constraints and project execution times. They evaluated transportation projects in Texas using multi-criteria decision making (MCDM) methods. Prioritization of different projects was done using AHP and TOPSIS methods. They used the AHP method to determine the weight of their desired criteria using pairwise comparison of criteria and used the TOPSIS method for the final prioritization of projects (Shelton & Medina, 2010) Also, Hamorko et al. used the AHP method to determine the weight of their desired criteria and then prioritized the implementation of their desired solutions using the Fuzzy TOPSIS method (Hamurcu et al., 2020). Mirza Hossein et al. Also used a combination of AHP analysis and GIS to prioritize emergency locations for the Silk Road.(Mirza hossein et al, 2020). Recently, Habibi et al. Have used the hybrid approach in prioritizing smart public transportation (Habibi et al, 2021)

In recent years, new digital developments have been applied to the prioritization of ITS, image processing (Mirzahossein et al, 2021), and newer indices have been used for prioritization. The use of intelligent systems in driving simulators (Asadamraji et al 2019), in road safety management, and risk perception (Asadamraji et al 2018) has also received much attention and has led to changes in the ranking of projects related to intelligent transportation (Asadamraji et al 2021). In addition, if the priorities and locations are correct, they can be used in traffic issues, for example, one of the applications is the use of cameras to detect traffic patterns.(Gholampour et al.2020)

In the implementation of intelligent transportation projects in a corridor that requires coordination between different departments, each project should be evaluated in terms of the desired indices and their scoring to prioritize projects with higher priority and efficiency due to administrative, financial, and time constraints.

3. Method

Smartification of the country's roads is done by implementing projects and installing equipment and repairing and maintaining them. Thus, it is necessary to implement the proposed systems in the form of practical projects in accordance with the needs of each road. Systems can be implemented on roads in the form of practical projects. So, a number of projects that can be implemented at the road level are selected according to the needs and facilities of each road. Thus, project prioritization and budget allocation are essential, due to limited resources, the most important of which are financial resources, manpower, equipment, and time.

3.1. Prioritization Criteria

To prioritize the allocation of funds for the implementation projects of ITS in a national corridor, three main criteria have been considered. These criteria are:

3.2. Execution Time

One of the most important criteria in the implementation of construction projects such as ITS is project scheduling. If the duration of a project is long, the priority of its implementation will be less, but this should be considered in combination with other criteria in the proposed index.

3.3. Benefit to Cost Ratio of the Project

An ITS project is appropriate when the benefits outweigh the costs, i.e. the ratio of benefits to project costs is greater than one. Hence, one of the criteria for implementing the projects of ITS in a corridor of the country was the ratio of profit to costs.

3.4. Ease of Implementation

The third criterion used in the project implementation of the ITS is the possibility of project implementation and, more completely, the ease of project implementation. Projects may be profitable at a reasonable cost, but there are many problems in implementation, such as sanctions, lack of infrastructure, and other practical problems. An ITS project is considered appropriate if it has fewer implementation problems.

3.5. Weighing the Budget Allocation Prioritization Criteria

To weigh the budget allocation prioritization criteria for the implementation of intelligent transportation systems projects in a corridor, Shannon's entropy method was used. For this purpose, different stages of calculating the weights of each criterion were considered according to this method, and for the relevant calculations three equations 1 to 3 were used.

$$E_j = -K\sum_{i=1}^{m} P_{ij} \times \ln(p_{ij}) \quad (1)$$

Where

E_j is entropy

p (x) is the probability distribution of the random variable X

And k is a constant number between 0 and 1.

$$d_j = 1 - E_j \quad (2)$$

$$w_j = \frac{d_j}{\sum_{i=1}^{m} d_i} \quad (3)$$

In which, d_j is the degree of deviation of each index, and w_j is the weight of each criterion.

3.6. Budget Allocation Prioritization Index

The proposed index is presented according to the projects and criteria based on the average distance from the solutions. The steps to reach the budget allocation index are as follows:

Step 1: Forming a matrix between practical projects and budget allocation prioritization criteria

$$X = [X_{ij}]_{n\times m} = \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1m} \\ X_{21} & X_{22} & \cdots & X_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & \cdots & X_{nm} \end{bmatrix} \quad (4)$$

Step 2: Calculating the average solution of each prioritization criterion and budget allocation

The average of the solution for the criteria is calculated, which is in fact the average of the data for each criterion of the matrix between the projects in the matrix formed in step 1.

$$MP = [MP_j]_{1\times m} \quad (5)$$

Where

$$MP_j = \frac{\sum_{i=1}^{n} X_{ij}}{n}$$

Step 3: Calculating the positive and negative distances from the average solution of the projects

Positive distance values are calculated from the mean PF negative distance from the mean NF- using the following equations. For a criterion with a positive aspect (increase in the criterion increases the profit):

$$\mathrm{PF}_{ij} = \frac{\max(0\&(X_{ij} - MV_j))}{MV_j} \quad (6)$$

$$\mathrm{NF}_{ij} = \frac{\max(0\&(MV_j - X_{ij}))}{MV_j} \quad (7)$$

For the criterion with a negative aspect (decreasing the criterion increases the profit)

$$PF_{ij} = \frac{\max(0\&(MV_j - X_{ij}))}{MV_j} \quad (8)$$

$$NF_{ij} = \frac{\max(0\&(X_{ij} - MV_j))}{MV_j} \quad (9)$$

Step 4: Calculating WP and WN values:

Weighing the PF and NF values and multiplying the criteria weights by the variables

$$WP_i = \sum_{j=1}^{m} w_j PF_{ij} \quad (10)$$

$$WN_i = \sum_{j=1}^{m} w_j NF_{ij} \quad (11)$$

Step 5: Calculating the normal values of WP and WN

$$NWP_i = \frac{WP_i}{max_i(WP_i)} \quad (12)$$

$$NWN_i = 1 - \frac{WN_i}{max_i(WN_i)} \quad (13)$$

Step 6: Calculating the final index

$$RI_i = 0.5(NWP_i + NWN_i) \quad (14)$$

Where $0 \leq RIi \leq 1$

Final step: Prioritizing the allocation of funds to the practical projects of ITS in the corridor

Using the index value calculated from step six, the budget allocation to ITS projects is prioritized in the corridor under consideration

4. Results

To use the budget allocation prioritization index to implement ITS projects, a country corridor was selected. For this purpose, Tehran road to Imam Khomeini port was chosen. The reason for choosing this corridor was its importance in the country and covering many northern, central, and southern provinces of the country. There were also a variety of road functional categories in the corridor, which led to a variety of ITS projects.

4.1. Definition of Projects

In the mentioned corridor, 12 practical ITS projects were selected, which are mentioned below:

- Online status issuance system (public transport management) on all corridor roads
- Electronic toll collection systems (ETC) on Khorramabad-Andimeshk road
- Use of new speed cameras and license plate detection on corridor roads
- Combined video surveillance cameras on all corridor roads
- Variable speed limit (VSL) on all corridor roads
- Variable message sign (VMS) on all corridor roads
- Frost prevention systems on Salafchegan-Arak, Arak-Boroujerd, and Boroujerd-Khorramabad roads
- Road Weather Information Systems (RWIS) on Boroujerd-Khorramabad, Khorramabad-Andimeshk, and Ahvaz-Bandar Imam Khomeini Roads
- Automatic vehicle location (AVL) in all public vehicles in the corridor
- Traffic counting system on all roads
- Weigh-in-motion systems on Salafchegan-Arak, Arak-Boroujerd, Boroujerd-Khorramabad, Khorramabad-Andimeshk, and Ahvaz-Bandar-Imam roads
- Automatic accident detection system in tunnels and accident hotspots of roads

4.2. Prioritization Criteria in ITS Projects in Selected Corridor

At the execution time, profit to cost ratio as well as ease of execution were determined as criteria in the selected corridor. In this section, the data required to analyze each criterion are presented separately.

4.2.1. Execution Time

In the meetings held with the study and practical institutions active in the field of smartification of the country's roads, information on how to implement the project and the minimum time required were obtained. In this regard, based on previous studies and experiences, information about the optimal execution time and project guarantee period were calculated. The results are reported in Table 1.

Table 1. Optimal time of implementation of road ITS projects

project	Project name	Execution time
1	On-line status issuance system (public transport management) on all corridor roads	23 months
2	Electronic toll collection systems (ETC) on Khorramabad-Andimeshk road	16 months
3	Use of new speed cameras and license plate detection on corridor roads	6-8 months
4	Combined video surveillance cameras on all corridor roads	7 months
5	Variable speed signs on all corridor roads	8 months
6	Variable message signs (VMS) on all corridor roads	8 months

project	Project name	Execution time
7	Frost prevention systems on Salafchegan-Arak, Arak-Boroujerd, and Boroujerd-Khorramabad roads	12 months
8	Road Weather Information Systems (RWIS) on Boroujerd-Khorramabad, Khorramabad-Andimeshk and Ahvaz-Bandar Imam Khomeini Roads	12 months
9	Automatic accident detection system in tunnels and accident hotspots of roads	11 months
10	Weigh-in-motion systems on Salafchegan-Arak, Arak-Boroujerd, Boroujerd-Khorramabad, Khorramabad-Andimeshk, Andimeshk-Ahvaz and Ahvaz-Bandar-Imam roads	14 months
11	Automatic vehicle location (AVL) in all public vehicles in the corridor	13 months
12	Traffic counting system on all corridor roads	8 months

According to Table 1, the fastest installation and operation process is related to the operation of video surveillance cameras, speed cameras, and license plate registration on roads. Thus, the installation and construction of these cameras on suburban roads can be considered a short-term project on a large scale. Similarly, launching traffic counting systems, VSL, and VMS on the country's roads can be done faster and can be considered a suitable solution for the rapid improvement of the country's roads. In general, most proposed systems in traffic management user services have high installation and execution speed, and equipping the roads with crisis management systems will require a long period of time compared to other systems.

4.2.2. Expected Costs and Benefits

The ratio of benefits to costs is one of the most important parameters considered as a primary criterion in determining the success or failure of practical projects. In general, this criterion can determine the acceptance or rejection of a project in terms of success. Table 2 shows the ratio of benefits to costs in terms of smartification of the studied roads according to similar experiences from other countries.

Table 2. Ratio of benefits to costs

project	Project name	B/C
1	On-line status issuance system (public transport management) on all corridor roads	5.1
2	Electronic toll collection systems (ETC) on Khorramabad-Andimeshk road	5
3	Use of new speed cameras and license plate detection on corridor roads	2.6-12
4	Combined video surveillance cameras on all corridor roads	3-15
5	Variable speed signs on all corridor roads	2.1-22.3
6	Variable message signs (VMS) on all corridor roads	1.8-22
7	Frost prevention systems on Salafchegan-Arak, Arak-Boroujerd, and Boroujerd-Khorramabad roads	1.3-2.7
8	Road Weather Information Systems (RWIS) on Boroujerd-Khorramabad, Khorramabad-Andimeshk and Ahvaz-Bandar Imam Khomeini Roads	7-6
9	Automatic accident detection system in tunnels and accident hotspots of roads	8.6
10	Weigh-in-motion systems on Salafchegan-Arak, Arak-Boroujerd, Boroujerd-Khorramabad, Khorramabad-Andimeshk, Andimeshk-Ahvaz and Ahvaz-Bandar-Imam roads	3.69
11	Automatic vehicle location (AVL) in all public vehicles in the corridor	1.5-4.5
12	Traffic counting system on all corridor roads	2-3

Table 2 shows the benefit-to-cost ratio; for some systems and equipment, the benefit-to-cost ratio is in a broad range, indicating that proper performance in terms of optimal equipment, proper maintenance, and other related issues can affect the performance of the system and change it in a range of costs to a range of benefits.

Based on the experiences of other countries in relation to the benefits gained as a result of the implementation of ITS, in optimal conditions of cost and implementation, the operation of versatile video surveillance cameras and speed cameras on the road can be introduced as systems in which their ratio of benefits to costs is in the high range. Intelligent systems for automatic accident detection and launching RWIS can also be considered as profitable systems.

4.2.3. Ease of Implementation

In the implementation of national projects at the macro level, in addition to the implementation cost and time required for the operation of the system, ease of implementation is also considered as a determining factor in accepting or rejecting the project. Execution of projects is usually done in simple, relatively simple, relatively hard, hard, and very hard conditions, which are specified in the tables with odd figures in the range of 1-9. Number 1 indicates the simplicity of project implementation and number 9 indicates the high difficulty of project implementation at the operational scale. Table 3 shows the ease of implementing the proposed road projects.

Thus, according to the prioritization table of ease of project implementation, it is determined that speed control and license plate recognition systems, VMS, and VSL can be installed, implemented, and operated on the road surface compared to other systems and can therefore be exploited in a shorter time than other projects. On the other hand, the installation, implementation, and operation of frost prevention systems on roads is more difficult than other systems and can be considered as projects at a higher level.

Table 3. Ease of project implementation

project	Project name	Ease of implementation
1	On-line status issuance system (public transport management) on all corridor roads	7
2	Electronic toll collection systems (ETC) on Khorramabad-Andimeshk road	9
3	Use of new speed cameras and license plate detection on corridor roads	3
4	Combined video surveillance cameras on all corridor roads	5
5	Variable speed signs on all corridor roads	3
6	Variable message signs (VMS) on all corridor roads	3
7	Frost prevention systems on Salafchegan-Arak, Arak-Boroujerd, and Boroujerd-Khorramabad roads	9
8	Road Weather Information Systems (RWIS) on Boroujerd-Khorramabad, Khorramabad-Andimeshk and Ahvaz-Bandar Imam Khomeini Roads	5
9	Automatic accident detection system in tunnels and accident hotspots of roads	7
10	Weigh-in-motion systems on Salafchegan-Arak, Arak-Boroujerd, Boroujerd-Khorramabad, Khorramabad-Andimeshk, Andimeshk-Ahvaz and Ahvaz-Bandar-Imam roads	7
11	Automatic vehicle location (AVL) in all public vehicles in the corridor	9
12	Traffic counting system on all corridor roads	5

4.3. Priority of Budget Allocation to Practical Projects of ITS Using the Proposed Index

Considering the cases mentioned in the previous paragraphs and prioritizing the options according to the criteria of implementation time, ease of implementation, and the amount of benefits to costs ratio, the proposed options were implemented and prioritized, which are actually projects to be implemented at the studied roads simultaneously according to the criteria of time and ease of implementation as well as the ratio of benefits to costs using the proposed index of different steps. Tables 4 to 9 and Figure 1 show the analyses performed and prioritization of the allocation of budget to projects.

Table 4. Projects and budget allocation prioritization criteria matrix

Criteria / Practical projects	B/C	Time	Ease of project implementation
P1	5.1	23	7
P2	5	16	9
P3	7.3	7	3
P4	9	7	5
P5	1.76	8	3
P6	4.61	8	3
P7	2.45	12	9
P8	6.5	12	5
P9	8.6	11	7
P10	3.69	14	7
P11	3	13	9
P12	2.5	8	5
MP	4.959	11.583	6

Table 5. Positive distance from average alternative

PF_{ij}	B/C	Time	Ease of project implementation
P1	0.028	0	0
P2	0.008	0	0
P3	0.472	0.396	0.5
P4	0.815	0.396	0.167
P5	0	0.309	0.5
P6	0	0.309	0.5
P7	0	0	0
P8	0.311	0	0.167
P9	0.734	0.05	0
P10	0	0	0
P11	0	0	0
P12	0	0.309	0.167

Table 6. Positive distance from average alternative

NF_{ij}	B/C	Time	Ease of project implementation
P1	0	0.986	0.167
P2	0	0.381	0.5
P3	0	0	0
P4	0	0	0
P5	0.645	0	0
P6	0.07	0	0
P7	0.506	0.036	0.5
P8	0	0.036	0
P9	0	0	0.167
P10	0.256	0.209	0.167
P11	0.395	0.122	0.5
P12	0.456	0	0

Table 7. Positive factor weighted matrix

w_jPF_{ij}	B/C	Time	Ease of project implementation
P1	0.0128	0	0
P2	0.0037	0	0
P3	0.2124	0.0871	0.165
P4	0.3667	0.0871	0.055
P5	0	0.0681	0.165
P6	0	0.0681	0.165
P7	0	0	0
P8	0.1398	0	0.055
P9	0.3304	0.0111	0
P10	0	0	0
P11	0	0	0
P12	0	0.0681	0.055

Table 8. Negative factor weighted matrix

w_jNF_{ij}	B/C	Time	Ease of project implementation
P1	0	0	0
P2	0	0	0
P3	0	0	0
P4	0	0	0
P5	0.2903	0	0.1650
P6	0.0317	0.0079	0
P7	0.2277	0	0.055
P8	0	0.0459	0.055
P9	0	0.0269	0.165
P10	0.1152	0	0
P11	0.1778	0	0
P12	0.2231	0	0

Table 9. NWP_i , NWN_i and Final index (RI) for 12 practical project

Projects	NWP_i	NWN_i	RI_i
P1	0.0251	1	0.513
P2	0.0073	1	0.504
P3	0.913	1	0.956
P4	1	1	1
P5	0.4581	0	0.229
P6	0.4581	0.913	0.686
P7	0	0.3791	0.190
P8	0.383	0.7784	0.581
P9	0.6712	0.5785	0.625
P10	0	0.7471	0.374
P11	0	0.6095	0.305
P12	0.2419	0.5099	0.376

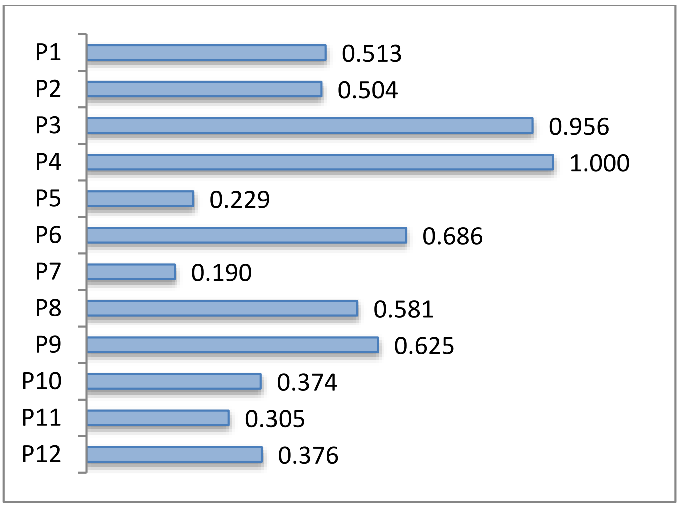

Figure 1. Ranking of budget allocation to 12 practical projects of intelligent transportation systems

As Figure 1 shows, the installation of combined video surveillance cameras on all corridor roads was selected as the first priority, and the budget should be allocated to this project. In the next priority, new speed control cameras were selected for purchase and implementation, and in the third priority, according to the criteria and other options, variable message signs and automatic accident detection systems were considered in accident hotspots and corridor tunnels.

5. Conclusion

In this study, the experiences of ITS in other countries and using and implementing projects on suburban roads were examined. According to the proposed methods and needs assessments, the possibility of using various projects of ITS in a main corridor of the country (Tehran-Bandar Imam Khomeini) was examined. To determine the practical priority of the projects, a new index was used, in which the average of solutions was considered as the main model. Concerning 12 projects and three main criteria, the duration of the project, ease of implementation, and profit to cost ratio were prioritized. Some of the results obtained are:

- According to Shannon’s entropy method, the most important criterion for allocating budget for practical projects of ITS in the corridor was profit to cost (0.45), ease of implementation (0.33), and project time (0.22), respectively.
- According to the presented model, the most important priority in the selected corridor roads was traffic management and road control, which resulted in the highest number of versatile video surveillance cameras.
- In addition to traffic management, vehicle speed was an important factor in the occurrence of accidents in this corridor, so the practical project of using new speed cameras with high capabilities was selected and was set as the second priority according to the three criteria compared to other practical projects.
- To manage traffic and choose the right route and timely notification of the project, variable message signs was used along the corridor, which was finally selected as the third priority.
- Another important problem of this corridor was the high number of accidents, which necessitated the use of traffic accident prevention systems. As a result, new automatic accident detection systems were nominated as one of the practical projects. The proposed index was selected as the fourth priority of budget allocation after the step-by-step stages.
- With this index, the purchase of equipment in the context of budget constraints and sanctions can be prioritized.

- By changing the executive projects according to the needs of other corridors, the proposed index can be used in other corridors as well.

According to the research, some suggestions for the development and definition of other researches can be presented as follows:

- Applying other meta-innovative methods and new multi-criteria decision models such as Kodas method in prioritizing ITS projects
- Development of the proposed method in other main corridors of the country, especially east-west corridors and transit routes
- Feasibility study and prioritization to use other projects of ITS in the corridors of the country
- Introducing more criteria for prioritizing ITS on roads

6. References

– Mousavi, M. S., & Jaberi-pour, J. (2010). Developing a Methodology for Choosing ITS Market Packages in Intercity Roads. In 17th ITS World CongressITS JapanITS AmericaERTICO.

– Guerrero-Ibáñez, J., Zeadally, S., & Contreras-Castillo, J. (2018). Sensor technologies for intelligent transportation systems. Sensors, 18(4), 1212.

– Shladover, S. E. (2018). Connected and automated vehicle systems: Introduction and overview. Journal of Intelligent Transportation Systems, 22(3), 190-200.

– An, S. H., Lee, B. H., & Shin, D. R. (2011, July). A survey of intelligent transportation systems. In 2011 Third International Conference on Computational Intelligence, Communication Systems and Networks (pp. 332-337). IEEE.

– Piarc-ITS Handbook- 2 nd Edition, (2004). PIARC,ISBN 2-84060-174-5 published by Route 2 Market Ltd, Swanley, Kent BR8 8JR, UK.

– Tian, D., Li, W., Wu, G., & Barth, M. J. (2017). Examining the Safety, Mobility and Environmental Sustainability Co-Benefits and Tradeoffs of Intelligent Transportation Systems.

– Zhang, X., Zhang, Q., Sun, T., Zou, Y., & Chen, H. (2018). Evaluation of urban public transport priority performance based on the improved TOPSIS method: A case study of Wuhan. Sustainable cities and society, 43, PP. 357-365.

– Figueiredo, L., Jesus, I., Machado, J. T., Ferreira, J., & de Carvalho, J. M. (2001). Towards the development of intelligent transportation systems. In Intelligent transportation systems (Vol. 88, pp. 1206-1211).

– Biswas, S., Tatchikou, R., & Dion, F. (2006). Vehicle-to-vehicle wireless communication protocols for enhancing highway traffic safety. IEEE communications magazine, 44(1), PP.74-82.

– Naboulsi, D., Fiore, M., Ribot, S., & Stanica, R. (2015). Large-scale mobile traffic analysis: a survey. IEEE Communications Surveys & Tutorials, 18(1), PP. 124-161.

– Montella, A., Pariota, L., Galante, F., Imbriani, L. L., & Mauriello, F. (2014). Prediction of drivers' speed behavior on rural motorways based on an instrumented vehicle study. Transportation Research Record, 2434(1), PP.52-62.

– Krmac, E., & Djordjević, B. (2017). An Evaluation of Indicators of Railway Intelligent Transportation Systems using the Group Analytic Hierarchy Process. Electronics Science Technology and Application, 4(2).

– Habibi, H. M., Mirzahossein, H., & Zargari, S. A. (2021). Hybrid approach of technical requirements prioritizing to meet the needs of road high-demand public transportation under uncertainty conditions: A case study of Arba'een trips. *Case Studies on Transport Policy*, *9*(2), 681-692.

– Novak, D. C., Koliba, C., Zia, A., & Tucker, M. (2015). Evaluating the outcomes associated with an innovative change in a state-level transportation project prioritization process: A case study of Vermont. Transport Policy, 42, PP.130-143.

– Shelton, J., & Medina, M. (2010). Integrated multiple-criteria decision-making method to prioritize transportation projects. Transportation research record, 2174(1), 51-57.

– Hamurcu, M., & Eren, T. (2020). Strategic planning based on sustainability for urban transportation: An application to decision-making. Sustainability, 12(9), 3589.

– Mirzahossein, Hamid; Gholampour, Iman, Sedghi, Maryam and Zhu, Lei (2021) "How realistic is static traffic assignment? Analyzing automatic number-plate recognition data and image processing of real-time traffic maps for investigation", Transportation Research Interdisciplinary Perspectives, Vol. 9, No.100320, 17 February 2021, PP.1-11

– Asadamraji, M., Saffarzadeh, M., Ross, V., Borujerdian, A., Ferdosi, T., & Sheikholeslami, S. (2019). A novel driver hazard perception sensitivity model based on drivers' characteristics: A simulator study. Traffic injury prevention, 20(5), 492-497.

– Asadamraji, M., Saffarzadeh, M., Borujerdian, A., & Ferdousi, T. (2018). Hazard detection prediction model for rural roads based on hazard and environment properties. Promet-Traffic&Transportation, 30(6), 683-692.

– Asadamraji, E., Rajabzadeh GHatari, A., & Shoar, M. (2021). A Maturity Model for Digital Transformation in Transportation Activities. International Journal of Transportation Engineering, 9(1), 415-438.

– Mirzahossein, H., Sedghi, M., Habibi, H. M., & Jalali, F. (2020). Site selection methodology for emergency centers in Silk Road based on compatibility with Asian Highway network using the AHP and ArcGIS (case study: IR Iran). *Innovative Infrastructure Solutions*, *5*(3), 1-14.

– Gholampour, I., Mirzahossein, H., & Chiu, Y. C. (2020). Traffic pattern detection using topic modeling for speed cameras based on big data abstraction. *Transportation Letters*, 1-8.