Evaluation of Criteria Used for Sustainable and Intelligent Transportation System Selection

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Abstract: - Sustainable and intelligent transportation systems aim to make contribution to economy and reduce environmental damages by providing a number of benefits namely road safety, efficient city management, energy efficiency, and reduced travel time and fuel consumption. This study presents an intuitionistic fuzzy cognitive map (IFCM) application to evaluate the importance degrees of selection criteria of sustainable and intelligent transportation systems. An intuitionistic decision based approach is proposed to evaluate criteria due to the cause-and-effect relationships among concepts; uncertainty, vagueness, and hesitation in data. A committee of three experts that work all as managers in logistics sector in Turkey provide the evaluation of causal relations among criteria. They express their opinions by reaching a consensus and the power of interrelationships and then concepts' values are identified employing the iterative formulation of IFCM.

Key-Words: - Sustainable and intelligent transportation systems, intuitionistic fuzzy cognitive map, cause-and-effect relationships, hesitation in data

1 Introduction

Nowadays transportation systems are vital piece of daily lives of human beings. It was evaluated that almost 40% of the population spends nearly one hour out every day. As individuals have turned out to be substantially more subject to transportation systems lately, transportation systems confront new opportunities and new difficulties.

The area of sustainable development is gathering big attention in the last 30 years, which can be caused by the changes in societal necessities and transforming living habits technological advance, combined with growing city population. Different monetary, natural, and social factors ought to be taken as a great importance to meet basic objectives of sustainability while seeking after financial, environmental, and social objectives [1].

Sustainable transportation is a challenging area of study with a number of problems to handle. With the aim of handling the issues mentioned above, multi criteria decision making (MCDM) models have been improved by a number of scholars. Selection relies on number of criteria, for instance time of journey, traffic safety, use of road capacity, mobility, energy efficiency, pollution, use of land and resources, etc.

Several studies that employed different MCDM methods, have been conducted in the recent past related to sustainable and intelligent transportation. Different sustainable transport system alternatives for Delhi are analyzed by Yedla and Shrestha [2]. Alternative fuel buses for Taipei (Taiwan) were evaluated by Hsiao et al. [3] who used fuzzy AHP and TOPSIS in that study. Tzeng et al. [4] used VIKOR and TOPSIS, based on the weights computed by AHP, to evaluate alternative-fuel buses for metropolitan cities of Taiwan. Vahdani et al. [5] demonstrated two decision making frameworks which applies fuzzy multiple criteria, and revealed their methods for the case of Iran along with data gathered from three decision makers. A novel fuzzy group MCDM method that is able to generate the best ranking in a defined decision problem is provided by Chang et al. [6]. Bonnini [7] studied the issue of establishing the satisfaction of public transport tools by the students of the University of Ferrara. In the study of Kaya and Kahraman [8], they are obtaining an environmental effect evaluation model for industrial planning of the city which is focused on the combining the Fuzzy AHP–ELECTRE methods. In another study, Kaya and Kahraman [9] focused on Istanbul and profounds an integrated VIKOR–AHP technique for selecting alternative forestation locations within the urban.

2 Intuitionistic Fuzzy Cognitive Maps

Intuitionistic fuzzy cognitive map (IFCM) technique enables to represent the power of causal links among concepts by using intuitionistic fuzzy numbers in cognitive mapping [10]. Causal links among concepts are determined through experts' opinions by utilizing linguistic variables that are associated with intuitionistic fuzzy numbers according to an intuitionistic fuzzy scale. Thus, membership, non-membership, and hesitation values are identified. Using experts' knowledge, N x N weight matrix is obtained, where N denotes the number of concepts. To calculate the values assigned to the concepts, an iterative formulation is employed until the concepts' values will no longer change, in other words, the system will be stabilized [11]. This formulation is as

$$A_i^{(k+1)} = f\left(A_i^{(k)} + \sum_{\substack{j \neq i \\ j=1}}^{N} A_j^{(k)} w_{ji}^{\mu} - A_j^{(k)} w_{ji}^{\pi})\right) \quad (1)$$

where $A_i^{(k)}$ is the value of concept C_i at k^{th} iteration, w_{ji} is the weight of the connection from C_j to C_i , w_{ji}^{μ} and w_{ji}^{π} denote the matrices that show membership values and hesitation values of causal links, respectively, and f is a threshold function, which is considered as sigmoid function for this work.

The stepwise application of the employed methodology is as

Step 1: Form a consensus consisting of project management experts.

Step 2: Determine evaluation criteria (concepts in cognitive mapping) $i = 1,2,..,j,..,n$.

Step 3: Identify causal links between pair of concepts by collecting experts' opinions.

Step 4: Determine membership values (μ) for causal links between pair of concepts.

Step 5: Determine non-membership values (ν) for causal links between pair of concepts.

Step 6: Determine hesitation values (π) for causal links between pair of concepts.

Step 7: Calculate concepts' values (A_i) employing the iterative formulation (1) of IFCM.

Repeat Step 7 until the values of concepts will converge.

3 Numerical Illustration

Sustainable and intelligent transportation systems can be defined as information and technology applications that support logistics services by increasing mobility and security, and decreasing environmental effects namely pollution and land and resource usage. In this work, selection criteria of sustainable and intelligent transportation systems are assessed employing IFCM tool, which is to reveal the cause-and-effect interrelationships among evaluation criteria when crisp data are not available and data contain hesitation.

Initially, selection criteria of sustainable and intelligent transportation systems are determined as a result of both interviews with experts and literature review as in Table 1.

Table 1. Evaluation criteria

Label	Concept
C_1	Time of journey
C_2	Traffic safety
C_3	Optimum use of available road capacity
C_4	Mobility
C_5	Energy efficiency
C_6	Pollution prevention
C_7	Use of land and resources

The evaluation of causal links among concepts is provided by a committee of three decision-makers that are all managers in logistics sector of Turkey. Decision makers express their opinions by making a consensus and they used the linguistic scale given in Table 2.

Table 2. Linguistic scale

Linguistic term	Intuitionistic fuzzy number
VH	<0.95,0.05>
H	<0.70,0.25>
M	<0.50,0.40>
L	<0.25,0.70>
VL	<0.05,0.95>

The evaluations are given in Tables 3, 4, 5, and 6. By using the data in Table 5 and 6, the weight matrix given in Table 7 is obtained. IFCM methodology is employed and the weights of sustainable and intelligent transportation system selection factors are obtained by running the formulation (1) till concepts' values will converge. These operations are completed by using FCMapper software. The criteria weights are shown in Table 8.

Table 3. Linguistic data for causal links

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	-	-	-	-	VL	M	M
C_2	-	-	-	VH	-	-	-
C_3	VH	H	-	VH	VL	VL	VH
C_4	H	-	-	-	-	-	VL
C_5	-	-	-	-	-	-	H
C_6	-	-	-	-	-	-	-
C_7	VH	L	L	M	-	-	-

Table 4. Membership values for causal links

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0	0	0	0.05	0.5	0.5
C_2	0	0	0	0.95	0	0	0
C_3	0.95	0.7	0	0.95	0.05	0.05	0.95
C_4	0.7	0	0	0	0	0	0.05
C_5	0	0	0	0	0	0	0.7
C_6	0	0	0	0	0	0	0
C_7	0.95	0.25	0.25	0.5	0	0	0

Table 5. Non-membership values for causal links

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0	0	0	0.95	0.4	0.4
C_2	0	0	0	0.05	0	0	0
C_3	0.05	0.25	0	0.05	0.95	0.95	0.05
C_4	0.25	0	0	0	0	0	0.95
C_5	0	0	0	0	0	0	0.25
C_6	0	0	0	0	0	0	0
C_7	0.05	0.7	0.7	0.4	0	0	0

Table 6. Hesitation values for causal links

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0	0	0	0	0.1	0.1
C_2	0	0	0	0	0	0	0
C_3	0	0.05	0	0	0	0	0
C_4	0.05	0	0	0	0	0	0
C_5	0	0	0	0	0	0	0.05
C_6	0	0	0	0	0	0	0
C_7	0	0.05	0.05	0.1	0	0	0

Table 7. Weight matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0	0	0	0.05	0.4	0.4
C_2	0	0	0	0.95	0	0	0
C_3	0.95	0.65	0	0.95	0.05	0.05	0.95
C_4	0.65	0	0	0	0	0	0.05
C_5	0	0	0	0	0	0	0.65
C_6	0	0	0	0	0	0	0
C_7	0.95	0.2	0.2	0.4	0	0	0

4 Conclusions

Sustainable and intelligent transportation systems are supposed to provide several benefits named as faster travel time, better city management, road safety, reduced fuel consumption, energy efficiency, etc. Hence, these systems create a research area with multiple problems to handle at the same time. In order to cope with these issues, a multiple criteria decision approach may be proposed.

In this work, selection criteria of sustainable and intelligent transportation systems are evaluated employing IFCM tool, which takes into consideration the causal links between pair of concepts and hesitation in data. In order to obtain the importance weights of sustainable and intelligent transportation systems criteria, factors are initially listed through experts' opinions and literature survey. The resulting concepts' values are obtained by applying IFCM methodology, "time of journey" is the most important factor followed by "mobility" and "use of land and resources", however "energy efficiency" and "optimum use of available road capacity" are less important ones. Future research directions will focus on selecting the best performing sustainable and intelligent transportation system for Istanbul, Turkey.

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Table 8. Criteria weights

Label	Concept	Weight
C_1	Time of journey	0.957666
C_2	Traffic safety	0.811039
C_3	Optimum use of available road capacity	0.709746
C_4	Mobility	0.940120
C_5	Energy efficiency	0.682662
C_6	Pollution prevention	0.765714
C_7	Use of land and resources	0.922017