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PRIORITIZATION OF ROAD TRANSPORTATION RISKS: AN APPLICATION IN GİRESUN PROVINCE

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Abstract: The purpose of this study is to determine and rank the road transportation risk factors that are crucial for effective and economic supply chain management. Road transportation risk factors can be defined as equipment related risks, risk to be lost and disappearance, risks related to delivery and packaging, inadequacy of qualified personnel and technical equipment, risks caused from incompatibility to logistic information system/technology, security risk, compulsory reasons, risks originated from regulations and arrangements, risks related to waiting at customs gate and transport infrastructure based risks. Accordingly, fuzzy PIPRECIA as a multi-criteria ranking method was used to prioritize the risk factors. According to the results, while the transport infrastructure based risks criterion was found as the most important, the risk to be lost and disappearance factor was obtained as the least important one.

Keywords: *Road transportation, road transportation risk factors, PIPRECIA, Fuzzy sets.*

1. Introduction

Goods, money and documents that are subject to commerce are started to circulate in market after globalization happened in 21th century. Companies try to find new methods in order to be competitive and reduce risks in related markets with globalization and the rapid development of information technologies. Circulation of goods is possible with suitable risk management plan under controlled, in time and most economical manner.

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International transportation becomes crucial in parallel with the development of international commerce due to consumers' habits in recent years. It is a requirement of transporting related goods and raw materials from one point to another because of rising needs and globalized commerce. Economic growth leads to the increased demand for freight shipment especially. Observed advancements in the communication between transportation and information technologies contribute to the circulation of goods. In this context, local and global commerce can be possible via the assurance of transportation activities.

Each process of international trade contains various risks. Transportation risk can be considered as the most crucial and critical one due to including damages for goods that are subject to international trade. Risks related to transportation activities include not only driver based accidents in a transportation process, but also error based accidents in goods traffic. In other words, transportation risk can be defined as issues such as driver errors, missing and incorrect operations related to goods subject to trade in packaging and loading processes.

It is not possible to develop and generalize international trade without bringing transportation sector based risks that are drivers of commerce and goods circulation under control. Risk and risk management concepts are started to gain importance, while international trade makes progress from exchange periods to virtual worlds. Each step of international trade includes different risks too. Therefore, globalization increased risks in the international trade. Transportation risks in the logistic activities need to be evaluated thoroughly due to having direct impact on the goods subject to trade.

Risks happened in transportation activities can cause loss of property and material damage. Hence, transportation risk can be described as damage risk too. However, issues observed in transportation can cause loss of lives apart from material damage. Additionally, a time concept is handled as an essential risk element because incompatibility in arrangements related to good transport lead to material damage.

Risk management in transportation activities can be differentiated for each mode and include related people identification, determination of danger and related risk, taking a risk control process into account according to the dangers, reviewing process and taking additional precautions for the risk control process.

Road transportation is one of the mostly preferred transportation types due to low cost, delivery time and transport. General transportation and authorization rules are possible for each country. Additional rules can be applied according to the countries involved in a transportation process. That condition creates a risk element as obligation for obeying the rules related to road transportation regulations and arrangements. Accordingly, road transportation risk factors can be stated as equipment related risks, risk to be lost and disappearance, risks related to delivery and packaging, inadequacy of qualified personnel and technical equipment, risks caused from incompatibility to logistic information system/technology, security risk, compulsory reasons, risks related to waiting at customs gate and transport infrastructure based risks (Pezier, 2002; Cavinato, 2004; Tang, 2006; Manuj and Mentzer, 2008; Enyinda et al., 2010; Hoffman et al., 2013; Ho et al., 2015; Kara and Fırat, 2015; Koban and Keser, 2015; Korucuk and Erdal, 2018; Korucuk and Memiş, 2018).

In this way, aforementioned road transportation risk factors are important for all stakeholders and have a direct impact on a business competitive level via cost minimization. In this context, the purpose of this study is to rank the road transportation risk criteria. A case study is made in Girusen province, Turkey. PIPRECIA as a multi-criteria decision-making method is used for prioritization under fuzzy environment in order to better represent decision-makers' judgments.

Other parts of the study are presented as follows: Studies for transportation and related risk factors are explained in the second part. Fuzzy PIPRECIA is introduced in the third section. Case study applied in Giresun province and findings are presented in the fourth part. Conclusions and future suggestions are made in the last section.

2. Literature Review

Transportation and transportation risk factors related studies can be presented as below:

Lazar et al. (2001) made risk evaluation in hazardous waste transportation via geographical information systems. Chen et al. (2003) made overall evaluation related to transportation risks in radioactive substance and waste under normal and accident conditions. Erkut and Ingolfsson (2005) examined transportation risk models in dangerous goods carriage and proposed new ones after a revision process.

Xin et al. (2007) evaluated routing, inventory, planning, management-organization and external factors under logistic risks context. Ghazali (2009) examined the operational risks for highway projects in Malaysia. Risks are defined as wage scales, traffic congestion, road network change and excess load carriage.

Adams (2010) searched a transportation risk based model and proposed a human behaviour based model. Wang (2011) used AHP model for ranking logistical risk factors according to carriage, technology, process, management, decision-making and environment contexts.

Khan (2013) considered the risk factors in employee life cycle and presented various risk analysis methods. Zeng and Song (2015) made fuzzy based risk assessment in order to ensure road safety in project carriage. Govindan and Chaudhuri (2016) applied DEMATEL method for evaluating risk factors in third party logistical service providers. Prakas et al. (2017) proposed supply chain network design structure and model related to supply chain and logistical risks. Furthermore, they observed the efficiency of supply chain risk design in risk evaluation. İzer (2017) investigated new risk reduction technologies for cold chain logistics.

Korucuk and Erdal (2018) ranked logistical risk factors for firms in cold chain transportation and found the most ideal risk management tool. Noriega et al. (2018) examined risk factors related to livestock carriage in Mexico. Korucuk and Memiş (2018) measured the risk factors for the supply chain via AHP and found quality risk as the most essential one. Budzynski et al. (2019) examined tramway transportation risks and made propositions for increasing transportation quality and security.

According to the depth literature review, there is not enough study in order to determine the importance levels for road transportation risk factors and that shows the originality and novelty of this concept. In addition, authors anticipate the contribution of this study to literature from method and application area viewpoint.

3. Methodology

3.1. Fuzzy Pivot Pairwise RElative Criteria Importance Assessment- Fuzzy PIPRECIA Method

The Fuzzy PIPRECIA method was developed by Stević et al. (2018). It consists of 11 steps shown below.

Step 1. Forming the required benchmarking set of criteria and forming a team of decision-makers. Sorting the criteria according to marks from the first to the last, which means they need to be sorted unclassified. Therefore, in this step, their significance is irrelevant.

Step 2. In order to determine the relative importance of criteria, each decision-maker individually evaluates the pre-sorted criteria by starting from the second criterion, Equation (1).

$$\overline{s_j^r} = \begin{cases} >\bar{1} & if \quad C_j > C_{j-1} \\ =\bar{1} & if \quad C_j = C_{j-1} \\ <\bar{1} & if \quad C_j < C_{j-1} \end{cases} \tag{1}$$

$\overline{s_j^r}$ denotes the evaluation of the criteria by a decision-maker r. In order to obtain a matrix $\overline{s_j}$, it is necessary to perform the averaging of matrix $\overline{s_j^r}$ using a geometric mean. Decision-makers evaluate the criteria by applying the linguistic scales developed and defined in Stević et al. (2018).

Step 3. Determining the coefficient $\overline{k_j}$

$$\overline{k_j} = \begin{cases} =\bar{1} & if \quad j=1 \\ 2-\overline{s_j} & if \quad j>1 \end{cases} \tag{2}$$

Step 4. Determining the fuzzy weight $\overline{q_j}$

$$\overline{q_j} = \begin{cases} =\bar{1} & if \quad j=1 \\ \dfrac{\overline{q_{j-1}}}{\overline{k_j}} & if \quad j>1 \end{cases} \tag{3}$$

Step 5. Determining the relative weight of the criterion $\overline{w_j}$

$$\overline{w_j} = \frac{\overline{q_j}}{\sum_{j=1}^{n} \overline{q_j}} \tag{4}$$

In the following steps, it is necessary to apply the inverse methodology of the fuzzy PIPRECIA method.

Step 6. Evaluation of the applying scale defined above, but this time starting from a penultimate criterion.

$$\overline{s_j^r}' = \begin{cases} >\bar{1} & if \quad C_j > C_{j+1} \\ =\bar{1} & if \quad C_j = C_{j+1} \\ <\bar{1} & if \quad C_j < C_{j+1} \end{cases} \tag{5}$$

$\overline{s_j^r}'$ denotes the evaluation of the criteria by a decision-maker r.

It is again necessary to average the matrix $\overline{s_j^r}$ by applying a geometric mean.

Step 7. Determining the coefficient $\overline{k_j}'$

$$\overline{k_j}' = \begin{cases} =\bar{1} & if \quad j = n \\ 2 - \overline{s_j}' & if \quad j > n \end{cases} \tag{6}$$

n denotes a total number of criteria. Specifically, in this case, it means that the value of the last criterion is equal to fuzzy number one.

Step 8. Determining the fuzzy weight $\overline{q_j}'$

$$\overline{q_j}' = \begin{cases} =\bar{1} & if \quad j = n \\ \dfrac{\overline{q_{j+1}}'}{\overline{k_j}'} & if \quad j > n \end{cases} \tag{7}$$

Step 9. Determining the relative weight of the criterion $\overline{w_j}'$

$$\overline{w_j}' = \frac{\overline{q_j}'}{\sum_{j=1}^{n} \overline{q_j}'} \tag{8}$$

Step 10. In order to determine the final weights of the criteria, it is first necessary to perform the defuzzification of the fuzzy values $\overline{w_j}$ and $\overline{w_j}'$

$$\overline{w_j}'' = \frac{1}{2}(w_j + w_j') \,. \tag{9}$$

Step 11. Checking the results obtained by applying Spearman and Pearson correlation coefficients.

3.2. The Evaluation of Criteria Using the Fuzzy PIPRECIA Method

In this study, ten criteria are handled for evaluating road transportation risks by eight decision-makers. Criteria related to road transportation risks are presented in Table 1.

Table 1. Criteria related to road transportation risks

Criteria	Mark
Risk to be lost and disappearance	C1
Equipment related risks	C2
Risks related to delivery and packaging	C3
Inadequacy of qualified personnel and technical equipment	C4
Risks caused from incompatibility to logistic information system/technology	C5
Security risk	C6
Compulsory reasons	C7
Risks originated from regulations and arrangements	C8
Risks related to waiting at customs gate	C9
Transport infrastructure based risks	C10

The evaluation of the criteria has been performed using a linguistic scale that involves quantification into fuzzy triangular numbers. Figure 1 and Figure 2 shows the evaluation of the criteria for fuzzy PIPRECIA and inverse fuzzy PIPRECIA by decision-makers and the average values (AV) which are used for further calculation. It is important to note that, compared to the original method developed, the average value (AV) is used here to average decision-makers' preferences (Đalić et al., 2020; Vesković et al., 2020; Tomašević et al., 2020; Stanković et al., 2020), which in this specific case contributed to the more accurate input parameters of the model. Whether a geometric mean or an average value is applied depends directly on a particular case. Both methods of averaging are valid.

PIPR.	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10		
DM1				0.333	0.400	0.500	1.400	1.600	1.650	0.400	0.500	0.667	0.500	0.667	1.000	1.400	1.600	1.650	0.400	0.500	0.667	1.500	1.750	1.800	0.400	0.500	0.667	0.333	0.400	0.500
DM2				0.667	1.000	1.000	1.600	1.900	1.950	0.333	0.400	0.500	0.667	1.000	1.000	1.600	1.900	1.950	0.400	0.500	0.667	1.300	1.450	1.500	0.500	0.667	1.000	1.400	1.600	1.650
DM3				0.400	0.500	0.667	1.400	1.600	1.650	1.400	1.600	1.650	0.500	0.667	1.000	1.400	1.600	1.650	0.333	0.400	0.500	1.500	1.750	1.800	0.500	0.667	1.000	1.500	1.750	1.800
DM4				1.400	1.600	1.650	1.400	1.600	1.650	0.400	0.500	0.667	1.300	1.450	1.500	1.500	1.750	1.800	0.400	0.500	0.667	0.333	0.400	0.500	1.400	1.600	1.650	1.500	1.750	1.800
DM5				1.100	1.150	1.200	0.400	0.500	0.667	0.333	0.400	0.500	1.400	1.600	1.650	1.600	1.900	1.950	0.500	0.667	1.000	1.500	1.750	1.800	1.600	1.900	1.950	1.500	1.750	1.800
DM6				1.100	1.150	1.200	0.500	0.667	1.000	1.300	1.450	1.500	0.286	0.333	0.400	1.600	1.900	1.950	0.400	0.500	0.667	1.500	1.750	1.800	1.600	1.900	1.950	1.400	1.600	1.650
DM7				1.100	1.150	1.200	1.200	1.300	1.350	1.500	1.750	1.800	0.500	0.667	1.000	1.400	1.600	1.650	1.200	1.300	1.350	0.500	0.667	1.000	1.400	1.600	1.650	0.400	0.500	0.667
DM8				1.100	1.150	1.200	1.200	1.300	1.350	0.500	0.667	1.000	1.300	1.450	1.500	1.400	1.600	1.650	0.400	0.500	0.667	1.200	1.300	1.350	1.100	1.150	1.200	0.286	0.333	0.400
AV				0.900	1.013	1.077	1.138	1.308	1.408	0.771	0.908	1.035	0.807	0.979	1.131	1.488	1.731	1.781	0.504	0.608	0.773	1.167	1.352	1.444	1.063	1.248	1.383	1.040	1.210	1.283

Figure 1. Evaluation of criteria by eight DMs for the fuzzy PIPRECIA

PIPR-I	C10			C9			C8			C7			C6			C5			C4			C3			C2			C1		
DM1				1.300	1.450	1.500	1.200	1.300	1.350	0.250	0.286	0.333	1.200	1.300	1.350	0.286	0.333	0.400	1.100	1.150	1.200	1.200	1.300	1.350	0.286	0.333	0.400	1.300	1.450	1.500
DM2				0.286	0.333	0.400	1.100	1.150	1.200	0.333	0.400	0.500	1.200	1.300	1.350	0.222	0.250	0.286	1.000	1.000	1.050	1.300	1.450	1.500	0.222	0.250	0.286	1.000	1.000	1.050
DM3				0.250	0.286	0.333	1.100	1.150	1.200	0.250	0.286	0.333	1.300	1.450	1.500	0.286	0.333	0.400	1.100	1.150	1.200	0.286	0.333	0.400	0.286	0.333	0.400	1.200	1.300	1.350
DM4				0.250	0.286	0.333	0.286	0.333	0.400	1.300	1.450	1.500	1.200	1.300	1.350	0.250	0.286	0.333	0.333	0.400	0.500	1.200	1.300	1.350	0.286	0.333	0.400	0.286	0.333	0.400
DM5				0.250	0.286	0.333	0.222	0.250	0.286	0.250	0.286	0.333	1.100	1.150	1.200	0.222	0.250	0.286	0.286	0.333	0.400	1.300	1.450	1.500	1.200	1.300	1.350	0.500	0.667	1.000
DM6				0.286	0.333	0.400	0.222	0.250	0.286	0.250	0.286	0.333	1.200	1.300	1.350	0.222	0.250	0.286	1.400	1.600	1.650	0.333	0.400	0.500	1.100	1.150	1.200	0.500	0.667	1.000
DM7				1.200	1.300	1.350	0.286	0.333	0.400	1.100	1.150	1.200	0.400	0.500	0.667	0.286	0.333	0.400	1.100	1.150	1.200	0.250	0.286	0.333	0.400	0.500	0.667	0.500	0.667	1.000
DM8				1.400	1.600	1.650	0.500	0.667	1.000	0.400	0.500	0.667	1.200	1.300	1.350	0.286	0.333	0.400	0.333	0.400	0.500	1.100	1.150	1.200	0.400	0.500	0.667	0.500	0.667	1.000
AV				0.653	0.734	0.788	0.614	0.679	0.765	0.517	0.580	0.650	1.100	1.200	1.265	0.257	0.296	0.349	0.832	0.898	0.963	0.871	0.959	1.017	0.522	0.588	0.671	0.723	0.844	1.038

Figure 2. Evaluation of criteria by eight DMs for Inverse fuzzy PIPRECIA

Based on the evaluation of the criteria and their averaging, Equation (1), a matrix sj is formed as in Figure 3.

PIPRECIA	sj		
c1			
c2	0.900	1.013	1.077
c3	1.138	1.308	1.408
c4	0.771	0.908	1.035
c5	0.807	0.979	1.131
c6	1.488	1.731	1.781
c7	0.504	0.608	0.773
c8	1.167	1.352	1.444
c9	1.063	1.248	1.383
c10	1.040	1.210	1.283

Figure 3. Sj form

Applying Equation (2), those values are subtracted from number 2. Following the rules of operations with fuzzy numbers, the kj matrix is obtained as in Figure 4.

kj		
1.000	1.000	1.000
0.923	0.988	1.100
0.592	0.692	0.863
0.965	1.092	1.229
0.869	1.021	1.193
0.219	0.269	0.513
1.227	1.392	1.496
0.556	0.648	0.833
0.617	0.752	0.938
0.717	0.790	0.960

Figure 4. Kj form

Applying Equation (3), the value qj is obtained as in Figure 5.

qj		
1.000	1.000	1.000
0.909	1.013	1.084
1.054	1.464	1.831
0.858	1.341	1.899
0.719	1.314	2.185
1.402	4.888	9.990
0.937	3.513	8.141
1.125	5.421	14.636
1.200	7.209	23.735
1.250	9.130	33.118

Figure 5. Qj form

Applying Equation (4), the relative weights are acquired as in Figure 6.

wj		
0.010	0.028	0.096
0.009	0.028	0.104
0.011	0.040	0.175
0.009	0.037	0.182
0.007	0.036	0.209
0.014	0.135	0.956
0.010	0.097	0.779
0.012	0.149	1.400
0.012	0.199	2.271
0.013	0.252	3.169

Figure 6. Wj form

After that, it is necessary to defuzzify obtained values by using the expression $df_{crisp} = \frac{l+4m+u}{6}$ obtaining the number df_{crisp} 0.036, 0.037, 0.058, 0.056, 0.060, 0.251, 0.196, 0.335, 0.513, 0.698 respectively.

In order to determine the final weights of the criteria, it is necessary to apply Equations (5)–(9) or the methodology of the inverse fuzzy PIPRECIA method. Based on the evaluation by the decision-makers and the application of the average value, the matrix sj' is obtained as in Figure 7.

PIPRECIA-I	sj		
c1	0.723	0.844	1.038
c2	0.522	0.588	0.671
c3	0.871	0.959	1.017
c4	0.832	0.898	0.963
c5	0.257	0.296	0.349
c6	1.100	1.200	1.265
c7	0.517	0.580	0.650
c8	0.614	0.679	0.765
c9	0.653	0.734	0.788
c10			

Figure 7. Sj form

Applying Equation (6), the values of matrix kj' are obtained as in Figure 8. Applying Equation (7), the following values are obtained as in Figure 9.

kj		
0.963	1.156	1.277
1.329	1.413	1.478
0.983	1.041	1.129
1.038	1.102	1.168
1.651	1.704	1.743
0.735	0.800	0.900
1.350	1.420	1.483
1.235	1.321	1.386
1.213	1.266	1.347
1.000	1.000	1.000

Figure 8. Kj form

qj		
0.093	0.165	0.312
0.118	0.191	0.301
0.175	0.269	0.399
0.197	0.280	0.393
0.230	0.309	0.407
0.401	0.527	0.673
0.361	0.421	0.495
0.536	0.598	0.668
0.742	0.790	0.825
1.000	1.000	1.000

Figure 9. Qj form

After that, it is necessary to apply Equation (8) to obtain relative weights for the fuzzy Inverse PIPRECIA method as in Figure 10.

wj		
0.017	0.036	0.081
0.022	0.042	0.078
0.032	0.059	0.104
0.036	0.062	0.102
0.042	0.068	0.106
0.073	0.116	0.175
0.066	0.093	0.128
0.098	0.131	0.173
0.136	0.174	0.214
0.183	0.220	0.260

Figure 10. Wj form

After that, it is necessary to defuzzify obtained values by using the expression $df_{crisp} = \frac{l+4m+u}{6}$ obtaining the number df_{crisp}, 0.040, 0.045, 0.062, 0.064, 0.070, 0.118, 0.094, 0.133, 0.174, 0.220 respectively.

Applying Equation (9), the final weights of road transportation risk criteria and rank of them are obtained as in Figure 11.

	I	II	wj	
C1	0.036	0.040	0.038	**10**
C2	0.037	0.045	0.041	**9**
C3	0.058	0.062	0.060	**8**
C4	0.056	0.064	0.060	**7**
C5	0.060	0.070	0.065	**6**
C6	0.251	0.118	0.185	**4**
C7	0.196	0.094	0.145	**5**
C8	0.335	0.133	0.234	**3**
C9	0.513	0.174	0.343	**2**
C10	0.698	0.220	0.459	**1**

Figure 11. Final weights

It has been shown in Figure 12 the complete previous calculation, and the last column shows the defuzzified values of the relative weights of the criteria in terms of fuzzy PIPRECIA method.

PIPRECIA	sj			kj			qj			wj			Defazi	Rank
c1				1.000	1.000	1.000	1.000	1.000	1.000	0.010	0.028	0.096	0.036	10
c2	0.900	1.013	1.077	0.923	0.988	1.100	0.909	1.013	1.084	0.009	0.028	0.104	0.037	9
c3	1.138	1.308	1.408	0.592	0.692	0.863	1.054	1.464	1.831	0.011	0.040	0.175	0.058	7
c4	0.771	0.908	1.035	0.965	1.092	1.229	0.858	1.341	1.899	0.009	0.037	0.182	0.056	8
c5	0.807	0.979	1.131	0.869	1.021	1.193	0.719	1.314	2.185	0.007	0.036	0.209	0.060	6
c6	1.488	1.731	1.781	0.219	0.269	0.513	1.402	4.888	9.990	0.014	0.135	0.956	0.251	4
c7	0.504	0.608	0.773	1.227	1.392	1.496	0.937	3.513	8.141	0.010	0.097	0.779	0.196	5
c8	1.167	1.352	1.444	0.556	0.648	0.833	1.125	5.421	14.636	0.012	0.149	1.400	0.335	3
c9	1.063	1.248	1.383	0.617	0.752	0.938	1.200	7.209	23.735	0.012	0.199	2.271	0.513	2
c10	1.040	1.210	1.283	0.717	0.790	0.960	1.250	9.130	33.118	0.013	0.252	3.169	0.698	1
							10.452	36.293	97.620				2.241	

Figure 12. Calculation and results obtained by the application of fuzzy PIPRECIA for road transportation risk criteria

Accordingly, calculation and results obtained by the application of inverse fuzzy PIPRECIA for road transportation risk criteria are presented in Figure 13.

PIPRECIA-I	sj			kj			qj			wj			Defazi
c1	0.723	0.844	1.038	0.963	1.156	1.277	0.093	0.165	0.312	0.017	0.036	0.081	0.040
c2	0.522	0.588	0.671	1.329	1.413	1.478	0.118	0.191	0.301	0.022	0.042	0.078	0.045
c3	0.871	0.959	1.017	0.983	1.041	1.129	0.175	0.269	0.399	0.032	0.059	0.104	0.062
c4	0.832	0.898	0.963	1.038	1.102	1.168	0.197	0.280	0.393	0.036	0.062	0.102	0.064
c5	0.257	0.296	0.349	1.651	1.704	1.743	0.230	0.309	0.407	0.042	0.068	0.106	0.070
c6	1.100	1.200	1.265	0.735	0.800	0.900	0.401	0.527	0.673	0.073	0.116	0.175	0.118
c7	0.517	0.580	0.650	1.350	1.420	1.483	0.361	0.421	0.495	0.066	0.093	0.128	0.094
c8	0.614	0.679	0.765	1.235	1.321	1.386	0.536	0.598	0.668	0.098	0.131	0.173	0.133
c9	0.653	0.734	0.788	1.213	1.266	1.347	0.742	0.790	0.825	0.136	0.174	0.214	0.174
c10				1.000	1.000	1.000	1.000	1.000	1.000	0.183	0.220	0.260	0.220
							3.853	4.551	5.472				1.021

Figure 13. Calculation and results obtained by the application of inverse fuzzy PIPRECIA for road transportation risk criteria

Figure 14 shows the final results of the procedure for determining the individual significance of each of the road transportation risk criteria. As explained above, based on the personal preferences of the eight experts, the significance of the observed criteria was obtained using the Fuzzy PIPRECIA method. Then, the defuzzification of the values was carried out to obtain the final weights of all the road transportation risk criteria, and, based on them, we can determine that the most significant criterion is C10 (transport infrastructure based risks) with a weight coefficient of 0.459, followed by the ninth criterion C9 (risks related to waiting at customs gate) with a weight of 0.343. As opposed to that, C1 (risk to be lost and disappearance) was found as the least important criterion with a weight of 0.038.

SCC for the ranks obtained with fuzzy PIPRECIA and Inverse fuzzy PIPRECIA is 0.988, which means that these ranks are nearly to complete correlation. Additionally, Pearson's correlation coefficient has been calculated for the weights of the criteria obtained using these approaches and is 0.956.

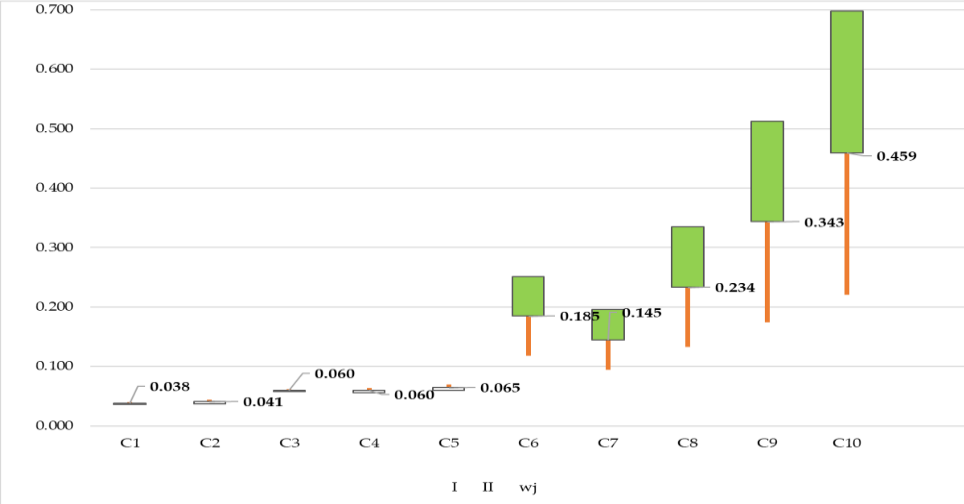

Figure 14. Final values of the road transportation risk criteria obtained using the fuzzy PIPRECIA method

4. Conclusion

The aim of the present study is to determine and rank the road transportation risk factors that are important for effective and economic supply chain management. According to the results of the study transport infrastructure based risks and risks related to waiting at customs gate were obtained as the most important ones. On the other hand, risk to be lost and disappearance and equipment related risks were found as the least important ones. In future studies, transportation risk factors can be enlarged and considered apart from road. Also, criteria can be examined in a large application area. Furthermore, various weighting methods apart from PIPRECIA can be considered in fuzzy, hesitant fuzzy, intuitionistic fuzzy, spherical fuzzy or neutrosophic environments.

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