Prioritization of Logistics Risks with Plithogenic PIPRECIA Method

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Abstract. Rapidly changing markets, actors, new legal regulations, information and data intensity have increased uncertainty, and as a result, businesses that want to continue operating in the market need to pay more attention to risk criteria. Risk can be explained as unplanned event which affects a business's overall performance. Logistics practices that develop and change continuously show a great variety such as weather and road accidents to faults in operations. Logistics risks have important roles in supply chains efficiency as the risks in logistics may adversely affect all parts of the supply chains and lead to decreases in business performances. Multi-criteria decision making methods are commonly used in risk prioritisation. In this study, a newly developed method called Plithogenic PIvot Pairwise RElative Criteria Importance Assessment (PIPRECIA) Method is used to prioritise logistics risks. For identifying weights, data were collected from three experts in the logistics field. Six logistics risks were considered and according to the results of Plithogenic PIPRECIA Transportation-related risk is determined as the most significant risk.

Keywords: Logistics risks · MCDM · PIPRECIA

1 Introduction

Logistics sector has always contained risk in its operations as there were several uncertainties even in the back such as weather, human factors, and safety issues. However, today's logistics sector is quite complicated with rapidly changing markets, actors, new legal regulations, information and data intensity. This complexity has increased uncertainty more than before, and as a result, businesses that want to continue operating in the market need to pay more attention to the risk.

Risk can be explained as unplanned event which affects a business's overall performance. Logistics practices that develop and change continuously show a great variety such as weather and road accidents to faults in operations. Supply chain and logistics are two terms used interchangeably in the literature as logistics risks has an important role

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in supply chains efficiency as the risks in logistics may adversely affect all parts of the supply chains and lead decreases in business performances. Sustaining stable logistic operations is a requirement for the success of a supply chain.

Risk assessment is a methodology for defining, classifying, and assessing threats. Private and state authorities commonly use risk assessments for decisions related to legislative issues and resource designation decisions. Risk assessment consists two stages; qualitative and quantitative stages. Qualitative stage involves a process of defining, characterizing, and rating risks. Quantitative stage on the other hand involves assessing the risk probability and effects of the risks [1].

As there are many logistics risks to consider, many of which have interconnections, assessment of logistics risks is difficult. Because of the complicated relationships between these risks, prioritizing the risks for mitigation is a difficult task. Multi criteria decision making (MCDM) methods are commonly used in the literature to overcome the uncertainty in prioritizing various conflicting risks therefore a newly developed method called Plithogenic PIvot Pairwise RElative Criteria Importance Assessment (PIPRECIA) method is used to prioritise logistics risks in this study.

This study consists of five sections. In the first section, introduction is presented. In the second section, the studies about the logistics risks have been reviewed. In the third section, methodology has been explained. In the fourth section, research methodology has been applied. In the lest section, conclusion of this study has been presented.

2 Literature Review

Logistics risks have been researched by several studies in the literature. To be thorough in our risk assessment, we conducted a comprehensive literature review to identify all risk factors discussed in previous studies (Table 1).

Various papers used MCDM methods to examine the risks involved in logistics sector. Tüysüz and Kahraman [16] assessed project risks using fuzzy AHP. Sattayaprasert et al. [17] developed a risk assessment model with AHP to evaluate the risks in dangerous goods transportation. Ren [18] assessed fire risks in logistics warehouses located in the cities with fuzzy AHP found that there are four factors that influence the fire risk: warehouse, product, management, and environment. Sari et al. [19] assessed the risks involved in the urban rail with fuzzy AHP. Zhao et al. [20] used the Expectation Maximization Algorithm to derive three key risk factors impacting dangerous goods freight: human factors, equipment and infrastructure, packing and handling. In green logistics, Oztaysi et al. [21] used hesitant fuzzy TOPSIS to assess the risks involved in transforming urban areas. Ilbahar et al. [22] developed a new integrated model consisting Pythagorean Fuzzy Proportional Risk Assessment (PFPRA), Pythagorean fuzzy AHP, to assess the risks related to occupational health and safety. Gul [23] proposed a risk assessment model with fuzzy FAHP for prioritizing evaluation criteria in oil transportation.

Table 1. Review of logistics risks in literature.

Authors	Problems	Risk factors
Tsai [2]	Maritime logistics	Information risk
Jia et al. [3]	Road transportation	Accidents Terrorist attacks
Ambituuni et al. [4]	Road transportation	Accidents
Afenyo et al. [5]	Maritime logistics	Accidents
Park et al. [6]	Global supply chains	Operational risks
Tubis [7]	Road transportation	Operational risks
Ghaleh et al. [8]	Road transportation	Accidents
Huang et al. [9]	3PL logistics	Quality risk
Liu et al. [10]	Maritime logistics	Hazardous good accidents
Ofluoglu et al. [11]	Disaster logistics	Demand Risk Transportation risk Supply risk Interruption Risk Damage Risk
Tumanov [12]	Multimodal transport	Accidents
Mohammadfam et al. [13]	Road transportation	Safety risks Health risks
Ovidi et al. [14]	Railways	Accidents
Zhao et al. [15]	Urban logistics	Accidents

3 Methodology

In this study, the Plithogenic PIPRECIA method is developed to evaluate the logistics risks and to determine the most important logistics risk.

3.1 Neutrosophic Set

$\tilde{k} = (k_1, k_2, k_3); \alpha, \theta, \beta$ is a single valued triangular neutrosophic set including truth membership $T_k(x)$, indeterminate membership $I_k(x)$ and falsity membership function $F_k(x)$ as follows [24]:

$$T_k(x) = \begin{cases} \alpha_k\left(\frac{x-k_1}{k_2-k_1}\right) & if\ k_1 \leq x \leq k_2 \\ \alpha_k & if\ x = k_2 \\ 0 & otherwise \end{cases} \tag{1}$$

$$I_k(x) = \begin{cases} \left(\frac{k_2-x+\theta_k(x-k_1)}{(k_2-k_1)}\right) & if\ k_1 \leq x \leq k_2 \\ \theta_k & if\ x = k_2 \\ \left(\frac{x-k_2+\theta_k(k_3-x)}{(k_3-k_2)}\right) & otherwise \end{cases} \tag{2}$$

$$F_k(x) = \begin{cases} \left(\frac{k_2 - x + \beta_k(x - k_1)}{(k_2 - k_1)}\right) & if\ k_1 \le x \le k_2 \\ \beta_k & if\ x = k_2 \\ \left(\frac{x - k_2 + \beta_k(k_3 - x)}{(k_3 - k_2)}\right) & if\ k_2 \le x \le k_3 \\ 1 & otherwise \end{cases} \tag{3}$$

3.2 Plithogenic PIPRECIA

The steps of the Plithogenic PIPRECIA method are explained below.

Step 1: Logistics risks are determined, and decision-makers rank the logistics risks from most important to least important.

Step 2: Commencing with the second criterion, the j th criterion and the $j-1$ th criteria are compared and, in this comparison, they will use plithogenic relative importance ($\tilde{t}_j$) values. These plithogenic values in Table 2 are used for this comparison.

Table 2. Linguistic scale (Adapted from Abdel-Basset et al. [24]).

Linguistic variable	Triangular Neutrosophic Scale (TNS)
Absolutely significant (AS)	((0.95, 0.90, 0.95), 0.90, 0.10, 0.10)
Very strongly significant (VSS)	((0.90, 0.85, 0.90), 0.70, 0.20, 0.20)
Strong significant (STS)	((0.70, 0.65, 0.80), 0.90, 0.20, 0.10)
Equal significant (ES)	((0.65, 0.60, 0.70), 0.80, 0.10, 0.10)
Fairly weakly significant (FWS)	((0.40, 0.35, 0.50), 0.60, 0.10, 0.20)
Weakly significant (WS)	((0.15, 0.25, 0.10), 0.60, 0.20, 0.30)
Very weakly significant (VWS)	((0.10, 0.30, 0.35), 0.10, 0.20, 0.15)

Step 3: A contradiction degree obtains better precision for plithogenic aggregation operations [25], so the contradiction degree is determined between each criterion and the dominant criterion value [26]. Therefore, the contradiction degree ($c : V \times V \rightarrow [0, 1]$) is defined.

Step 4: The judgments of all decision-makers are combined with the following equation.

$$\begin{aligned} &((k_{i1}, k_{i2}, k_{i3}), 1 \le i \le n) \wedge p((m_{i1}, m_{i2}, m_{i3}), 1 \le i \le n) \\ &= \left(k_{i1} \wedge_F m_{i1}, \frac{1}{2}(k_{i2} \wedge_F m_{i2}) + \frac{1}{2}(k_{i2} \vee_F m_{i2}), k_{i3} \vee_F m_{i3}\right), 1 \le i \le n \end{aligned} \tag{4}$$

where $\wedge_F$ and $\vee_F$ indicate the fuzzy t-norm and t-conorm, respectively.

Step 5: The neutrosophic numbers ($\tilde{t}_j$) are transformed into crisp numbers (t_j) as follows:

$$U(k) = \frac{1}{9}(a_1 + b_1 + c_1) \times (2 + \alpha - \theta - \beta) \tag{5}$$

Step 6: The final ranking of the criteria is obtained by combining the criteria rankings of the decision-makers with the geometric mean.

Step 7: k_j coefficient is computed as:

$$k_j = \begin{cases} 1 & j = 1 \\ 2 - t_j & j > 1 \end{cases} \tag{6}$$

Step 8: p_j recalculated weight is computed as:

$$p_j = \begin{cases} 1 & j = 1 \\ \frac{p_{j-1}}{k_j} & j > 1 \end{cases} \tag{7}$$

Step 9: The final weights (w_j) of criteria are obtained as follows:

$$w_j = \frac{p_j}{\sum_{k=1}^{n} p_k} \tag{8}$$

4 Application

In this study, logistics risks are evaluated and these risks are prioritized. Judgments of three experts were obtained for the evaluation regarding the risks. Six logistics risks were identified by the decision of three experts. These six risks are as follows: Transportation-related Risks (TRR), Purchasing-related Risks (PUR), Information-related Risks (INR), Inventory-related Risks (IVR), Packaging-related Risks (PAR), and Organization-related Risks (ORR). Experts have listed these risks according to their importance. The risks rankings of the experts are shown in Table 3.

Table 3. The risks rankings of the experts.

Experts	Risks		
	Exp-1	Exp-2	Exp-3
TRR	1	1	1
PUR	3	2	3
INR	2	4	5
IVR	4	3	2
PAR	6	5	4
ORR	5	6	6

Each expert assigned plithogenic values to each risk, starting with the second risk to compare the risks. The risks comparisons of Expert 1 are shown in Table 4.

Table 4. The risks comparisons of expert 1.

Risks	Rankings	Risks	Linguistic	TNS
TRR	1	TRR	-	-
PUR	3	INR	VWS	((0.10, 0.30, 0.35), 0.10, 0.20, 0.15)
INR	2	PUR	WS	((0.15, 0.25, 0.10), 0.60, 0.20, 0.30)
IVR	4	IVR	ES	((0.65, 0.60, 0.70), 0.80, 0.10, 0.10)
PAR	6	ORR	WS	((0.15, 0.25, 0.10), 0.60, 0.20, 0.30)
ORR	5	PAR	WS	((0.15, 0.25, 0.10), 0.60, 0.20, 0.30)

The contradiction degree of each risk is equally taken as 1/6. Then, the judgments of all decision-makers are combined by using Eq. 4. Aggregated plithogenic values of risks are transformed into crisp numbers by using Eq. 5. Aggregated plithogenic values ($\tilde{t}_j$) of risks and crisp numbers (t_j) are presented in Table 5.

Table 5. Aggregated Plithogenic values of risks and crisp numbers.

Risks	$\tilde{t}_j$	t_j
TRR	-	-
PUR	((0.070, 0.350, 0.629), 0.215, 0.175, 0.375)	0.357
INR	((0.227, 0.513, 0.811), 0.520, 0.125, 0.323)	0.194
IVR	((0.217, 0.413, 0.800), 0.413, 0.100, 0.333)	0.315
PAR	((0.079, 0.425, 0.755), 0.133, 0.200, 0.401)	0.390
ORR	((0.251, 0.550, 0.876), 0.618, 0.200, 0.323)	0.214

The rankings of the risks according to experts are combined with the geometric mean. Then, Eqs. 6–8 are used to determine the weights of logistics risks. The results of plithogenic PIPRECIA are shown in Table 6.

Table 6. The results of Plithogenic PIPRECIA.

Risks	Rankings by geometric mean	t_j	k_j	p_j	w_j
TRR	1	-	1	1	0.423
PUR	2	0.357	1.643	0.609	0.258
IVR	3	0.315	1.685	0.361	0.153
INR	4	0.194	1.806	0.200	0.085
PAR	5	0.390	1.610	0.124	0.052
ORR	6	0.214	1.786	0.069	0.029

According to Table 6, risks are listed from the most important to the least as follows: TRR, PUR, IVR, INR, PAR and ORR.

5 Conclusion

The today's logistics sector is very complex and has a high level of risk. Logistics risk assessment is a difficult task due to several logistic risks to consider and trade-offs. Multi criteria decision making (MCDM) approaches are widely used in the literature to address the difficulty in prioritizing different competing risks. In this analysis, a recently evolved approach called Plithogenic PIPRECIA is used to prioritize logistics risks. The logistics risks are assessed and prioritized in this study based on the opinions of three experts. Experts determined that there were six logistics risks, and these risks were prioritized by Plithogenic PIPRECIA. It has been found that the most important risk is Transportation-related Risks followed by Purchasing-related Risks, Inventory-related Risks, Information-related Risks, Packaging-related Risks, and Organization-related Risks. This method can be applied to different decision-making problems such as supplier selection, location selection in future studies. There are various studies about logistics risk in the literature however Plithogenic PIPRECIA is a new model and therefore there are only two studies in the literature. Therefore, this study contributes to the literature. Plithogenic PIPRECIA model can be used in other areas of decision problems such as location selection, performance evaluation, or machine selection problems in future studies.

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