Evaluation of Third-party Reverse Logistics Providers Using Fuzzy Axiomatic Design

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Abstract

There is a dramatic increase in the amount of product returns mainly due to rapid technological developments and more liberal return policies. This has increased the importance of the reverse logistics which involves the collection and either recovery or disposal of returned products. Many companies outsource their reverse logistics operations to third-party reverse logistics providers in order to ensure the cost-effective management of product returns. Hence successful implementation of third-party reverse logistics highly depends on the systematic evaluation of alternative third-party reverse logistics providers. In this study, a novel third-party reverse logistics provider evaluation methodology based on fuzzy axiomatic design is proposed. A numerical example is also provided in order to illustrate the applicability of the proposed approach.

Keywords
Third-Party Reverse Logistics Providers, Fuzzy Axiomatic Design, Multi-Criteria Decision Making

1. Introduction
Traditionally, companies have only dealt with the management of various logistics activities in order to ensure the cost-effective distribution of brand-new products to their customers and they have simply ignored the management of logistics activities related the products returned by their customers for any reason (e.g., end-of-life). This traditional approach is no longer valid since the governments of many countries have strict regulations on the treatment of returned products. Hence, effective solutions must be developed for the management of the operations related to reverse logistics which involves the collection and either recovery or disposal of returned products.

Many companies outsource their reverse logistics activities to third-party reverse logistics providers (3PRLPs) in order to avoid the management problems and costs associated with the personnel and the equipment dedicated to reverse logistics operations. Therefore, evaluation of 3PRLPs has a critical importance on the successful and cost-effective operation of many reverse logistics systems.

The research on the evaluation of 3PRLPs is very active due to the above-mentioned importance of 3PRLPs. Multi-criteria decision making (MCDM) techniques are generally used to develop 3PRLP evaluation approaches. Analytical Hierarchy Process (AHP) (Jain and Khan 2017), Analytical Network Process (Tavana et al. 2016), TOPSIS (Bai and Sarkis 2019), VIKOR (Prakash and Barua 2016; Bai and Sarkis 2019) and linear physical programming (Ilgin 2022) are among these techniques. Fuzzy versions of various MCDM techniques such as Fuzzy Analytical Hierarchy Process (FAHP) (Kannan 2009; Prakash and Barua 2016; Zarbakhshnia et al. 2020), Fuzzy TOPSIS (Senthil et al. 2014), Fuzzy SWARA (Zarbakhshnia et al. 2018) and Fuzzy COPRAS (Zarbakhshnia et al. 2018) are also employed in some 3PRLP evaluation approaches.

In this study, a 3PRLP evaluation approach is proposed by integrating FAHP and Fuzzy Axiomatic Design (FAD). First, 3PRLP evaluation criteria are determined. Then, criteria weights are calculated using FAHP. Finally, FAD is employed for the evaluation of 3PRLPs.

2. PRLP Evaluation Criteria

The following criteria are used in this study in order to evaluate alternative 3PRLPs:

- Quality (QLT): The service quality provided by a 3PRLP is an important criterion. Delivery performance, problem-solving ability and the provision of customized services are usually considered under this criterion (Kannan 2009; Tavana et al. 2016; Senthil et al. 2014; Zarbakhshnia et al. 2020).

- Cost (CST): The costs associated with transportation, warehousing, inventory and product acquisition are considered under this criterion (Kannan 2009; Tavana et al. 2016; Gupta and Ilgin 2018; Zarbakhshnia et al. 2020).

- Cooperation (COP): A 3PRLP should have the ability of working together with a client company. This will improve the coordination of reverse logistics activities (Gupta and Ilgin 2018).

- Flexibility (FLX): A 3PRLP should have the ability of meeting the changing needs of a client company regarding to the types and quantities of returned products as well as the location and size of orders (Kannan 2009; Tavana et al. 2016; Gupta and Ilgin 2018).

- Information Technology (ITC): Information technology infrastructure of a 3PRLP should support various online transactions such as online tracking of transportation information (Kannan 2009; Senthil et al. 2014; Tavana et al. 2016; Gupta and Ilgin 2018).

- Experience and Reputation (EXR): A 3PRLP should have a good record and reputation in the management of third-party reverse logistics operations (Senthil et al. 2014; Zarbakhshnia et al. 2020).

3. Determination of Criteria Weights

The importance weights of 3PRLP evaluation criteria are determined using FAHP (Chang 1996). Conversion scale of FAHP is provided in Table 1. The fuzzy pairwise comparison matrix presented in Table 2 is constructed and the weight values presented in Table 3 are obtained by applying the steps of FAHP.

Table 1. Conversion scale for FAHP (Ilgin 2017)

Linguistic scale	**Fuzzy triangular scale**	**Reciprocal fuzzy triangular scale**
Equally important	(1, 1, 1)	(1, 1, 1)
Moderately important	(2/3, 1, 3/2)	(2/3, 1, 3/2)
Strongly important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
Absolutely important	(7/2, 4, 9/2)	(2/9, 1/4, 2/7)

Table 2 Fuzzy pair-wise comparison matrix

	QLT	CST	COP	FLX	ITC	EXR
QLT	(1, 1, 1)	(2/3, 1, 3/2)	(5/2, 3, 7/2)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(2/3, 1, 3/2)
CST	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(1, 1, 1)	(2/3, 1, 3/2)	(1, 1, 1)
COP	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)
FLX	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(1, 1, 1)	(2/3, 1, 3/2)	(1, 1, 1)
ITC	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)
EXR	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(1, 1, 1)	(2/3, 1, 3/2)	(1, 1, 1)

Table 3 Criteria weights

QLT	CST	COP	FLX	ITC	EXR
0.27	0.19	0.02	0.19	0.14	0.19

4. Evaluation of Third-Party Reverse Logistics Providers Using Fuzzy Axiomatic Design

The alternative 3PRLPs are evaluated using FAD (Kulak and Kahraman 2005b). The conversion scales presented in Tables 4 and 5 are employed for intangible and tangible criteria, respectively. Table 6 presents the design ranges for 3PRLP evaluation criteria.

Table 4 Conversion scale for intangible criteria (Kulak and Kahraman 2005a)

Linguistic scale	**Fuzzy triangular scale**
Poor (P)	(0, 0, 6)
Fair (F)	(4, 7, 10)
Good (G)	(8, 11, 14)
Very Good (VG)	(12, 15, 18)
Excellent (E)	(16, 20, 20)

Table 5 Conversion scale for tangible criterion (i.e., cost) (Chakraborty et al. 2017)

Linguistic scale	**Fuzzy triangular scale**
Very Low (VL)	(60, 60, 90)
Low (L)	(80, 100, 120)
Medium (M)	(110, 130, 150)
High (H)	(140, 160, 180)
Very High (VH)	(170, 200, 200)

Table 6 Design ranges for 3PRLP evaluation criteria

Criterion	**Design range**
QLT	VG
CST	L
COP	G
FLX	G
ITC	G
EXR	G

System ranges for 3PRLPs are provided in Table 7. Information contents (I) presented in Table 8 are calculated using the following equation:

$$I = \log_2\left(\frac{system\ range}{common\ range}\right)$$

where common range is the intersection area between design and system ranges.

Table 7 System ranges for 3PRLPs

	QLT	CST	COP	FLX	ITC	EXR
3PRLP1	VG	M	F	F	G	G
3PRLP2	G	L	F	G	F	G
3PRLP3	G	M	G	F	G	G
3PRLP4	VG	M	F	G	F	F

Table 8 Information contents for 3PRLPs

	QLT	CST	COP	FLX	ITC	EXR
3PRLP1	0.00	4.00	3.17	3.17	0.00	0.00
3PRLP2	3.17	0.00	3.17	0.00	3.17	0.00
3PRLP3	3.17	4.00	0.00	3.17	0.00	0.00
3PRLP4	0.00	4.00	3.17	0.00	3.17	3.17

The weighted information contents (*WI*) of 3PRLPs are calculated as follows by using the criteria weights presented in Table 3 and the information content values presented in Table 8:

$$WI_{3PRLP1} = 0.27*0.00 + 0.19*4.00 + 0.02*3.17 + 0.19*3.17 + 0.14*0.00 + 0.19*0.00 = 1.43$$

$$WI_{3PRLP2} = 0.27*3.17 + 0.19*0.00 + 0.02*3.17 + 0.19*0.00 + 0.14*3.17 + 0.19*0.00 = 1.36$$

$$WI_{3PRLP3} = 0.27*3.17 + 0.19*4.00 + 0.02*0.00 + 0.19*3.17 + 0.14*0.00 + 0.19*0.00 = 2.22$$

$$WI_{3PRLP4} = 0.27*0.00 + 0.19*4.00 + 0.02*3.17 + 0.19*0.00 + 0.14*3.17 + 0.19*3.17 = 1.87$$

When the weighted information content values are evaluated, it can be seen that 3PRLP2 with the lowest weighted information content value is the most suitable 3PRLP.

5. Conclusions

Outsourcing of reverse logistics operations to 3PRLPs is a strategy followed by many companies in order to deal with the increased amount of product returns. The successful implementation of this strategy largely depends on the performance of the selected 3PRLP and performance evaluation of 3PRLPs requires linguistic assessments provided by decision makers. Hence, there is a need for the development of 3PRLP selection approaches that can handle the uncertainty associated with linguistic assessments. In this study, FAHP and FAD techniques are integrated in order to develop a 3PRLP evaluation approach that can deal with the linguistic assessments provided by decision makers. The applicability of the proposed approach is tested by applying it to a numerical example.

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Biography

Mehmet Ali Ilgin, is an associate professor of industrial engineering at Manisa Celal Bayar University. He holds a PhD in industrial engineering from Northeastern University and BS and MS in industrial engineering from Dokuz Eylul University. His research interests are in the areas of environmentally conscious manufacturing, maintenance planning, multi criteria decision making and simulation. He has published a number of research papers in international journals such as Computers and Industrial Engineering, International Journal of Production Research and International Journal of Advanced Manufacturing Technology. He co-authored two CRC Press books: “Remanufacturing Modeling and Analysis” and “Multiple Criteria Decision Making Applications in Environmentally Conscious Manufacturing and Product Recovery".