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A novel technique for evaluating and selecting logistics service providers based on the logistics resource view

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Abstract

The increasing importance of logistics outsourcing and availability of logistics services providers (LSPs) highlights the significance and complexity of the LSP evaluation and selection process. Most existing LSP evaluation and selection studies use historical performance data and assume independence among decision criteria. This paper proposes an integrated logistics outsourcing approach to evaluate and select LSPs based on their logistics resources and capabilities. This novel approach combines a fuzzy decision making trial, evaluation laboratory (FDEMATEL) and fuzzy techniques to order preferences by similarity to ideal solution (FTOPSIS) methods. The new multi-criteria decision making (MCDM) model addresses the impact relationships between decision criteria and ranks LSP alternatives against weighted resources and capabilities. The effectiveness of this approach is demonstrated through a real case study and a two-phase sensitivity analysis confirms its robustness.

Keywords: Logistics Outsourcing Modelling, Logistics Resources, LSP evaluation and selection, MCDM, FDEMATEL, FTOPSIS.

1. Introduction

The growing demand for logistics outsourcing and the increase in the number and type of logistics services providers (LSPs) highlight the increasing importance of the LSP evaluation and selection process. Firms use different approaches to analyse, evaluate and select their LSP partners. The complexity of the decision and the large number of criteria involved increase the attractiveness of the Multi Criteria Decision Making (MCDM) approaches. LSP performance is a vital dimension in the evaluation process and many firms use LSPs' past performance records to select appropriate LSPs (Straight, 1999; Lai et al., 2002; Liu and Lyons, 2011; Rezaei et al., 2014; Du et al., 2015; Moghaddam 2015). However, using past performance records alone is insufficient for performing a comprehensive evaluation. There is no guarantee that an LSP will replicate its past performance, particularly if the LSP will encounter unfamiliar work conditions. In many cases, the availability, accessibility and accuracy of performance measures should be investigated. Therefore, using LSPs' past performance as a single evaluation dimension is insufficient especially under high uncertainty decision-making environments. Many LSP evaluation and selection studies have failed to address the inherent uncertainty in data and the interdependencies among LSPs' evaluation and selection criteria – an area that has not been extensively studied. Moreover, the importance and complexity of the LSP evaluation and selection process increases in developing economies and emerging markets where the need for professional LSPs capable of supporting these economies in their development process is crucial. However, the lack of research about the developing logistics sectors increases the importance of this study. To overcome the aforementioned shortcomings, this study uses LSPs' logistics resources and capabilities to model the logistics outsourcing process and therefore, to evaluate and select the most appropriate LSP in developing economies. To the best of our knowledge, this is the first study to provide a fuzzy-based logistics outsourcing model that uses logistics resources and capabilities instead of performance metrics to evaluate and select LSPs under high uncertainty. This is the first study to analyse the logistics resources impact-relationship and therefore to identify independent resources among them. Again, to the best of our knowledge, this is the first study to analyse the logistics outsourcing decision based on the LSPs' resources and capabilities in the developing economies (Case of Jordan).

Firms' resources and capabilities and their effects on firm performance have been extensively studied using the Resource-Based View (RBV) theory. The RBV theory (Wernerfelt 1984 and Barney 1991) states that firm performance and competitive advantage are highly affected by firms' unique and valuable resources. Therefore, firms acquire various resources to generate the flexibility necessary to provide services that meet customer needs. A number of studies have identified the resources of various LSPs and their effects on firm performance (Hunt 2001; Lai et al., 2008; Hartmann and Grahl 2011; and Karia and Wong 2013).

This study uses logistics resources to develop an advanced hybrid LSP evaluation and selection model. This model uses the decision making trial and evaluation laboratory (DEMATEL) method to evaluate and construct interdependency relationships between logistics resources and capabilities, identify independent resources and determine their weight. It also uses the technique for ordering preferences by similarity to ideal solution (TOPSIS) method to evaluate, rank and select an appropriate LSP. However, data uncertainty problems make it difficult for experts and Decision Makers (DMs) to provide crisp values to present different criteria weights and to quantify the precise rankings of LSPs. Therefore, the concept of fuzzy sets is integrated with the DEMATEL and TOPSIS methods to handle the uncertainty of the data. Fuzzy sets help DMs express their preferences using triangular fuzzy numbers (TFNs) through applications of specific linguistic expressions.

The remainder of this paper is organised as follows. Section 2 summarises the importance of logistics outsourcing and discusses the RBV and its relationship with LSP performance. Section 3 provides a logistics resource and performance literature review. Section 4 explains the hybrid model and illustrates the implementation procedures. Section 5 provides the results (resources weights, impact relationships and LSP rankings) and conducts a sensitivity analysis. Section 6 concludes the study.

2. Background

Logistics outsourcing has attracted the attention of firms, academics and researchers. Logistics outsourcing has proven to be an effective way to achieve a competitive advantage, improve customer services and reduce logistics costs (Boyson et al., 1999; Jonsson 2008; Aguezzoul 2014). Logistics outsourcing can reduce fixed costs and increase flexibility, allowing for a greater focus on a firm's core activities, a reduction of heavy asset investments and an improvement of service quality (Hsu et al., 2012). At the same time, the decision to outsource includes a number of risks related to the loss of control, long-term commitment and the failures of some LSPs to perform their duties (Farahani et al., 2011; Wang et al., 2014; Soeanu et al., 2015). Table 1 summarises some of the expected advantages and disadvantages of logistics outsourcing:

Table 1: Expected Advantages and Disadvantages of Logistics Outsourcing

Expected Advantages (Benefits)	Expected Disadvantages (problems)
Allows focus on core competences	Loss of control
Increase management capabilities	Poor worker quality
Save costs and time	Poor service levels
Reduce heavy assets investment	Misleading feedbacks
Increase flexibility and agility	Coordination problems
Increase efficiency	Environmental responsibilities
Value-added services and service variety	
Increase global inventory visibility	
Share responsibilities and reduce risks	
Economies of scale	
Share knowledge and experience	

2.1 Resource-Based View (RBV) and LSPs' Performance

Resources and capabilities are among the strategic choices that firms use to achieve a competitive advantage. According to Mentzer et al. (2004), logistics resources can be divided into tangible and intangible resources. Lai et al. (2008) and Karia and Wong (2013) suggested using RBV theory to examine the impact of resources and capabilities on LSPs' performance. Based on the RBV theory, Karia and Wong (2013) developed a theoretical model of logistics resources and capabilities. They called it resource-based logistics (RBL). The RBL constructs logistics resources into tangible and intangible groups. The tangible resources group consists of technology and physical resources, while the intangible resources group consists of management expertise, relational and structure resources. According to RBL, these logistics resources and capabilities determine an LSP's performance. Therefore, logistics resources and capabilities are valid factors for evaluating and selecting the best LSP.

3. Literature Review

A number of studies have identified the strategic resources of LSPs and their effects on LSP performance from various perspectives. During the 1990s, a limited number of studies investigated LSPs' resources and capabilities and analysed the relationship between LSPs' resources and capabilities as well as their performance (Chiu 1995; Kahn and Mentzer 1998; and Larson and Kulchitsky 1999). Other studies, such as that of Novack and Wells (1992), investigated the strategic aspects of LSPs' resources and capabilities in terms of creating competitive advantage. Dramatic changes in the number and types of LSPs had occurred by the late 1990s, which in turn affected the number, nature and scope of logistics studies. The increasing demand for and number of LSPs augmented the number of studies of the logistics sector in general and of LSP evaluation and selection in particular.

Hunt (2001) analysed the effect of the availability of tangible and intangible resources on a firm's ability to produce efficiently and effectively, classifying resources into financial, physical, human, organisational, informational and relational resources. Lai et al. (2008) found that logistics resources and capabilities have a significant positive relationship to firm performance and affect LSPs' competitiveness. Hartmann and Grahl (2011) studied the flexibility of LSPs using RBV to measure the impact of this flexibility on customer loyalty. Karia and Wong (2013) used the RBV theory to develop the resource-based logistics (RBL) theory, which argues that logistics resources and capabilities are the determinants of LSP performance.

In addition to financial measures, a number of non-financial measures have been used to analyse the relationship between LSPs' resources and capabilities and a firm's performance. Ryoo and Kim (2015) analyse the impact of the knowledge complementarities on the supply chain performance. They use a two suppler and buyer samples to test the knowledge complementarities, inter-firm knowledge exchange and supply chain performance. Positive and significant relationships were found between knowledge exchange and supply chain performance. Ramanathan et al. (2014) analyse the impact of the RFID usability features in the UK LSPs adoption of this technology. A positive influence of the RFID usability over the adoption level has been found. Meanwhile, Vlachos (2014) evaluates the impact of RFID practices on supply chain performance. He found that the implementation of RFID practices significantly affect the supply chain performance in different areas such as supplier, inventory, distribution, sales and forecasting. Knemeyer and Murphy (2006) focused on LSPs' relationships as the main logistics resources that affect firm performance. Min et al. (2005) used a similar approach to investigate the collaboration between LSPs and users and the effects of the collaboration on performance indicators, such as effectiveness, efficiency and profitability. Other studies used the RBV theory to list and analyse logistics resources and capabilities and to investigate the effects of these resources and capabilities on firm performance. The RBV theory allowed researchers to see the entire picture by including large numbers of resources and capabilities (Lowson 2003 and Aldin et al., 2004). Shang and Marlow (2005) found that logistics performance is related to IT and information-sharing resources. Similar to Shang and Marlow (2005), Wu and Huang (2007) and Huang et al. (2006) used RBV to investigate the effects of logistics IT capabilities on firm performance. Wu et al. studied supply chain IT capabilities and Huang et al. studied an individual logistics firm. In addition to the financial indicators, Wu and Huang (2007) used market indicators, such as market share and competitor rankings, to analyse the effect of supply chain IT alignment and advancement on firm performance.

There is a strong relationship between LSPs' resources and capabilities and their performance. Despite this strong relationship, logistics resources and capabilities have not been used to evaluate and select LSPs. This finding provides a valid base for using logistics resources and capabilities to evaluate and select the most appropriate LSP. This study among the first studies that modelling the logistics outsourcing process to provide a hybrid model to evaluate and select the best LSP based on the tangible and intangible resources of the LSP. The fuzzy DEMATEL (FDEMATEL) and fuzzy TOPSIS (FTOPSIS) methods were combined into one novel hybrid model in this study. The following sections provide a systematic description of the main components of this hybrid model.

4. The Hybrid Model

This study uses Mentzer et al.'s (2004) general resource classification and the RBL theory to develop an LSP resource and capabilities model. According to the RBL, tangible and intangible logistics resources and capabilities consist of five main components representing the base of the hybrid model to evaluate and select LSPs.

4.1 Tangible Logistics Resources and Capabilities

Tangible resources include two main categories: physical and technological resources. Physical resources represent an LSP's ability to acquire, use and maintain logistics vehicles, machines, tools and facilities. Based on logistics activities, this study classifies physical logistics resources into four categories:

- Warehousing (storage area, handling equipment, cranes and winches, etc.)
- Transportation (trucks, trains, planes, ships, etc.)
- Production and packaging
- Improvements to and maintenance of these resources

Technological logistics resources represent an LSP's ability to acquire, use and maintain advanced logistics technologies for use with other physical resources to perform logistics activities effectively and efficiently. Technological resources help LSPs manage, control, monitor and improve logistics operations. Table 2 summarises tangible logistics resources with their measures and supportive references.

Table 2: Tangible Logistics Resources

	Resources	Measures	References
Physical Resources	Warehousing facilities	Warehousing area. Vehicle's age, numbers and capacity. Automation levels.	(Lai 2004); (Selviaridis et al., 2007); (Karia and Wong 2013); (Efendigil et al., 2008); (Rajesh et al., 2011); (Falsini et al., 2012)
	Transportation facilities	Types, size, purpose and ages of: trucks, train, planes and ships.	(Stefansson 2006); (Selviaridis et al., 2007); (Rajesh et al., 2011)
	Production and Packaging facilities	Assembly lines; Packaging equipment; Labelling equipment.	(Stefansson 2006); (Selviaridis et al., 2007); (Falsini et al., 2012)
	Improvements and maintenance of tangible logistics resources	Maintenance contracts; Periodic maintenance; Periodic training to use physical and technological resources; New technology adaptation.	(Selviaridis et al., 2007); (Karia and Wong 2013)

Technological Resources	Physical IT	Computers and platform networks. Databases equipment.	(Selviaridis et al., 2007); (Rajesh et al., 2011)
	Communication systems and tracking and tracing tools	RFID, GPS, GPD, GIS. Internal connectivity coverage. External connectivity coverage.	(Marasco 2008); (Karia and Wong 2013); (Rajesh et al., 2011); (Jaimes et al., 2011) (Ramanthan et al., 2014); (Vlachos, 2014)
	Internet-based technology and information systems	Web-based IS. Networking and real-time collaboration.	(Wu et al., 2006); (Selviaridis et al., 2007); (Marasco 2008); (Lai et al., 2008); (Karia and Wong 2013); (Ryoo and Kim, 2015).

4.2 Intangible Logistics Resources and Capabilities

RBL classifies intangible logistics resources into three categories (management expertise, relational and organisational). To provide a more holistic view, this study uses the intellectual capital concept to classify intangible logistics resources and capabilities. Intellectual capital is the amount by which the market value of an LSP exceeds its tangible (physical and financial) assets minus its liabilities (Mehri et al., 2013). Normally, intellectual capital is classified into three main categories: human, structural and relational capital. Table 3 conceptualises intangible logistics resources by providing a brief description and classifications, measures and supportive studies.

Table 3: Intangible Logistics Resources

Resources	Classifications	Description	Measures	References
Human resources and capabilities	**Skills, Education, Knowledge, Training.**	The accumulated employees' logistics education, knowledge, skills and management experiences.	Total investment in terms of salaries and wages of the staff. Number/type of certificates. Years of managerial experience.	(Karia and Wong 2013); (Mehri et al., 2013); (Ryoo and Kim, 2015).

Structural resources and capabilities	**Advanced software and databases.**	All software used in data processing (collecting, organising, storing, maintaining, mining and sending and distribution) effectively and accurately.	Automated storage and warehousing software (computerised). EDI.	(Wu et al., 2006); (Selviaridis et al., 2007) ; (Marasco 2008); (Rajesh et al., 2011); (Mehri et al., 2013)
	Image and Reputation	Opinion of the public about the firm's image, services reputation and satisfaction level (Rajesh et al., 2011).	Firm's local rank according to logistics associations.	(Boyson et al., 1999); (Jharkharia and Shankar 2007); (Rajesh et al., 2011)
	Cultural and managerial commitment	The shared values, principles and firm's philosophy about different topics such as trust, openness, participation and interaction, TQM and sustainability.	Practices and routines. Values, norms and principles. Participation and empowerment. Innovation, trust and openness.	(Lai et al., 2008); (Karia and Wong 2013)
Relational resources and capabilities	**Collaboration and cooperation (information sharing and long-term relationships)**	LSP's ability to build and sustain long-term healthy relationships with outsources and other logistics network members. LSP ability and willingness to share right information at the right time for the right partner. LSP ability and experience to cooperate with other supply chain members.	Long-term relationships. Information sharing. Flexibility in services. (size and direction of shipments, adding manpower)	(Jharkharia and Shankar 2007); (Karia and Wong 2013); (Kayikci and Stix, 2014); (Sprenger et al., 2014).

The tangible and intangible resource dimensions helps to create a more comprehensive and balanced logistics outsourcing process and allows DMs to choose between LSPs based on their tangible and intangible logistics resources. Instead of using one or two limited dimensions, this balance trade-off provides a more realistic picture by compensating for some low-score resources with high-score resources. Figure 1 summarises this trade-off.

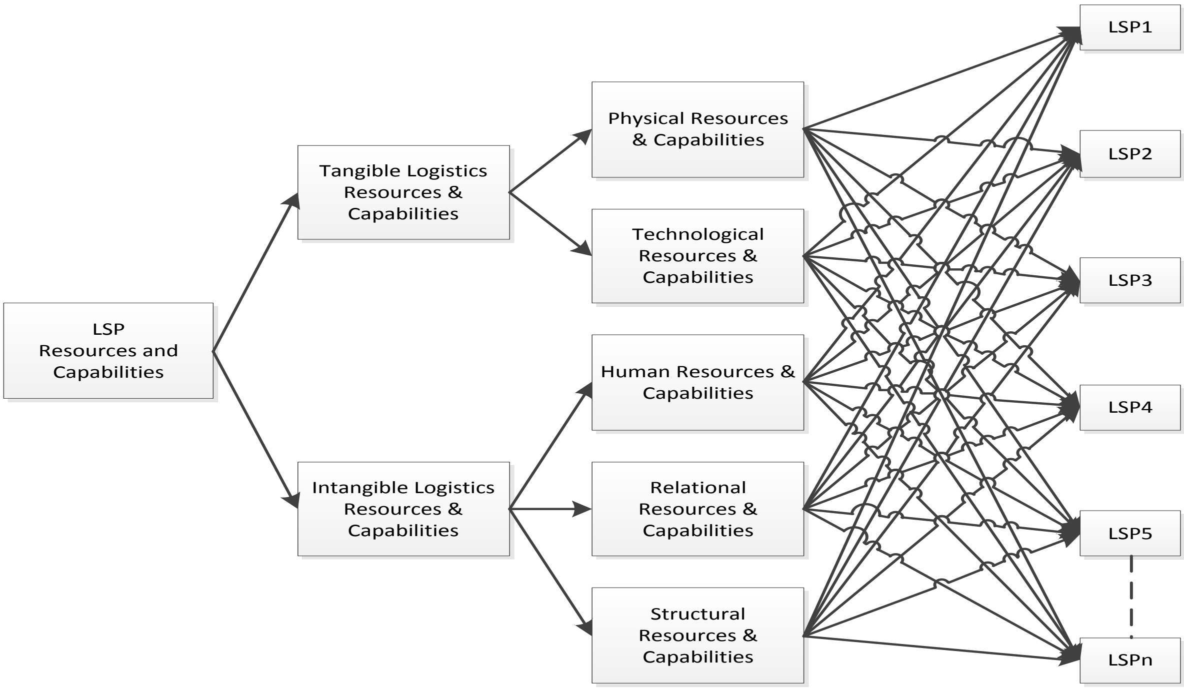

Figure 1: LSPs' Trade-off Model Based on their Resources and Capabilities

4.3 DEMATEL

DEMATEL can convert qualitative designs into quantitative analysis by analysing the component structure of each criterion and determining the direction and intensity of all direct and indirect relationships (Lee et al., 2011). DEMATEL helps determine which components are central to the complex system and which components affect one another and themselves. DEMATEL converts the relationships among factors into a comprehensible model to facilitate the decision making process. The visual impact-relations-map (IRM) provides a better understanding of the causal relationships between components. DEMATEL can be divided into the following steps (Yang and Tzeng, 2011):

1- Find the average matrix ***(A)***, the initial direct-relation matrix.
2- Calculate the normalised initial direct-relation matrix ***(X)***.
3- Compute the total-relationship matrix ***(T)*** by multiplying the normalised *(X)* by $(I\text{-}X)^{-1}$, where *I* is the *n x n* identity matrix.
4- Identify the Cause and Effect Groups.

5- Set a threshold value and obtain the IRM. Only factors with effects greater than the threshold value should be chosen and shown in the IRM (Tzeng et al., 2007; Wu 2008; Shieh et al. 2010).

6- Find criteria importance and weights.

Let R_i be the sum of the i^{th} row and let C_j denote the sum of the jth column in matrix $\boldsymbol{T}$. R_i shows the total effects, both direct and indirect, given by factor i to the other factors and C_j shows the total effects, both direct and indirect, received by factor j from the other factors. Therefore, $(R_i + C_j)$ gives us an index representing the total effects both given and received by factor i. $(R_i + C_j)$ shows the degree of importance that factor i plays in the system. Meanwhile, $(R_i - C_j)$ shows the net effect that factor i contributes to the system. When $(R_i - C_j)$ is positive, factor i is a *net causer* and belongs to the '*Cause Group*' and when $(R_i - C_j)$ is negative, factor i is a *net receiver* and belongs to the '*Effect Group*' (Pamučar and Ćirovic, 2015; Dalalah et al. 2011; Tzeng et al. 2007; Tamura et al., 2002). The importance of each criterion ω_i can be measured using the length of the vector from the origin to each criterion (Dalalah et al. 2011; Baykasoğlu 2013; Pamučar and Ćirovic, 2015) Equation1:

$$\omega_i = \left\{(R_i + C_j)^2 + (R_i - C_j)^2\right\}^{1/2} \qquad \textbf{(1)}$$

The final criterion weight W_i is the normalised importance (Equation 2):

$$W_i = w_i / \sum_{i=1}^{n} w_i \qquad \textbf{(2)}$$

When using DEMATEL, DMs must specify both the direction of the relative importance of the criteria and the degree of relativity. This is a challenge for DMs. Due to uncertainty, information leaks and ambiguity, experts cannot provide crisp values of the criteria importance ranking. In this case, integrating Fuzzy logic into DEMATEL can help address the uncertain side of the decision making process.

The modified fuzzy DEMATEL model is an extended crisp DEMATEL method that follows the same logic and steps, except that it uses linguistic terms with triangular fuzzy numbers (TFNs) instead of (0,1,2,3,4) crisp values (Hosseini and Tarohk, 2013; Felix and Devadoss 2013; and Lin 2013). Table 4 summarises these linguistic terms and their values.

Table 4: Linguistic Terms and their TFN Values

Linguistic Terms	TFN
Very high Influence (VH)	(0.75, 1.0, 1.0)

High Influence (H)	(0.5, 0.75, 1.0)
Low Influence (L)	(0.25, 0.5, 0.75)
Very Low Influence (VL)	0.0, 0.25, 0.5)
No Influence (NO)	(0.0, 0.0, 0.25)

This paper uses the modified fuzzy DEMATEL method that presented by Dalalah et al. (2011). Start with the fuzzy initial direct-relation matrix $\hat{A}$, where each $\hat{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is a TFN and $\hat{a}_{ij}$ (i-1,2,…,n) is regarded as a TFN (0,0,0) where necessary. By normalising matrix $\hat{A}$, the normalised fuzzy initial matrix X (direct-relation matrix) can be acquired by dividing each element in the matrix Â by the $\max_{l\le i\le n}\left(\sum_{j=1}^{n} u_{ij}\right)$. The fuzzy total-relation matrix $\check{T}$ is computed based on the following definition (Lin and Wu 2008, Hosseini and Tarohk 2013; Pamučar and Ćirovic, 2015): $\check{T}= X\times(I-X)^{-1}$, where (I) is the identity fuzzy matrix. The fuzzy sum of row $(R_i)^f$ and fuzzy sum of column $(C_i)^f$ as well as the fuzzy $(R_i+ C_j)^f$ and fuzzy $(R_i - C_j)^f$ of $\check{T}$ matrix can then be calculated. The final step is to calculate the defuzzified $(R_i+ C_j)^{def}$ and $(R_i - C_j)^{def}$. Defuzzification of any fuzzy number can be performed by finding the point that divides the fuzzy set area into two equal parts (Dalalah et al., 2011).

$$= \begin{cases} \boldsymbol{u} - \sqrt{\frac{(\boldsymbol{u}-\boldsymbol{l})(\boldsymbol{u}-\boldsymbol{m})}{2}}, & \boldsymbol{u}-\boldsymbol{m} > m - l \\ \sqrt{\frac{(\boldsymbol{u}-\boldsymbol{l})(\boldsymbol{u}-\boldsymbol{m})}{2}} + \boldsymbol{l} & \boldsymbol{u}-\boldsymbol{m} < m - l \\ \boldsymbol{m}, & \boldsymbol{otherwise} \end{cases} \qquad \textbf{(3)}$$

4.4 TOPSIS

The TOPSIS method introduced by Hwang and Yoon (1981) and improved by Yoon (1987) and Hwang et al. (1993) is the most frequently used ranking method in the decision making literature. The advantages of TOPSIS lie in its ability to identify the best alternative quickly and in its ability to integrate with a number of weighted methods, such as DEMATEL. A compensatory aggregation method allows managers and DMs to trade-off between the criteria of alternatives where the good scores of some criteria compensate for the bad scores of other criteria. This trade-off helps managers and DMs select the best alternative that should have the shortest geometric distance to the positive ideal solution (PIS) and the longest geometric distance from the negative ideal solution (NIS). The following steps summarise the TOPSIS method (Dalalah et al., 2011; Baykasoğlu 2013): (1) Create an evaluation matrix consisting of m alternatives and n criteria. (2) Normalise the evaluation matrix using the normalisation method. (3) Calculate the weighted normalised decision matrix (***T)*** by multiplying each criterion column by its weight. (4) Determine the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS). (5) Calculate the distance between the target alternative *(i)* and the NIS (*d*-) and the distance between the alternative *(i)* and the PIS (*d+)*. (6) Calculate the Closeness Coefficient (*CC*) by dividing (d^-) by the sum of (d^+) and (d^-). (7) Rank the alternatives according to their CC_i values. An alternative to the highest value is the best value (the longest distance from the NIS and shortest distance to the PIS).

To handle problems with data uncertainty and to give DMs the opportunity to smoothly evaluate alternatives, a number of studies (Chen, 2000; Chen et al., 2006; and Büyüközkan et al., 2008) used an extension of the TOPSIS method in a fuzzy situation with TFNs. The following linguistic rating variables have been defined to evaluate LSPs' alternatives with respect to each criterion: Very Good (VG) (0.75, 1, 1), Good (G) (0.5, 0.75, 1), Fair (F) (0.25, 0.5, 0.75), Poor (P) (0, 0.25, 0.75) and Very Poor (VP) (0, 0, 0.25).

The average of experts' evaluations will be used to construct the fuzzy decision matrix and the normalised fuzzy decision matrix. Then, the weighted normalised fuzzy decision matrix (*T*) can be constructed using criteria weight. After determining the fuzzy positive-ideal solution (FPIS) (A^*) and fuzzy negative-ideal solution (FNIS) (A^-), the distances (d_i^*, d_i^-) for each alternative from A^* *and* A^- can be calculated using the area compensation method. In this method, if a value is compared to two fuzzy numbers A and B, then the distance between these two fuzzy numbers, *d(A,B)*, is the maximum difference between A and B ($max\{|u_i - u_j|, |l_i - l_j|\}$). Finally, calculate the closeness coefficient (CC_i) for each alternative and rank the alternatives according to their CC_i. The alternative with the highest *CCi* is the best alternative (shortest distance to the best condition and longest distance to the worst condition)

4.5 Implementation Procedures

Evaluating and selecting the appropriate LSP is an issue for all logistics service users. The selection of an inappropriate LSP directly affects logistics service users' ability to perform their core activities, satisfy their customers and achieve their strategic objectives. This study helps firms evaluate and select their appropriate LSP through a novel integrated approach of fuzzy DEMATEL and TOPSIS methods. This is one of the first studies to use the FDEMATEL-FTOPSIS integrated approach to evaluate logistics resources impact-relationships and therefore evaluate and select appropriate LSPs. The procedures for developing this integrated model required various types of information in various stages. Three special questionnaires were developed and used: (i) An information sheet to collect LSPs' information, (ii) a FDEMATEL questionnaire to collect experts' evaluations of the LSPs' resources and capabilities impact relationships and (iii) a FTOPSIS questionnaire to collect experts' evaluations of the LSP alternatives against the weighted resources and capabilities. Figure 2 clarifies the hybrid model procedures.

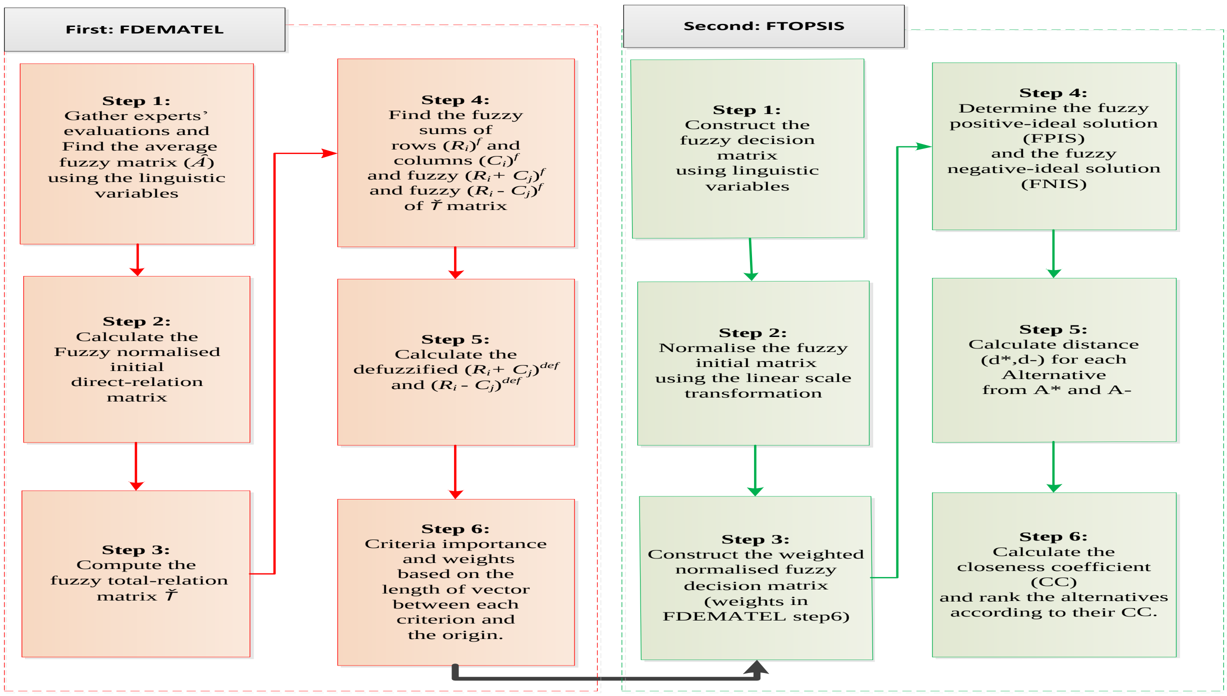

Figure 2: The Hybrid Model Procedures

5. Results

5.1 FDEMATEL

Several well-known logistics experts were approached for their opinions and a carefully constructed questionnaire was used to ascertain those opinions. Seven logistics experts with more than ten years of logistics experience were contacted. Four experts completed the entire questionnaire. The experts who provided full responses were: (i) a Vice President of Business Development/Logistics, Logistics Company/Freight management services with more than 30 years of experience in logistics and supply chain management; (ii) a Logistics Director, Logistics International Freight Services with more than 35 years of experience in logistics and supply chains and (iii) a Logistics and SC academic/researcher with more than 10 years of experience and more than 30 published works.

Beginning with the first level of the logistics resources and capabilities framework (Figure 1), the logistics experts were asked to evaluate the extent to which they believe that factor *i* influences factor *j* by using linguistic variables defined in Table 4. The average matrix at the first level was obtained. The same procedures were repeated for each portion of the framework.

A Physical Resources and Facilities factor was used to demonstrate the FDEMATEL procedures. Table 5 summarises the experts' evaluations regarding the degrees of influence among the Physical Resources and Facilities factors. Table 6 is the initial fuzzy average matrix (A^{fuz}) (direct-relations matrix).

Table 5: Experts' opinions of the physical resources and capabilities factors

Experts	W-T	W-P	W-Im	T-W	T-P	T-Im	P-W	P-T	P-Im	Im-W	Im-T	Im-P
Exp1	H	V.L	L	L	No	V.L	V.H	H	L	L	V.L	V.L
Exp2	No	V.L	V.L	No	No	H	V.L	No	L	V.L	V.L	L
Exp3	H	V.H	L	H	L	L	L	V.H	L	H	H	H
Exp4	H	L	H	H	V.L	V.L	L	L	V.L	V.L	V.L	V.L

W: warehousing, **T**: transportation, **P**: production & packaging and **Im**: improvement and maintenance.

Table 6: Physical Resources and Capabilities A^{fuz} Matrix

A^{fuz} matrix	Warehousing			Transportation			Production/Packaging			Improvement & maintenance		
Warehousing	0.000	0.000	0.000	0.375	0.563	0.813	0.250	0.500	0.688	0.250	0.500	0.750
Transportation	0.313	0.500	0.750	0.000	0.000	0.000	0.063	0.188	0.438	0.188	0.438	0.688
Production	0.313	0.563	0.750	0.375	0.563	0.750	0.000	0.000	0.000	0.188	0.438	0.688
Improvement	0.188	0.438	0.688	0.125	0.375	0.625	0.188	0.438	0.688	0.000	0.000	0.000

Each fuzzy number in Table 6 is the average of the experts' evaluations of the degree of influence between two factors. For example, on average, the Transportation Resources influence over Warehousing Resources equals$(0.313, 0.500, 0.750)$:

$$\frac{1}{4}(L + No + H + H) = \frac{1}{4}\big((0.25, 0.5, 0.75) + (0.0, 0.0, 0.25) + 2(0.5, 0.75, 1.0)\big)$$

The normalised fuzzy direct relation matrix (X^{fuz}) was obtained. Table 7 summarises the X^{fuz} matrix of Physical Resources and Facilities.

Table 7: Normalised X^{fuz} Matrix

X^{fuz} matrix	Warehousing			Transportation			Production/Packaging			Improvement & maintenance		
Warehousing	0.000	0.000	0.000	0.167	0.250	0.361	0.111	0.222	0.306	0.111	0.222	0.333
Transportation	0.139	0.222	0.333	0.000	0.000	0.000	0.028	0.083	0.194	0.083	0.194	0.306
Production	0.139	0.250	0.333	0.167	0.250	0.333	0.000	0.000	0.000	0.083	0.194	0.306
Improvement	0.083	0.194	0.306	0.056	0.167	0.278	0.083	0.194	0.306	0.000	0.000	0.000

Normalising the fuzzy direct relation matrix transforms the various criteria scales into a comparable scale. The fuzzy total-relation matrix is shown in Table 8. Table 9 summarises R_i^{fuz}, C_i^{fuz}, R_i^{def}, C_j^{def}, $(R_i+C_i)^{def}$, $(R_i-C_i)^{def}$ and the factor type.

Table 8: T^{fuz} matrix

T^{fuz} matrix	Warehousing			Transportation			Production/Packaging			Improvement & maintenance		
Warehousing	0.060	0.313	3.075	0.207	0.514	3.342	0.136	0.427	2.892	0.146	0.475	3.263
Transportation	0.162	0.417	2.928	0.042	0.236	2.680	0.056	0.271	2.484	0.109	0.386	2.859
Production	0.184	0.515	3.269	0.210	0.517	3.270	0.037	0.247	2.610	0.124	0.457	3.192
Improvement	0.113	0.425	3.057	0.093	0.407	3.043	0.101	0.371	2.677	0.029	0.246	2.767

Table 8 summarises the experts' overall influence ratings of Physical Resources and Capabilities. Each FTN is the total direct and indirect fuzzy influence of each criterion *i* over criterion *j*. For example, the total direct and indirect fuzzy influence of the Warehousing criterion over the Transportation criterion is (0.207, 0.514, 3.342). The sum of the Warehousing row (R_i^{fuz}) (0.549, 1.730, 12.573) is the total direct and indirect fuzzy influence that the Warehousing criterion has over the system. Meanwhile, the sum of the 'Warehousing' column (C_i^{fuz}) (0.518, 1.671, 12.330) is the total direct and indirect influence of the system over the 'Warehousing' criterion, as shown in Table 9.

Table 9: Physical Resources and Capabilities Importance, Relations and Types

Factors	R_i^{fuz}			C_i^{fuz}			R_i^{def}	C_i^{def}	$(R_i+C_i)^{def}$	$(R_i-C_i)^{def}$	Type
Warehousing	0.549	1.730	12.573	0.518	1.671	12.330	4.499	4.396	8.895	0.103	Cause
Transportation	0.370	1.311	10.951	0.553	1.674	12.335	3.809	4.410	8.219	-0.601	Effect
Production	0.555	1.736	12.341	0.329	1.315	10.663	4.436	3.713	8.149	0.722	Cause
Improvement	0.335	1.448	11.544	0.409	1.564	12.082	4.022	4.247	8.268	-0.225	Effect

Using Equation 3 to defuzzify (R_i^{fuz}) and (C_i^{fuz}) gives the values of R_i^{def} and C_i^{def}. These defuzzified values are used to give the values of $(R_i+C_i)^{def}$ and $(R_i-C_i)^{def}$, which in turn are used to acquire the IRM. Then, using Equation 3 to defuzzify the T^{fuz} matrix. Only factors with effects greater than the threshold value should be chosen and therefore shown in an IRM (visual diagram). The average value of the T^{def} matrix is defined as the Threshold in this hybrid model (Tzeng et al., 2007; Wu 2008; Shieh et al. 2010). The average value of the T^{def} is (1.048). Therefore, only shaded cells in Table 10 were represented in the IRM (Figure 3).

Table 10: T^{def} Matrix

T matrix	Warehousing	Transportation	Production	Improvement
Warehousing	1.035	1.237	1.049	1.179
Transportation	1.065	0.885	0.845	1.015
Production	1.208	1.218	0.866	1.144
Improvement	1.089	1.071	0.953	0.909

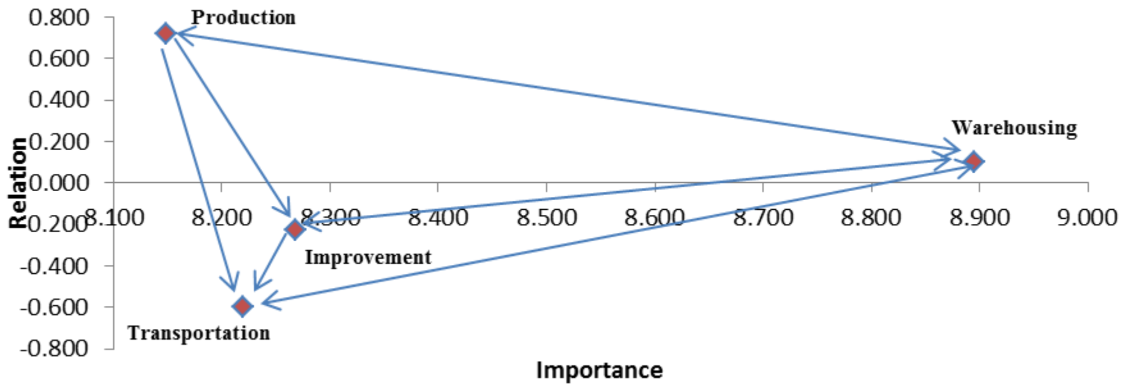

Figure 3: Physical logistics resources IRM

The same procedures were used to evaluate the cause-and-effect relationships, relative importance and relative weights for all of the criteria. Table 11 summarises the $(R_i+C_i)^{def}$, $(R_i\text{-}C_i)^{def}$, criterion type, relative importance and relative weight (global and local) for all of the criteria in the LSP resources and capabilities framework. The local and global weights of each criterion in this group can be obtained using Equations 1 and 2. The global weight of any criterion is the result of multiplying its local weight and the global weight of the cluster or group where it belongs. For example, the local weight of Physical logistics resources is (0.500). This cluster is under the 'Tangible resources' dimension. The global weight of Tangible resources is (0.500). Therefore, the global weight of Physical logistics resources is (0.500×0.500), which equals (0.250).

Table 11: FDEMATEL Outputs

Factor	$R_i+C_i^{def}$	$R_i\text{-}C_i^{def}$	Type	Relative Importance	Local Weight	Global Weight
(A) Tangible R&C	6.027	0.604	Cause	6.057	0.500	**0.500**
1- Physical R&C	5.841	-0.705	Effect	5.883	0.500	0.250
1-1 Warehousing	8.895	0.103	Cause	8.896	0.265	0.066
1-2 Transportation	8.219	-0.601	Effect	8.241	0.245	0.061
1-3 Production and packaging	8.149	0.722	Cause	8.181	0.244	0.061
1-4 Improvement and maintenance	8.268	-0.225	Effect	8.271	0.246	0.062
2- IT-based R&C	5.841	0.705	Cause	5.883	0.500	0.250
2-1 Physical IT	9.808	0.569	Cause	9.824	0.330	0.083
2-2 Communication Tracking & Tracing	9.759	-0.148	Effect	9.760	0.328	0.082

2-3 IS and internet based systems	10.155	-0.420	Effect	10.164	0.342	0.085
(B) Intangible R & C	6.027	-0.604	Effect	6.057	0.500	**0.500**
1- Human R&C	6.306	0.328	Cause	6.315	0.357	0.178
1-1 Education	5.438	0.375	Cause	5.451	0.362	0.065
1-2 Knowledge	4.716	-0.278	Effect	4.725	0.313	0.056
1-3 Skills	4.899	-0.097	Effect	4.900	0.325	0.058
2- Relational R&C	6.069	-0.323	Effect	6.078	0.344	0.172
2-1 Collaboration	15.117	-1.094	Effect	15.157	0.345	0.059
2-2 Long-term relationships	14.552	-1.039	Effect	14.589	0.332	0.057
2-3 Information sharing	14.079	2.133	Cause	14.239	0.324	0.056
3- Structural R&C	5.298	-0.005	Effect	5.298	0.299	0.150
3-1 Databases and Software	3.273	0.846	Cause	3.380	0.345	0.052
3-2 Image & Reputation	3.123	-0.466	Effect	3.157	0.322	0.048
3-3 Cultural & mgmt.	3.249	-0.380	Effect	3.271	0.333	0.050

5.2 Impact-relationships

This study is among the first to develop logistics resources IRM using FDEMATEL outputs. These maps help clarify how logistics resources and capabilities affect one another and themselves and identify resources that are central to the LSP evaluation and selection problem.

5.2.1 Tangible-intangible Logistics Resources Impact-relationship

Tangible and intangible logistics resources are equally important in the logistics-based decision making processes (50%), as shown in Table 11. Tangible logistics resources and capabilities are ‘cause factors' that affect intangible logistics resources and capabilities, which are classified as 'effect factors'. Tangible logistics resources and capabilities significantly affect intangible resources and capabilities. LSP can build a good reputation, attract qualified logistics employees, build and sustain healthy relationships with other LSPs and customers and create and sustain a strong firm culture by obtaining and maintaining appropriate tangible logistics resources and capabilities.

5.2.2 Tangible Logistics Resources Impact-relationship

Both Physical and IT-based logistics resources are important in logistics-based decisions (50% each). In terms of causal relationships, IT-based resources and capabilities significantly influence physical resources and capabilities. Good IT Facilities, Communication Systems and IS & Internet-based Facilities support other Warehousing & Inventory’, Transportation, Production and Improvement physical resources. An LSP that obtains advanced IT-based resources will have better warehousing and inventory management and be more capable of using its physical resources and transportation capacity and of providing an outstanding delivery performance. As shown in Table 11, IS and Internet-based systems and facilities are the most important elements of IT-based resources. Excellent LSPs have advanced websites that enable them to create real-time decision making, information sharing, order tracking and shipment processes. These technologies enable LSPs to provide better logistics services, which support both LSPs and logistics service users in their daily processes and help them achieve their strategic objectives.

5.2.3 Intangible Logistics Resources and Capabilities Impact-relationship

Human Resources are the most important intangible resources and capabilities (Table 11). Human resources have the strongest influence over other intangible resources, both relational and structural. Based on the IRM (Figure 4), we see that: (i) Human resources and capabilities are the most important intangible logistics resources and capabilities. (ii) Human resources have a direct impact relationship with structural resources and a mutual impact relationship with relational logistics resources. (iii) Qualified human resources help build and sustain healthy long-term relationships with customers, suppliers and other LSPs. (iv) Healthy long-term networks of relationships help LSPs attract, obtain and retain highly qualified human resources. (v) LSPs that obtain the right qualified human resources will be more capable of creating the right mix of structural resources (databases, software, departments, management and firm culture). In general, firms prefer to address LSPs that have similar cultural and managerial features. Therefore, the mix of structural resources affects LSPs' ability to build healthy long-term relationships with customers and other LSPs.

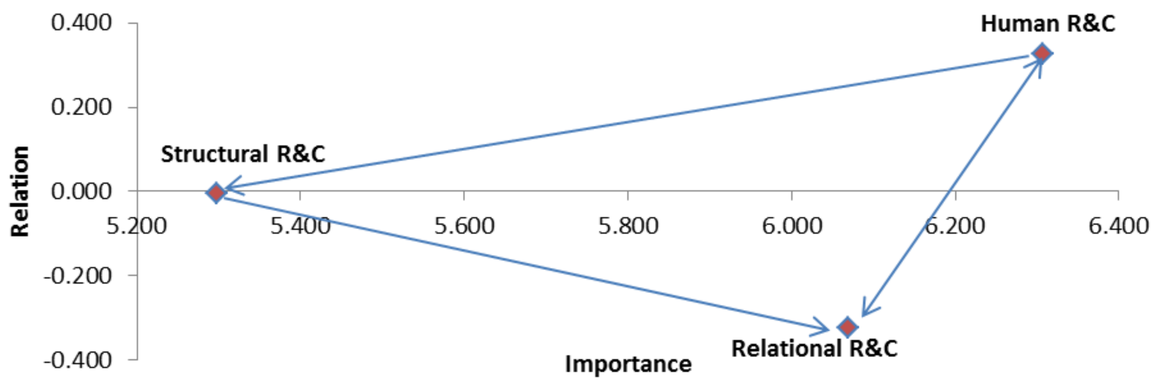

Figure 4: Intangible Logistics Resources and Capabilities IRM

In term of relational resources, there is a mutual impact-relationship between collaboration and long-term relationships. LSPs with good collaboration records will be more able to build and sustain health long-term relationships. Simultaneously, the "Long-term relationships' help LSPs to build new, good 'Collaboration' records. At the same time, good collaboration records will lead to more future collaborations, which explain the collaboration loop relationship (Figure 5). 'Information sharing' is the success key of the LSP's relations with customers, suppliers and other LSPs. LSP's ability and willingness to share information with customers, suppliers and other LSPs influence both the level of collaboration and the length of relationship.

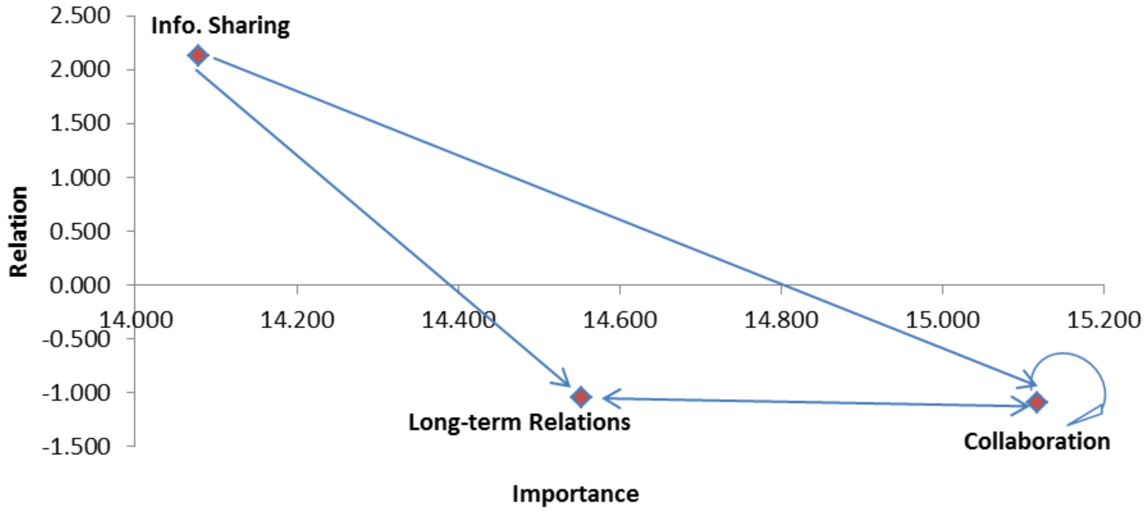

Figure 5: Relational Resources IRM

This study is among the first to integrate FDEMATEL and FTOPSIS methods to model the logistics outsourcing process and therefore to evaluate and select appropriate LSPs based on their logistics resources and capabilities under uncertainty. Logistics resource weights, relative weights and impact relationships were calculated and analysed using FDEMATEL. The next step entailed evaluating and ranking LSP alternatives based on their logistics resources and capabilities.

5.3 FTOPSIS

The FTOPSIS method was used to obtain experts' evaluations of LSP alternatives against the weighted resources and capabilities criteria. Sixteen weighted resources and capabilities criteria were used in the evaluation process. These criteria consisted of C1: Warehousing & Inventory Facilities; C2: Transportation Facilities; C3: Production & Packaging Facilities; C4: Facilities Improvement & Maintenance; C5: Physical IT; C6: Communication Tools; C7: IS & Internet-based Facilities; C8: Knowledge & Experience; C9: Education & Training; C10: Skills; C11: Collaboration; C12: Long-term Relationships; C13: Information Sharing; C14: Database & Software; C15: Image & Reputation and C16: Firm Culture.

Jordanian LSPs were chosen as a case study. Amman and Aqaba host most of Jordan's LSPs. Data on Jordanian LSP resources and capabilities were collected using a special information sheet and the LSPs' websites. Thirty-five information sheets were distributed in Amman and the logistics village in Aqaba. Eight information sheets were collected. Seven LSPs provided data regarding their resources and capabilities. The collected data were used to develop a special questionnaire to help logistics experts evaluate LSP alternatives. Three last-year logistics and transportation PhD candidates were asked to evaluate the seven LSPs. The linguistic variables defined in Table 4 were used in these evaluation processes. Table 12 shows the first expert's linguistic evaluation of LSP alternatives and Table 13 shows the average of the three experts' evaluations.

Table 12: First Expert's Linguistic Evaluations of the LSPs Alternatives

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
LSP 1	VP	VP	P	G	F	P	P	P	P	F	VG	P	F	VP	P	G
LSP 2	F	VP	G	G	G	P	G	F	VP	F	VG	G	P	F	F	F
LSP 3	F	G	P	G	G	VG	G	G	P	G	F	F	VP	G	P	G
LSP 4	VG	G	P	VG	G	VG	G	G	G	F	G	G	F	G	F	G
LSP 5	G	P	P	F	G	VG	VG	G	F	G	VG	VG	P	F	G	G
LSP 6	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	VG	G	G	G	VG	VG
LSP 7	F	G	P	VG	G	VG	F	VP	F	VP	VG	VP	VP	G	VG	VG

Where, **VG**: Very Good, **G**: Good, **F**: Fair, **P**: Poor, **VP**: Very Poor and **C1:C16** are the 16 criteria.

Table 13: Average Fuzzy Evaluation Matrix

	C1	**C2**		**C16**
LSP 1	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	⋯	(0.50, 0.750, 1.0)
LSP 2	(0.167, 0.417, 0.667)	(0.0, 0.167, 0.417)	⋱	(0.417, 0.667, 0.917)
	⋮	⋮	⋮	⋮
LSP 7	(0.333, 0.583, 0.833)	(0.417, 0.667, 0.917)		(0.667, 0.917, 1.0)

Table 14 shows the normalised fuzzy evaluation matrix. The maximum upper limit (max u_{ij}) equals 1.

Table 14: Normalised Fuzzy Evaluation Matrix

	C1	C2		C16
LSP 1	(0.0, 0.0, 0.25)	(0.0, 0.0, 0.25)	⋯	(0.50, 0.75, 1.0)
LSP 2	(0.167, 0.417, 0.667)	(0.0, 0.167, 0.417)	⋱	(0.417, 0.667, 0.917)
	⋮	⋮	⋮	⋮
LSP 7	(0.333, 0.583, 0.833)	(0.417, 0.667, 0.917)		(0.667, 0.917, 1.0)

Based on the weights found in the FDEMATEL stage, Table 15 shows the weighted fuzzy matrix.

Table 15: Weighted fuzzy matrix

Criteria	**C1**	**C2**		**C16**
Weight	**0.066209**	**0.061339**		**0.049930**
LSP 1	(0.0, 0.0, 0.017)	(0.0, 0.0, 0.015)	⋯	(0.025, 0.037, 0.050)
LSP 2	(0.011, 0.028, 0.044)	(0.0, 0.01, 0.026)	⋮ ⋱	(0.021, 0.033, 0.046)

	⋮	⋮		⋮
LSP 7	(0.022, 0.039, 0.055)	(0.026, 0.041,		(0.033, 0.046, 0.050)

The FPIS and FNIS for each resources criterion is calculated. Using Aspiration Level, every v_i^+ is (1, 1, 1) and every v_i^- is (0, 0, 0):

FPIS = {(1, 1, 1) …, (1, 1, 1)}

FNIS= {(0, 0, 0) …, (0, 0, 0)}

The distance of each LSP alternative to FPIS (d_i^*) and FNIS (d_i^-) is calculated. All of the values of d_i^* and d_i^- are non-fuzzy positive numbers. Table 16 summarises the d_i^*, d_i^- and closeness coefficient for each LSP alternative.

Table 16: Distance to FPIS and to FNIS with CCi of the LSP Alternatives

LSP	d_i^*	d_i^-	CC_i	**Rank**
1	**15.798**	0.627	0.03818	7
2	**15.614**	0.822	0.05001	6
3	**15.626**	0.825	0.05014	5
4	**15.545**	0.885	0.05386	2
5	**15.584**	0.877	0.05330	3
6	**15.357**	0.976	0.05977	1
7	**15.590**	0.839	0.05107	4

The CC_i value represents the position of each LSP alternative with respect to the FPIS and FNIS. This value is used to estimate the extent to which each LSP alternative belongs to the PIS and NIS. The LSP with the highest CC_i value has the shortest distance to the FPIS and the longest distance to the FNIS. Therefore, this LSP is the best LSP.

Based on the CC_i values in Table 16, **LSP 6** is the most appropriate alternative. The final ranking order of the LSP alternatives is: **LSP6 ≻LSP4 ≻LSP5 ≻LSP7 ≻LSP3 ≻LSP2 ≻LSP1.**

Figure 6 clarifies the rank of these LSPs based on their CC_i scores and shows the tough competition on the second position between LSPs 4 and 5 and on the fifth position between LSPs 2 and 3.

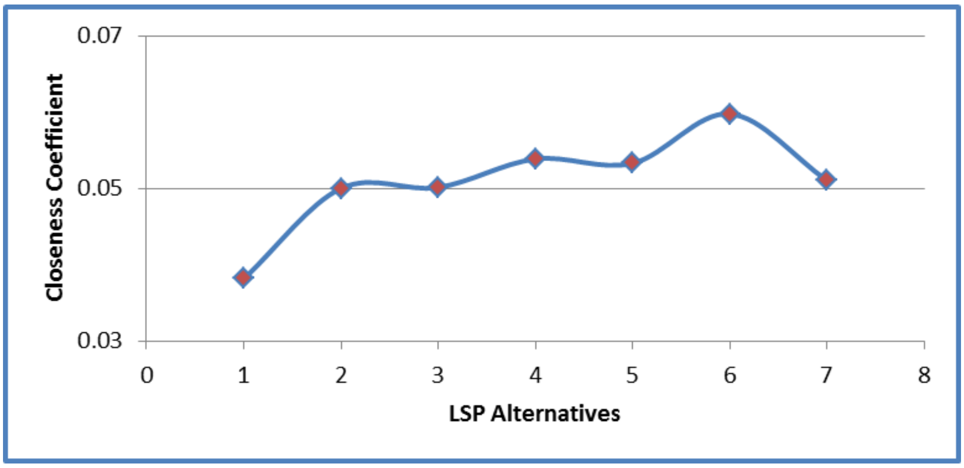

Figure 6: LSPs Ranking Order based on their CCi Scores

5.4 Independent Factors

DMs prefer to address a small number of critical factors rather than with a large number of mixed factors. FDEMATEL outcomes classified the logistics resources and capabilities into two groups: cause and effect groups (dependent and independent factors). This section determines the extent to which using the independent factors alone will produce the same results as using the 16 factors together. To make this determination, FTOPSIS outcomes are recalculated using independent factors only with their new normalised global weights (C1=0.130, C3=0.119, C5=0.250, C8=0.178, C13=0.172 and C14=0.150). Table 17 and Figure 7compare the *CCi* values of the seven LSP alternatives in both cases.

Table 17: A Comparison of the LSPs Ranks using Independent Factors and all Factors

LSP	Using Independent Factors		Using all Factors	
	CC_i	Rank	CC_i	Rank
LSP1	0.08698	7	0.03818	7
LSP2	0.13492	2	0.05001	6
LSP3	0.11904	5	0.05014	5
LSP4	0.12712	3	0.05386	2
LSP5	0.12594	4	0.0533	3
LSP6	0.14888	1	0.05977	1
LSP7	0.11886	6	0.05107	4

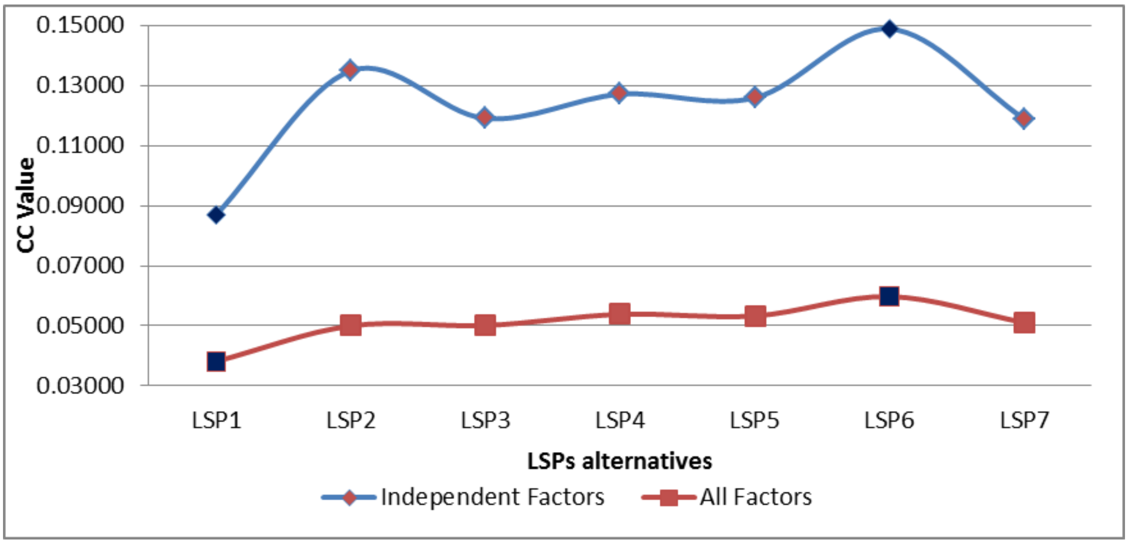

Figure 7: Comparing the LSPs Ranks using Independent Factors and all Factors

It is clear that independent factors provide nearly the same final LSP rankings. Therefore, DMs can simplify their decision making processes by using independent factors (cause factors) alone rather than using a large number of complex factors. However, DMs' preferences, evaluations, selection criteria and data quality affect the LSP evaluation and selection process. Additionally, working under high uncertainty conditions increases the complexity of these decisions and renders it difficult to analyse and select the most appropriate alternative. In this case, a sensitivity analysis technique was applied to test model robustness and detect the final decision certainty.

5.5 Sensitivity Analysis

The final selection of an alternative depends on both, the criteria weights and the MCDM method used. Changing the criteria weights may affect the decision making process and, in turn, LSP rankings. While because each MCDM method has its own features and mechanisms, different results may obtained using different MCDM methods. A two-phase sensitivity analysis is conducted to test the final solution stability to the criteria weights (independent factors) and selection method changes. In the first phase a series of tests are used to determine the extent to which changing the criteria weights affects the LSPs' CC_i values and therefore their final rankings. In the second phase, the stability of the final solution was tested by changing the ranking method. Therefore, the final LSP ranking orders have been recalculated using the fuzzy VIKOR method presented by Opricovic (2011).

There are at least two axioms that can be used to test the effect of criteria weight changing on the LSP evaluation and selection decision:

Axiom 1. A major increment/decrement in the criteria weight will certainly result in a major effect on the *CCi* values and the ranks of the LSPs alternatives with high performance levels in these criteria.

Axiom 2. A slight increment/decrement in the criteria weight should not result in a major effect on the relative *CCi* values and the LSPs final rankings.

To satisfy the first Axiom, an examination of the C3, C5, C13 and C14 independent criteria weight was carried out by setting each criterion weight to be 100%. Therefore, there were new LSP alternative order rankings as follow. If the weight of **C3** is sitting to be 100%, then the final ranking order will be: **LSP6 ≻LSP2 ≻LSP4 ≻LSP5 ≻LSP7 ≻LSP3 ≻LSP1.** If the weight of **C5** is sitting to be 100%, then, LSP alternatives 5, 6 and 7 will be in the first rank, LSP alternatives 2, 3 and 4 in the second rank and LSP1 is the final one. If the weight of **C13** is sitting to be 100%, then the final ranking order will be: **LSP6 ≻LSP4 ≻LSP2 *and* LSP5 ≻LSP3 *and* LSP7 ≻LSP1.** Meanwhile, if the weight of **C14** is sitting to be 100%, then, **LSP2** is the best one, then **LSP1** in the second rank, LSP alternatives 3, 4, 6 and 7 in the third rank and LSP5 in the last rank. Therefore, these results verify the model with respect to Axiom 1.

For the second Axiom, fifteen experiments were conducted in which each criterion weight was exchanged with another (Senthil et al. 2014). These experiments were conducted to find the LSPs' CC_i values for each experiment and therefore the LSPs' rankings. Table 18 summarises the sensitivity analysis results. LSP6 had the highest *CCi* value in very experiment. LSPs 6, 2 and 1 had the same rankings in all of the experiments: first, second and last, respectively. Meanwhile, LSPs 3, 4, 5 and 7 had some different rankings throughout the 16 experiments. These results verify the model with respect to the second Axiom.

Table 18: Sensitivity Analysis Results

Experiment	Criteria change	Ranks
Initial	No change	LSP6≻LSP2≻LSP4≻LSP5≻LSP3≻LSP7≻LSP1
1	C1-3	LSP6≻LSP2≻**LSP5**≻LSP4≻LSP3≻LSP7≻LSP1
2	C1-5	LSP6≻LSP2≻LSP4≻LSP5≻LSP3≻LSP7≻LSP1
3	C1-8	LSP6≻LSP2≻LSP4≻LSP5≻LSP7≻LSP3≻LSP1
4	C1-13	LSP6≻LSP2≻LSP4≻LSP5≻LSP7≻LSP3≻LSP1
5	C1-14	LSP6≻LSP2≻LSP4≻LSP5≻LSP7≻LSP3≻LSP1
6	C3-5	LSP6≻LSP2≻LSP4≻LSP5≻LSP3≻LSP7≻LSP1
7	C3-8	LSP6≻LSP2≻LSP4≻LSP5≻LSP7≻LSP3≻LSP1

8	C3-13	LSP6>LSP2>**LSP5**>LSP4>LSP7>LSP3>LSP1
9	C3-14	LSP6>LSP2>**LSP5**>LSP4>LSP7>LSP3>LSP1
10	C5-8	LSP6>LSP2>**LSP5**>LSP4>LSP3>LSP7>LSP1
11	C5-13	LSP6>LSP2>LSP4>LSP5>LSP3>LSP7>LSP1
12	C5-14	LSP6>LSP2>LSP4>LSP5>LSP3>LSP7>LSP1
13	C8-13	LSP6>LSP2>LSP4>LSP5>LSP7>LSP3>LSP1
14	C8-14	LSP6>LSP2>LSP4>LSP5>LSP7>LSP3>LSP1
15	C13-14	LSP6>LSP2>LSP4>LSP5>LSP3>LSP7>LSP1

For example: C1-3 means exchanging the weights of C1 with C3.

For the Second phase, this paper uses the modified fuzzy VIKOR method to test the solution stability to the ranking method change. The LSP final ranking position is based on the LSP comprehensive indicator (LSP fuzzy merit Q). LSP Q is based on the fuzzy weighted sum (S) and the fuzzy operator max (R). Table 19 summarises the LSPs ranking order under the S, R and Q outputs.

Table 19: LSPs Order Rankings - FVIKOR

		LSP1	**LSP2**	**LSP3**	**LSP4**	**LSP5**	**LSP6**	**LSP7**
S	*Sl*	16.031	15.822	15.806	15.741	15.747	15.639	15.796
	Sm	16.617	16.372	16.371	16.274	16.307	16.048	16.343
	Su	16.943	16.739	16.736	16.648	16.689	16.431	16.704
	Defuz.	16.552	16.326	16.321	16.234	16.262	16.042	16.296
	Rank	**7**	**6**	**5**	**2**	**3**	**1**	**4**
R	*Rl*	1.009	1.008	1.037	1.037	1.007	1.000	1.028
	Rm	1.047	1.057	1.018	1.018	1.035	1.031	1.028
	Ru	1.085	1.082	1.064	1.064	1.056	1.046	1.066
	Defuz.	1.047	1.051	1.034	1.034	1.033	1.027	1.038
	Rank	**6**	**7**	**4**	**3**	**2**	**1**	**4**
Q	*Ql*	-0.560	-0.74772	-0.59409	-0.650	-0.819	-0.952	-0.651
	Qm	0.573	0.42061	0.19112	0.108	0.233	-0.012	0.227
	Qu	1.000	0.80544	0.69814	0.623	0.610	0.332	0.684
	Defuz.	0.396	0.22473	0	0.047	0.064	-0.161	0.121
	Rank	**7**	**6**	**5**	**2**	**3**	**1**	**4**

It is clear that the LSP final order rankings are nearly the same in both phases. In the first phase, the final order ranking is the same as the independent resources ranking (Table 17), while the second phase order ranking is the same as the all resources ranking. Based on these results, we conclude that the methodology is robust and the decision making process is rarely sensitive to criteria weight and ranking method changes.

6. Conclusions, Limitations and Future Research

A novel technique for LSP evaluation and selection based on logistics resources and capabilities was introduced. This is the first time that the integrated FDEMATEL and FTOPSIS techniques were used to evaluate and select LSPs based on the logistics resources and capabilities of LSPs instead of their performance metrics. The FDEMATEL method was used to analyse the causal relationships of the LSPs' resources and capabilities. IRMs were used to clarify the strength and direction of each causal relationship in the complex logistics resources and capabilities framework. The FDEMATEL outputs help decision makers to understand how logistics resources affect each other and therefore how they affect the LSP's ability to achieve their strategic objectives effectively. Moreover, these results can help LSPs to bundle their resources in different mixes that fit with the LSUs needs and preferences. The total direct and indirect effect, relative importance and global and local weight of each resource and capability were analysed to clarify dependent and independent factors and to identify crucial logistics resources and capabilities for the LSP evaluation and selection process. Warehousing, Production & Packaging, Physical IT, Employee Education, Information Sharing and Databases & Software resources and capabilities were the cause factors of this system. The FTOPSIS method was used to evaluate LSP alternatives against weighted logistics resources and capabilities criteria. A real case study for ranking seven LSPs based on their resources and capabilities was conducted to verify the effectiveness of the proposed hybrid model. Fuzzy distances to the FPIS and from the FNIS were used to find the *CCi* value of each LSP alternative. Additionally, a comparison between LSP ranking using independent factors and all factors was made. This comparison identified crucial factors of the logistics outsourcing decision. All of the factors were used to evaluate and select the best LSP alternative and independent factors were used to conduct the evaluation process. Based on the outcomes of both cases, DMs can use independent factors alone to evaluate and select the best LSP, which simplified the logistics outsourcing process in our study. Finally, after the systematic application of this hybrid model and a real case demonstration, a two-phase sensitivity analysis was conducted to detect the final decision certainty and analyse the methodology robustness. In the first phase, criteria weights have been exchanged, while the VIKOR method has been used instead of the TOPSIS method in the second phase to test the final solution stability. The output of the both phases show that the methodology is robust and the decision making process is rarely sensitive to criteria weight changes.

The results of the study clarify that the proposed method is robust and reliable tool for the LSPs evaluation and selection decision. In addition to the logistics outsourcing decision under uncertainty, this method can be used for other outsourcing MCDM problems such as supplier and contractor selection. The experts' number, using one evaluation dimension (resources) and one case study are the main research limitations. Moreover, automation of calculations and giving different weights for experts are important areas to be considered. Therefore, for future research, it will be interesting to use a large number of experts, give experts different weights, provide a software and/or decision support tool, integrate the DEMATEL and ANP methods to evaluate and weight selection criteria, use different ranking methods to compare results with current proposed method and conduct comparative case studies.

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