Evaluating Green and Resilient Supplier Performance: AHP-Fuzzy Topsis Decision-Making Approach

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Keywords: Supplier Selection, Green Development, Supply Chain Resilience.

Abstract: This paper presents an approach for evaluating and ranking suppliers with respect to their traditional, green and resilience (TGR) characteristics. A set of criteria/sub-criteria were identified within a unified framework and their relative importance weighted using the analytical hierarchy process (AHP) algorithm. In addition, the suppliers were evaluated and ranked based on their performance towards the identified TGR criteria using the fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS) algorithm. The applicability and effectiveness of the proposed approach was proved through a real case study by revealing a comparatively meaningful ranking of suppliers. The study provides a noteworthy aid to management who understand the necessity of building supply chain resilience while concurrently pursuing 'go green' responsibilities.

1 INTRODUCTION

The supplier selection decision-making process represents a key activity in supply chain management since purchasing expenses exceed fifty percent of all firms' costs (Mohammed et al., 2017a). Supplier selection refers to a multi-criteria decision-making problem in evaluating suppliers' performance with respect to several criteria in order to purchase materials from the most appropriate source. Despite the importance of price, other evaluation criteria should be considered such as reliable delivery, which will ultimately effect productivity and efficiency within a production environment and therefore overall costs. Dickson (1966) highlighted 23 parameters that can be used by decision-makers to assess suppliers, Ha and Krishnan (2008) updated these and suggested several additional criteria. Nevertheless, the most prevalent traditional business criteria are quality, cost, and delivery. Popular green criteria include: environmental management systems, resource consumption, eco-design and waste management. Further supplier selection criteria can be found in Weber et al. (1991); Govindan et al. (2015); and Aissaoui et al. (2007).

Presently, there are ever increasing responsibilities placed on companies to consider the environmental impact of their supply chain activities (Mohammed et al., 2017b and 2015; Konur et al., 2016). Green supply chain management is the activity of purchasing, producing, marketing and performing various packaging and logistical activities that takes into account environmental implications (Mohamemd et al., 2017c). However, suppliers tend to represent inevitable sources of external risk (Rajesh and Ravi, 2015). Purchasing managers may consider traditional and more recently green criteria when assessing suppliers while neglecting resilience (Kannan et al., 2015). Resilience is the capability of the system to efficiently adapt an expected disruptions and back to its normal process, is a vital aspect of any supply chain management (Torabi et al., 2015). Following an earthquake in Japan (2011), Apple was unable to produce the iPad 2 due to lack of flash memory and super-thin battery (BBC News, 18 Mar 2011) caused by an unanticipated disruption to the supply chain. This particular event also interrupted the automotive sector and retail supply chains in the UK (Hall, 16 Apr 2010). Recently, hurricane Sandy led to massive disruptions in US supply chains (Torabi et al., 2015; Burnson, 30 Oct 2012). To protect their business, purchasing managers should include resilience in to their decision-making criteria (Torabi et al., 2015). Resilience criteria is represented by a supplier's capability to cope with risk and unexpected events more efficiently and quickly than other suppliers. The current work considers resilience criteria identified

Mohammed, A., Harris, I., Soroka, A., Mohamed, N. and Ramjaun, T.
Evaluating Green and Resilient Supplier Performance: AHP-Fuzzy Topsis Decision-Making Approach.
DOI: 10.5220/0006619902090216
In *Proceedings of the 7th International Conference on Operations Research and Enterprise Systems (ICORES 2018)*, pages 209-216
ISBN: 978-989-758-285-1

and analysed by Purvis et al. (2016). The latter proposed a framework for the development and implementation of a resilient supply chain strategy, which illustrates the relevance of various management paradigms. The authors considered four pillars (enablers) as key factors to improve supply chain resilience: redundancy, agility, leanness and flexibility (RALF). However, visibility was suggested as an essential resilience criterion by the purchasing manager for our case study.

Since additional criteria, such as environmental sustainability and resilience are paramount to building a successful and competitive supply chain, supplier selection complexity has increased. A novel approach is required, which incorporates three main criteria: traditional business, green and resilience. Despite the significant quantity of research already conducted around these topics, the vast majority of current literature considers the green and resilience aspects of supplier selection independently.

This paper addresses the knowledge gap by proposing a unified supplier selection approach that considers traditional, green and resilience criteria simultaneously. The evaluation criteria were identified from the literature and based on discussions with the purchasing manager from our case study. The development of this approach can be detailed into three phases. In phase one, the main traditional, green and resilience criteria and their sub-criteria were identified in a unified framework. Phase two, AHP was used to integrate judgments from a decision maker with the purpose of determining the weights of the criteria and sub-criteria. In the third phase, FTOPSIS was applied to evaluate and rank suppliers based on their TGR performance. The robustness of the proposed approach is validated within a case study for a manufacturing company and the work contributed to providing a framework for the supplier selection strategy, which incorporates traditional, green and resilience criteria.

2 LITERATURE REVIEW

Previous studies on supplier selection consider traditional criteria to be more extensive than the less established, green supplier selection (Govindan et al., 2015; Amindoust et al., 2012). Most Recently, Govindan et al. (2015) reviewed published research from 1997 to 2011 on MCDM and mathematical modelling used for green supplier selection problems. Shen et al. (2013) proposed a fuzzy approach for evaluating the green suppliers. Büyüközkan and Çifçi (2010) developed a fuzzy analytic network process (ANP)-based approach within a multi-person decision making scheme under incomplete preference relationships. Kuo and Lin (2011) proposed an integrated approach using ANP and DEA for green supplier evaluation. Akman (2015) suggested a two-step supplier-assessment framework to evaluate green suppliers. Kannan et al. (2015) investigated a green supplier selection problem in a plastic company using a fuzzy axiomatic design approach. Govindan and Sivakumar (2016) developed an integrated multi-criteria decision-making and multi-objective linear programming approach as an aid to select the best green supplier. Songa et al. (2017) proposed an integrated approach for evaluating suppliers with respect to economic, green and social criteria using the merit of pairwise comparison method in determining relative importance, the strength of decision making trial and evaluation laboratory (DEMATEL) in manipulating the complex and intertwined problems with fewer data, and the rough number's advantage in flexibly dealing with vague information.

Supply chain management includes a variety of complex activities subject to disruptions caused by unexpected incidents. Improving supply chain resilience is crucial for managing potential disruptions (Torabi et al., 2015). The reviewed literature showed that research studies using quantitative approaches to solve resilient supplier problem are limited. Mitra et al. (2009) and Sawik (2013) identified several pillars and criteria that should be considered for selecting resilient suppliers. Haldar et al. (2014) developed a fuzzy MCDM approach for supplier selection considering the importance degrees of specific attributes as linguistic variables formulated by triangular and trapezoidal fuzzy numbers. Torabi et al. (2015) proposed a fuzzy stochastic bi-objective optimization model to solve a supplier selection and order allocation problem to improve the supply chain resilience under operational and disruption risks. Sahu et al. (2016) proposed a supplier evaluation decision support system using the VIKOR method considering general and resiliency criteria. Pramanik et al. (2016) presented a fuzzy MCDM approach as an aid to developing a resilient supplier selection activity. Klibi and Martel (2012) formulated a mixed integer programming model for handling supplier selection and order allocation problem. Sawik (2013) designed a mixed-integer programming model to solve a supplier selection problem in a supply chain under disruption risks.

3 DEVELOPED GREEN AND RESILIENT SUPPLIER SELECTION APPROACH

A laboratory instrumentation Original Equipment Manufacturer wants to develop a resilient supplier selection approach for evaluating their current suppliers in order to plan for unexpected events. Additionally, the company is keen to take ownership of their environmental responsibilities. This research supports the company's requirements through development of a supplier selection approach to facilitate evaluation and ranking of suppliers based on their performance with respect to traditional, green and resilience criteria. Figure 1 shows the hierarchical supplier selection framework developed for this task. The traditional sub-criteria include: cost, quality, delivery reliability, performance history, turnover, lead time, and operating capacity. The green sub-criteria include: environmental management system, waste management and environment related certificate. The resilience sub-criteria include: flexibility, leanness, agility robustness and visibility (FLARV). AHP used linguistic expert assessment to determine the importance weight for each criteria and sub-criteria. FTOPSIS was then adapted towards evaluating suppliers based on their performance towards the criteria shown in Figure 1. Subsequently, the ranking order of suppliers was determined based on evaluation derived from FTOPSIS.

3.1 AHP

AHP is a multi-criteria decision making algorithm, developed for considering both qualitative and quantitative aspects of evaluation (Saaty, 1977). It attempts to reduce complex decisions to a series of pairwise comparisons and then reveals the final weights. In this work, AHP was applied for determining the importance weight for each TGR criteria and sub-criteria. Table 1 shows the evaluation scale in terms of linguistic variables that were used to perform pairwise comparisons among TGR criteria and sub-criteria. Decision makers need to give their opinion about the importance of every criteria and sub-criteria. AHP was implemented as follows:

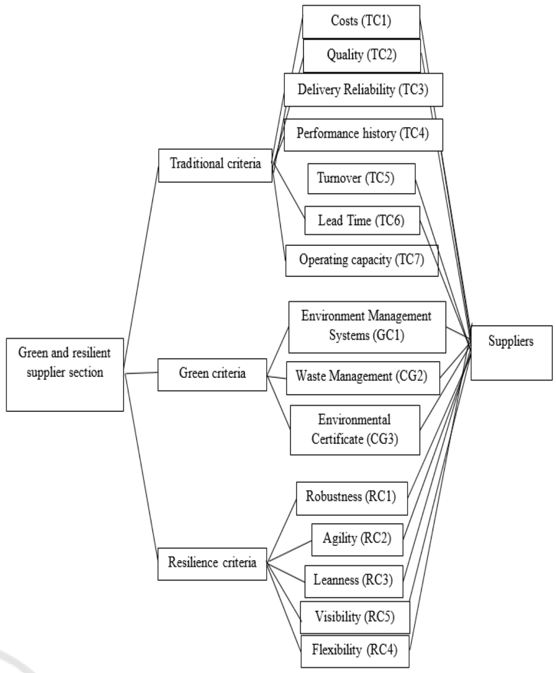

Figure 1: Criteria and sub-criteria for the traditional, green and resilient supplier selection.

1. Use a decision maker's preference to build a pair-wise comparison matrix (A) using the evaluation scale shown in Table 1:

$$A = \begin{bmatrix} 1 & a_{1,2} & a_{1,j} \\ a_{2,1} & 1 & a_{2,j} \\ \dots & \dots & \dots \\ a_{i,1} & a_{i,2} & 1 \end{bmatrix}; \; i = 1, 2, 3, \dots, I; \; j = 1, 2, 3, \dots, J \quad (1)$$

where I refers to the number of suppliers and J refers to the number of criteria.

2. Sum each column of A as follows:

$$Column\ S_i = \sum_{j \in J} a_{ij}, \quad (2)$$

3. Build the normalised decision matrix (R) by dividing each value in matrix A by the sum of its column:

$$R = \frac{A}{Column\ S_i} \quad (3)$$

4. Determine the weight w_j of each criterion by calculating the average of its weight with respect to other criteria:

Table 1: Evaluation scale in linguistic variables.

Scale	Linguistic Variable
1	Equally important (EI)
3	Weakly important (WI)
5	Strongly more important (SMI)
7	Very strongly important (VSI)
9	Extremely important (EI)

$$w_i = \frac{\sum_{i=1}^{I} rowS_i}{J} \tag{4}$$

3.2 Fuzzy TOPSIS

Hwang and Yoon (1981) developed TOPSIS to select an alternative based on its distance to the ideal solution and the negative ideal solution. FTOPSIS is an extension of TOPSIS developed by Chen (2006) to handle the uncertainty in the linguistic assessment. In this work, after determining the importance weight for each green and resilient criteria and sub-criteria, Fuzzy TOPSIS was applied to evaluate and rank suppliers with respect to their TGR performance. It is noteworthy to mention that fuzzy TOPSIS was used rather TOPSIS to cope with uncertain evaluation of some suppliers. Table 2 presents the linguistic variables and the correspondent triangular fuzzy numbers that were used to rank the alternatives considering each criterion. Decision makers need to give their opinions about the performance of every supplier based on TGR criteria. FTOPSIS was implemented as follows:

Eq. (6) is used to normalise the fuzzy decision matrix to get the normalised decision matrix ($\tilde{R}$):

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{nxm} \tag{5}$$

where

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{\sqrt{\sum_i m_{ij}^2}}, \frac{n_{ij}}{\sqrt{\sum_i m_{ij}^2}}, \frac{m_{ij}}{\sqrt{\sum_i m_{ij}^2}} \right) \tag{6}$$

The weights of the criteria (w_j) obtained from the AHP approach need to be multiplied by the elements of the normalised decision matrix ($\tilde{R}$) to form the weighted normalised decision matrix ($\tilde{V}$).

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{nxm} \tag{7}$$

where $\tilde{v}_{ij}$ is obtained using the following equation:

$$\tilde{v}_{ij} = \tilde{r}_{ij} \; x \; w_j \tag{8}$$

The fuzzy positive and negative ideal solutions are determined using Eqs. 9 and 10, respectively (Roy et al., 2004).

$$\tilde{A}^{+} = \left\{ \tilde{v}_1^{+}, \tilde{v}_2^{+}, \ldots, \tilde{v}_n^{+} \right\} \tag{9}$$

$$\tilde{A}^{-} = \left\{ \tilde{v}_1^{-}, \tilde{v}_2^{-}, \ldots, \tilde{v}_n^{-} \right\} \tag{10}$$

The distance of supplier 'I' from the fuzzy positive ideal solution (d_i^+) and the fuzzy negative ideal solution (d_i^-) are calculated as follows:

$$d_i^+ = \sum_{j \in n} d_v \left(\tilde{v}_{ij}, v_j^+ \right); \quad d_i^- = \sum_{j \in n} d_v \left(\tilde{v}_{ij}, v_j^- \right); \tag{11}$$

where v_j^+ and v_j^- are fuzzy positive and negative ideal points for criterion '*j*', respectively.

Based on d_i^+ and d_i^-, the fuzzy closeness coefficient (CC) for each supplier is then determined using Eq. 12. The supplier with the highest CC (varies between 0 and 1) is selected as the best green and resilient supplier.

$$CC = \frac{d_i^-}{d_i^+ + d_i^-} \tag{12}$$

Table 2: Linguistic variables and their TFN used for evaluating and ranking suppliers.

Linguistic variable	Triangular fuzzy number
Very low (VL)	(1, 1, 3)
Low (L)	(1, 3, 5)
Medium (M)	(3, 5, 7)
High (H)	(5, 7, 9)
Very high (VH)	(7, 9, 9)

4 APPLICATION: A REAL CASE STUDY

In To validate the applicability and effectiveness of the developed methodology, it was applied with a manufacturing company (Company A, henceforth) that design and produce thermal desorption and time-of-flight mass spectrometry instrumentation in the UK. Their products are used for a variety of applications such as: environmental monitoring, detection of chemical warfare agents, quality control & safety of food products, aroma profiling and environmental forensics. Company A aims to develop a purchasing strategy that helps in evaluating their current supplier with respect to green and resilience performance in addition to the traditional business criteria such as cost and quality. Company A aim to meet their growth target by 2020, however, current and projected turnover have not been revealed upon the company's request. Our novel approach to supplier selection has been applied in this case study to help the purchasing manager: (1) develop a unified TGR purchasing strategy and (2) evaluate their current supply chain resilience in term of suppliers' performance towards the previously defined TGR criteria (Figure 1).

The purchasing manager (PM) was invited to select a number of suppliers to validate the proposed approach in evaluating their performance towards the identified criteria illustrated in Figure 1. The PM has more than 18 years procurement experience. Two deep discussions (each about 2 hours) were held to explain, discuss and evaluate the TGR criteria, sub criteria and five suppliers' (S) performance.

In the first step, AHP was implemented to determine the importance weight for each TGR criteria and sub-criteria. Thus, the PM was invited to perform a pairwise comparison among TGR criteria and sub-criteria using the linguistic variables presented in Table 1. A pair-wise comparison matrix was built via the correspondence scale evaluation (refer to Table 1) as shown in Table 3. Eqs.1-4 were then applied to determine the importance weights of each criteria and sub-criteria which are presented in Table 4. According to the calculations shown in Table 4, the weight of traditional criteria is 0.263293; the weight of green criteria is 0.051821; and the weight of resilience criteria is 0.684886. The resilience criteria obtained the highest weight followed by the traditional and then green pillar. Thus, the resilience criteria are deemed to be the most important compared with the other traditional and green criteria. The PM confirmed that the company's current strategy was to build a resilient supply chain rather

Table 3: Decision matrix among TGR criteria.

TGR criteria	Traditional	Green	Resilience
Traditional	1	9	1/5
Green	1/9	1	1/9
Resilience	5	9	1

than selecting suppliers according to performance towards traditional criteria such as costs and quality. After determining the importance for each TGR criterion, fuzzy TOPSIS was implemented to obtain the ranking order of suppliers based on their TGR performance. The PM was invited for another interview to evaluate the performance of selected suppliers with respect to each sub-criterion using the evaluation scale presented in Table 2. Table 5 shows the linguistic evolution of suppliers towards their TGR performance. Fuzzy TOPSIS was applied using Eqs 5-12 to determine the matrix of normalized and weighted normalized triangular fuzzy numbers in addition to the positive ideal solution (D_i^+) and the negative ideal solution (D_i^-). The closeness coefficient (CC) for each supplier is determined by the obtained distances using Eq. 12. Table 6 shows the performance evaluation and rank of suppliers with respect to each TGR criterion, which is represented graphically, Figure 2. According to the obtained results, S_2 revealed the highest TGR performance with a closeness coefficient of 0.89373. Comparing with the other suppliers the closeness coefficient of S_4 (0.733641), S_2 (0.489352), S_5 (0.432518) and S_3 (0.117511) were respectively in rank after S_1.

5 CONCLUSIONS

This work presents a unified traditional business, green and resilient supplier selection approach. The framework was developed by identifying traditional, green and resilience criteria and sub-criteria. Two steps were followed to evaluate and rank suppliers. Firstly, AHP was applied to determine the importance weight of each criterion and sub-criterion based on the linguistic evaluation of a purchasing manager. The AHP results indicate that the resilience criteria are deemed the most important for company A, followed by traditional and green, respectively. Secondly, fuzzy TOPSIS was applied to reveal the order ranking of suppliers based on their TGR performance with respect to the importance weight of each criterion and sub-criterion. Based on the obtained suppliers' performance, we recommended that company A works with some of their suppliers (e.g. S_3 and S_5) to improve their resilience. The results

Table 4: Weights of TGR criteria and sub-criteria obtained by AHP.

Criteria	IW	Ranking	Sub-criteria	IW	Ranking
Traditional	0.263293	2	TC1	0.188584	2
			TC2	0.148292	4
			TC3	0.146552	5
			TC4	0.02105	7
			TC5	0.082984	6
			TC6	0.250322	**1**
			TC7	0.162216	3
Green	0.051821	3	GC1	0.481354	1
			GC2	0.282937	2
			GC3	0.235709	3
Resilience	0.684886	1	RC1	0.033343	5
			RC2	0.192122	3
			RC3	0.093336	4
			RC4	0.429723	1
			RC5	0.251476	2

Table 5: Evaluation of suppliers towards their traditional, green and resilience performance.

Criteria	Sub-criteria	S_1	S_2	S_3	S_4	S_5
Traditional	TC1	H	H	M	M	M
	TC2	M	M	M	M	M
	TC3	M	M	M	M	M
	TC4	VL	L	M	M	M
	TC5	H	L	M	L	L
	TC6	M	M	M	M	M
	TC7	H	M	M	M	M
Green	GC1	M	M	M	M	M
	GC2	M	M	M	M	M
	GC3	M	M	M	M	M
Resilience	RC1	M	M	M	H	L
	RC2	H	H	M	M	L
	RC3	M	M	M	L	L
	RC4	H	M	L	H	L
	RC5	L	L	L	M	L

Table 6: Closeness coefficient and distances from the positive ideal/negative ideal solutions related to suppliers.

	S_1	S_2	S_3	S_4	S_5
D_i^+	0.008212	0.008212	0.068047	0.023736	0.042167
D_i^-	0.069065	0.069065	0.009061	0.065376	0.032138
CC	0.89373	0.489352	0.117511	0.733641	0.432518
rank	1	3	5	2	4

Figure 2: A graphical comparison of suppliers' closeness coefficient performance with respect to TGR criteria individually.

demonstrate the applicability of the novel approach in assisting the purchasing manager at company A to produce a green and resilient purchasing strategy through supplier evaluation.

The developed methodology can be applied to other companies as a tool to measure the healthiness of their supply chain in terms of resilience and green performance. Furthermore, it mediates the uncertainty in experts' opinions through the use of fuzzy evaluation.

Ongoing work includes the incorporation of social criteria to those already studied here. Finally, the authors are developing a multi-objective optimization model to help decision makers in solving order allocation problem with respect to TGR performance of suppliers.

REFERENCES

Akman, G., 2015. Evaluating suppliers to include green supplier development programs via fuzzy c-means and VIKOR methods. *Comput. Ind. Eng. 86*, 69–82.

BBC News, 18 Mar 2011. Japan disaster: Supply shortages in three months. *BBC News*. (accessed 11.02.17).

Bing, X., Bloemhof-Ruwaard, J., Chaabane, A., van der Vorst, J., 2015. Global reverse supply chain redesign for household plastic waste under the emission trading scheme. J. Clean. Prod. 103, 28-39. Aissaoui, N., Haouari, M., Hassini, E., 2007. Supplier selection and order lot sizing modeling: a review. *Com. Oper. Res. 34*, 3516–3540.

Burnson, P., 30 October 2012. Nation's Supply Chains Disrupted by Hurricane Sandy. *Logistics Management*. (accessed 14.06.17).

Büyüközkan and Çifçi, 2010 G. Büyüközkan, G. Çifçi. Evaluation of the green supply chain management practices: a fuzzy ANP approach. *Production Planning & Control, iFirst (2010)*, pp. 1-14

Chen, C.T., Lin, C.T., Huang, S.F., 2006. A fuzzy approach for supplier evaluation and selection in supply chain management. *Int. J. Prod. Econ. 102*, 289–301.

Dickson, G., 1966. An analysis of vendor selection systems and decisions, *J. Purch. 2(1)*, 5–17.

Govindan, K., Rajendran, S., Sarkis, J., Murugesan, P., 2015. Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. *J. Clean. Prod. 98*, 66–83.

Govindan, K., Sivakumar, R., 2016. Green supplier selection and order allocation in a low-carbon paper industry: integrated multi-criteria heterogeneous decision making and multi-objective linear programming approaches. *Ann. Oper. Res. 238*, 243–276.

Ha, S.H., Krishnan, R., 2008. A hybrid approach to supplier selection for the maintenance of a competitive supply chain. *Expe. Sys. with Appl. 34*, 1303–1311.

Haldar, A., Ray, A., Banerjee, D., Ghosh, S., 2014. Resilient supplier selection under a fuzzy environment. *Int. J. Manage. Sci. Eng. Manage*. 9 (2), 147–156.

Hall, J., 16 Apr 2010. Volcanic Ash Cloud Leaves Shops Facing Shortages of Fruit, Vegetables and Medicine. *The Daily Telegraph*.

Hwang, C.L, Yoon, K., 1981. Multiple attribute decision making: methods and applications. New York: Springer-Verlag.

Kannan, D., Govindan, K., Rajendran, S., 2015. Fuzzy axiomatic design approach based green supplier selection: a case study from singapore. *J. Clean. Prod. 96*, 194–208.

Klibi, W.; Martel, A. Scenario-based Supply Chain Network risk modeling. *Eur. J. Oper. Res. 2012*, 223, 644–658.

Konur, D., Campbell, J.F., Monfared, J.A., 2016. Economic and environmental considerations in a stochastic inventory control model with order splitting under different delivery schedules among suppliers. *Omega, 71*, 46–65.

Kuo, R.J., Y.J. Lin. Supplier selection using analytic network process and data envelopment analysis. International. *Journal of Production Research (2011)*, pp. 1-12iFirst.

Mitra, K.; Gudi, R.D.; Patwardhan, S.C.; Sardar, G. Towards resilient supply chains: Uncertainty analysis using fuzzy mathematical programming. *Chem. Eng. Res. Des. 2009*, 87, 967–981.

Mohammed A. and Wang Q. 2015. Integrity of an RFID-enabled HMSC Network. *Proceedings of the Third International Conference on Digital Enterprise and Information Systems*, Shenzhen, China, 2015a, 79-86.

Mohammed A. and Wang Q. and Li X. 2017a. Developing a meat supply chain network design using a multi-objective possibilistic programming approach. *British Food Journal, 119*, 3, 690-706.

Mohammed, A. and Wang, Q., 2017b. The fuzzy multi-objective distribution planner for a green meat supply chain. *International J. Pro Eco., 184*, 47–58

Mohammed, A., Wang, Q., Alyahya, S. and Binnette, N. 2017c. Design and optimization of an RFID-enabled automated warehousing system under uncertainties: A multi-criterion fuzzy programming approach. *The International Journal of Advanced Manufacturing Technology. 91 (5)*, 1661-1670.

Pramanik, D., Subhash, N., Haldar, A., Mondal, S.C., Naskar, S.N., Ray. A., 2017. Resilient supplier selection using AHP-TOPSIS-QFD under a fuzzy environment. *International Journal of Management Science and Engineering Management*, 12 (1), 45-54.

Purvis, L., Spall, S., Naim, M. and Spiegler, V. 2016. Developing a resilient supply chain strategy during 'boom' and 'bust', *Production Planning & Control*, 27:7-8, 579-590.

Rajesh, R.; Ravi, V. Supplier selection in resilient supply chains: A grey relational analysis approach. *J. Clean. Prod. 2015*, 86, 343–359.

Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, 15(3), 234–281.

Sahu, A.K., Datta, S., Mahapatra, S.S., 2016. Evaluation and selection of resilient suppliers in fuzzy environment: Exploration of fuzzy-VIKOR. *Benchmarking: An International Journal*, 23 (3), 651-673.

Sawik, T. Selection of resilient supply portfolio under disruption risks. *Omega 2013*, 41, 259–269.

Shen, L., Olfat, L., Govindan, K., Khodaverdi, R. and Diabat, A. (2013), "A fuzzy multi criteria approach for evaluating green supplier's performance in green supply chain with linguistic preferences", *Resources, Conservation and Recycling*, Vol. 74 No. 1, pp. 170-179.

Songa, W., Xub, Z. and Liu, H-C. 2017. Developing sustainable supplier selection criteria for solar air-conditioner manufacturer: An integrated approach. *Renewable and Sustainable Energy Reviews 79 (2017)* 1461–1471.

Torabi, S.A., Baghersad, M., Mansouri, S.A., 2015. Resilient supplier selection and order allocation under operational and disruption risks. *Transportation Research Part E 79*, 22–48.

Weber, C.A., Current, J.R., Benton, W.C., 1991. Vender selection criteria and methods, *Eur. J. Oper. Res. 50 (1)*, 2–18.