Investigating the Influence of Emotional Intelligence on the Supplier Selection Decisions with Fuzzy Cognitive Maps

Maria Drakaki[1], Panagiotis Tzionas[2] and Kuanysh Abeshev[3]
[1]Department of Science and Technology, University Center of International Programmes of Studies, International Hellenic University, 14th km Thessaloniki -N.Moudania, GR-57001, Thermi, Greece
[2]Department of Industrial Engineering and Management, International Hellenic University, P.O. Box 141, GR-57400, Thessaloniki, Greece
[3]School of Engineering Management, Almaty Management University, Rozybakiyeva st., 227, 050060, Almaty, Kazakhstan

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Abstract: Supplier selection holds a strategic role in supply chain management. Multi-criteria decision making methods combined with fuzzy and intelligent approaches have been primarily used to solve supplier selection problems considering sustainability and risk factors. Yet sustainability criteria as well as risk factors proposed in the literature vary, as well as the assigned weight values that measure the relative importance of the various criteria and risks. Moreover, human decisions involve emotions. Therefore, it would be useful to identify potential causal relationships between criteria and risk factors and emotional intelligence of decision makers, in order to identify potential biases in the decision making process. In particular, trust and relationship building with the suppliers may affect the emotional intelligence of decision makers. For this purpose, in this paper a methodology which uses Fuzzy Cognitive Maps is presented, in order to investigate by simulation, different scenarios that could identify the influence of emotional intelligence of the decision makers regarding the supplier selection problem.

1 INTRODUCTION

Globalisation and sustainability have contributed to the strategic role of the supplier selection in the supply chain. Long-term relationships between firms and their suppliers as well as finding eligible suppliers are key aspects for the enhancement of the strategic position of the firms in the supply chain (Ho et al., 2010; Ghadimi et al., 2018).

Traditional supplier selection criteria include quality, cost, delivery and service (Songhori et al., 2011). However, sustainability has shifted the focus of supplier selection criteria from economic criteria to the Triple Bottom Line dimensions, which include besides the economic dimension, environmental and social ones (Chen et. al., 2006; Kuo et al., 2010; Govindan et al., 2015; Gören, 2017; Ghadimi, 2018; Drakaki et al., 2019a).

Besides, sustainability requirements apply to the selection of appropriate suppliers, whereas peer-to-peer governance relationships based on cooperation between buyers and their suppliers contribute positively to this end (Jiang, 2009). Thus, both sustainability and risks should be considered for the supplier selection problem (Alikhani et al., 2019; Drakaki et al., 2019a).

However, global supply chains are exposed to supply risks categorised into operational risks and disruptions (Tang, 2006). Disruptions are unexpected events which disrupt the normal supply of goods within a supply chain, whereas operational risks relate to supply problems such as quality, cost or production technology. Moreover, supply chain members are interconnected and therefore risks occuring at one member propagate to the other supply chain members. Yet integration of sustainability can contribute to the management of supply chain risks (Giannakis and Papadopoulos, 2016). Yet only a few studies exist that have considered both sustainability and risk factors for the supplier selection problem (Awasthi et al., 2018; Alikhani et al., 2019; Mokhtar et al., 2019; Drakaki et al., 2019a). Alikhani et al. (2019) considered risks as the outcome of supplier selection decisions, whereas some criteria and risk factors were

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interrelated and therefore cosidered dependent factors. Drakaki et al. (2019b) have not considered risks as independent factors and integrated risks in the decision making methodology. Hamdi et al. (2018) have presented a literature review on supplier selection under supply chain risk management. Mokhtar et al. (2019) considered financial and production stability, quality and cost as supply chain risk indicators for the operational disturbances which affect suppliers. The authors argued that feedback actions taken by manufacturers in order to reduce risk exposure can become the source of further risks for the suppliers.

Relationships with suppliers have been of primary importance for the supply chain performance. Das and Teng (2001) investigated the relationship between trust and risk within a company. The authors argued that the structural preferences of decision makers were made under the overall goal of risk minimisation and based on their perceptions of relational risk and performance risk. The relational risk was related to the level of partners' cooperation and commitment and the associated consequences. Therefore, relational risk was mostly related to trust between partners and decision makers' risk perceptions were influenced by psychological factors including trust propensity. Beneficial links between collaboration and partnership performance have been found in Zybell (2013). Rao and Goldsby (2009) categorised supply chain risks into environmental, industry, organisational, problem-specific and decision making risks. The authors argued that decision making risks were partially due to knowledge, skills, and bias of decision makers. Guertler and Spinler (2015) limited the set of risks and corresponding risk indicators for risk monitoring due to their interrelatedness. The authors proposed that the availability and continuity of contact persons could be considered a risk indicator for the risk of unstable communication with the suppliers. Manello and Calabrese (2019) argued that traditional supplier selection criteria such as price and delivery have similar importance with reputational factors for the supplier selection in the automotive industry. The authors argued that there is scarce literature related to how buyers actually select suppliers, in contrast to a plethora of literature related to how they should select suppliers. The authors argued that long-term cooperation is based on trust and information sharing.

The supplier selection problem has been investigated using Fuzzy Cognitive Maps (FCMs) (Xiao et al., 2012; Drakaki et al., 2019b). FCMs originate from cognitive maps and use fuzzy logic in order to include vague and qualitative information. An FCM is a signed weighted graph consisting of nodes and arcs where nodes represent the concepts of the system under consideration and the arcs represent the causal relationships between nodes. FCMs can be constructed by groups of experts and the causal relationships between nodes can be expressed with linguistic variables taking values in the term set T(influence)={ negatively very strong, negatively strong, negatively medium, negatively weak, negatively very weak, zero, positively very weak, positively weak, positively medium, positively strong} (Groumpos, 2010). The Center of Gravity method is used to calculate the numerical weights which take values in [-1, 1].

Timed evolution of FCMs is performed for a number of iterations until the FCM either stabilizes to a stable state or shows a cyclic behavior or does not converge. For an FCM with N concepts, C_i, i=1,…,N, the concept values are updated for a number of iterations. At iteration k+1, concept C_i is updated as follows

$$C_i^{(k+1)} = f(C_i^{(k)} + \sum_{\substack{j=1 \\ j\neq i}}^{N}(C_j^{(k)} \cdot w_{ji}) \qquad (1)$$

The weight value, w_{ji}, shows the degree of influence of concept j on concept i. The sigmoid function can be used as the threshold function f when the concept values are in [0, 1], and the tangent function is used when the values are in [-1, 1]. Numerous applications of FCMs exist for modeling and control of complex systems as well as to provide decision support tools [Hunter et al., 2004; Li and Lin, 2006; Chen and Paulraj, 2004; Xiao et al., 2012; Kontogianni et al., 2012; Papageorgiou et al., 2017; Drakaki et al., 2019b; Drakaki et al., 2019c).

In this paper the sustainable supplier selection problem with risk factors is considered, with focus on how the emotional intelligence of decision makers can influence their supplier selection decisions. Therefore, an FCM based methodology is proposed in order to identify the impact of causal relationships between concepts such as relationships of decision makers with suppliers and supplier selection criteria and risk factors which are included in the objective decision making process.

The proposed methodology is presented next. Conclusions include future directions.

2 THE METHODOLOGY

In the context of the supplier selection problem, the purpose of the this paper is to present a methodology which can identify the influence of the emotional intelligence of the decision makers on supplier selection criteria and risk factors.

The methodology consists of the following steps:

1. Identification of all concepts that are relevant to the aims of this paper in order to be included as FCM concepts.
2. Identification of the causal relationships between concepts and their signs.
3. Calculation of the weight matrix.
4. Simulations with scenario building in order to explore the influence of the emotional intelligence concepts on the values of supplier selection criteria and risk factors.

Identification of the FCM Concepts

The system concepts that are used in the FCM include decision makers' concepts related to emotional intelligence, supplier selection risk factors and supplier selection criteria. They have been chosen based on the presented literature. The FCM concepts related to emotional intelligence include trust, relationship building, relationship commitment, and bias (Das and Teng, 2001; Zybell, 2013; Ghadimi et al., 2018; Rao and Goldsby, 2009). The risk factors include quality, service, cost, long-term cooperation, supplier's profile, continuity, opportunism (Drakaki et al., 2019b; Alikhani et al., 2019). The sustainable supplier criteria include price, productivity, capacity, long-term relationship, lead time, quality, production technology, responsiveness, reputation, environmental management system, environmental competencies, occupational health and safety management system, employees' supportive activities (Gören, 2017; Drakaki et al., 2019a; Alikhani et al., 2019; Paul, 2015). Tables 1, 2 and 3 show the concepts related to emotional intelligence, risk factors and sustainable supplier selection criteria, respectively.

Table 1: FCM concepts related to emotional intelligence.

Emotional intelligence concepts	**Description**
Trust (C_1)	Mutual trust in the relationship.
Relationship building (C_2)	Cooperation, collaboration, communication, information sharing.
Relationship commitment (C_3)	Collaboration, information sharing, trust.
Bias (C_4)	Limitation of decision makers related to their knowledge and skills.

Table 2: Risk factors for sustainable supplier selection (as well as FCM concepts).

Risk factors	**Description**
Quality risk (C_5)	Risks related to the quality of the product.
Service risk (C_6)	Risks related to the capacity, production technology and resposiveness of the supplier.
Cost (C_7)	Risks related to product price of the supplier.
Long-term cooperation (C_8)	Risks arising from trust and relationship commitment with the supplier.
Supplier's profile (C_9)	Risks related to past performance of the supplier.
Continuity (C_{10})	Risks related to dispuptions such as natural disasters.
Opportunism (C_{11})	Risks related to opportunistic behavior of the supplier.

Table 3: Criteria for sustainable supplier selection (as well as FCM concepts).

Sustainability dimensions	**Criteria**
Economic dimension	Price (C_{12})
	Productivity (C_{13})
	Capacity (C_{14})
	Long-term relationship (C_{15})
	Continuity (C_{16})
	Lead Time (C_{17})
	Quality (C_{18})
	Production technology (C_{19})
	Responsiveness (C_{20})
	Reputation (C_{21})
Environmental dimension	Environmental management system (C_{22})
	Environmental competences (C_{23})
Social dimension	Occupational health and safety management system (C_{24})
	Supportive activities (C_{25})

Identification of the Causal Relationships between Concepts and Their Signs

Figure 1 shows the constructed FCM. The direction of arcs in Figure 1 shows the direction of causality between the nodes (concepts). The weight values, w_{ij}, of the connections show the degree of influence of the causality between nodes. In this paper, it is assumed that there is no influence among FCM concepts representing the emotional intelligence related concepts, among the supplier selection criteria, as well as among FCM concepts representing the risk factors.

Calculation of the Weight Matrix

Table 4 shows the weight matrix expressed in linguistic terms (Groumpos, 2010). Positive weight value between concepts C_i and C_j means that an increase in C_i will cause an increase in C_j, negative weight value means that an increase of C_i will cause a decrease in C_j, whereas a value of 0 indicates that there is no influence of C_i on C_j. The values of the linguistic terms will be determined based on the Center of Gravity method.

In this paper, it is assumed that concepts representing trust, relationship building and relationship commitment will negatively influence the values of the concepts representing risk factors. Therefore, an increase in the level of trust between decion makers and suppliers will lead to a decrease in the value of all risk factors used in the formulation of the supplier selection problem.

Simulations with Scenario Building

Simulation allows investigation of different "what if" scenarios. FCM concepts are assigned initial values and the behavior of the modeled system is observed as it evolves in time according to Equation (1). It is, therefore, possible to observe whether the system will reach in the future, after a number of iterations, a stable state or it will become unstable or will show a cyclic behavior. Therefore, simulations with scenario building provide decision support to decision makers by making predictions of future system states (Kontogianni et al., 2012). Therefore, three scenarios have been proposed.

1. The FCM concept values will be assigned initial values equal to 0. In this scenario all concepts are de-activated initially.The simulation results will show an upper bound for the performance of the system.
2. The FCM concept values will be assigned initial values equal to 1. In this scenario all concepts are fully activated initially.The simulation results will show a lower bound for the performance of the system.
3. The FCM concept values related to emotional intelligence will be assigned values equal to 0, whereas all other concepts will be assigned values equal to 0.5. The simulation results will show the impact of the emotional intelligence related concepts on risk factors and criteria values.

Table 4: The FCM weight matrix expressed in linguistic terms. The weight value w_{ij} shows the influence of concept C_i (represented by the columns) on the concept C_j (represented by the rows).

$C_j \backslash C_i$	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
C_1	zero	zero	zero	zero	zero	zero	zero	zero	zero	zero	zero
C_2	zero	zero	zero	zero	zero	zero	zero	zero	zero	zero	zero
C_3	zero	zero	zero	zero	zero	zero	zero	zero	zero	zero	zero
C_4	zero	zero	zero	zero	zero	zero	zero	zero	zero	zero	zero
C_5	nw	nw	nw	zero	zero	zero	zero	zero	zero	zero	zero
C_6	nw	nw	nw	zero	zero	zero	zero	zero	zero	zero	zero
C_7	nw	nw	nw	zero	zero	zero	zero	zero	zero	zero	zero
C_8	nw	nw	nw	zero	zero	zero	zero	zero	zero	zero	zero
C_9	nw	nw	nw	zero	zero	zero	zero	zero	zero	zero	zero
C_{10}	nw	nw	nw	zero	zero	zero	zero	zero	zero	zero	zero
C_{11}	nw	nw	nw	zero	zero	zero	zero	zero	zero	zero	zero
C_{12}	zero	zero	zero	pw	nw	zero	nw	nw	zero	zero	zero
C_{13}	zero	zero	zero	pw	nw	zero	zero	nw	zero	zero	zero
C_{14}	zero	zero	zero	pw	zero	nw	zero	nw	zero	zero	zero
C_{15}	zero	zero	zero	pw	zero	zero	zero	nw	zero	zero	zero
C_{16}	zero	zero	zero	pw	zero	zero	zero	nw	zero	zero	zero
C_{17}	zero	zero	zero	pw	zero	zero	zero	nw	zero	zero	zero
C_{18}	zero	zero	zero	pw	nw	nw	zero	nw	zero	zero	zero
C_{19}	zero	zero	zero	pw	zero	zero	zero	nw	zero	zero	zero
C_{20}	zero	zero	zero	pw	zero	nw	zero	nw	zero	zero	zero
C_{21}	zero	zero	zero	pw	nw	nw	nw	nw	nw	nw	nw
C_{22}	zero	zero	zero	zero	zero	zero	zero	nw	zero	zero	zero
C_{23}	zero	zero	zero	zero	zero	zero	zero	nw	zero	zero	zero
C_{24}	zero	zero	zero	zero	zero	zero	zero	nw	zero	zero	zero
C_{25}	zero	zero	zero	zero	zero	zero	zero	nw	zero	zero	zero

nw: negatively weak; pw: positively weak.
The concepts corresponding to the supplier selection criteria (C_{12}-C_{25}) have zero influence to each other/ Therefore, the corresponding columns have been omitted for simplicity, however the corresponding weight values are equal to zero.

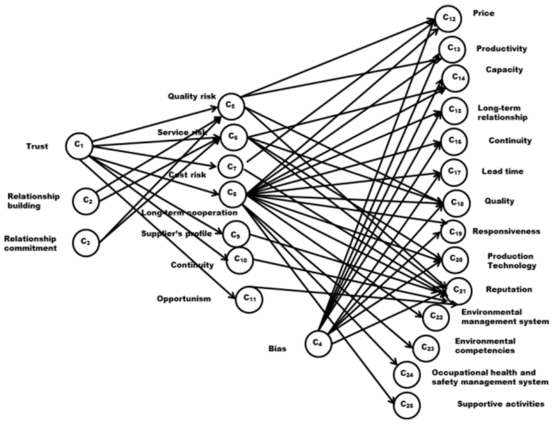

Figure 1: The FCM for the investigated system.

3 CONCLUSIONS

Supplier selection is of strategic importance for supply chain performance. In this paper, a methodology has been proposed, in order to study the influence of emotional intelligence of the decision makers regarding the supplier selection problem decisions. Supplier selection depends on the criteria and risk factors taken into account in the multi-criteria decision making methods. Yet both criteria and risk factors vary, as well as their assigned weight values. Decision makers may choose a different set of the above variables, influenced by their emotional intelligence. Concepts related to trust, relationship building, relationship commitment and bias have been linked to the emotional intelligence of the decision makers. A methodology which uses Fuzzy Cognitive Maps has been proposed in order to investigate by using simulations and building of different scenarios the causal relationships between the involved concepts. The FCM concepts are related to the emotional intelligence of the decision makers, risk factors and sustainability criteria for the supplier selection problem. Future research will apply the proposed method to a case study.

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