Economic Research-Ekonomska Istraživanja

ISSN: 1331-677X (Print) 1848-9664 (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

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To cite this article: Goran Đurić, Gordana Todorović, Aleksandar Đorđević & Ankica Borota Tišma (2019) A New Fuzzy Risk Management Model for Production Supply Chain Economic and Social Sustainability, Economic Research-Ekonomska Istraživanja, 32:1, 1697-1715, DOI: 10.1080/1331677X.2019.1638287

To link to this article: https://doi.org/10.1080/1331677X.2019.1638287

Published online: 23 Jul 2019.

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2019, VOL. 32, NO. 1, 1697–1715
https://doi.org/10.1080/1331677X.2019.1638287

A new fuzzy risk management model for production supply chain economic and social sustainability

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ABSTRACT
The issues of operational, organisational and process risk assessment in supply chains (SCs) are the most usually analysed, while other risk groups (like economic and social risks) are not taken into account, even though they have a critical effect on the competitive advantage and SCs sustainability over long time periods. The determination of risk value that may arise due to the materialisation of each defined risk factor (RF) is based on the assessment of the severity of RF consequences and frequency of RF occurrence. These judgments are obtained by decision makers and modelled by using fuzzy set theory. The relative importance of RFs are stated by fuzzy pair-wise comparison matrices in compliance with fuzzy analytical hierarchy process (FAHP). The risk level of SCs could be obtained in an exact way by applying fuzzy logic. The proposed model, to be presented in this paper, provides a possibility to easily and simply determine risk level from the automotive industry SC and to propose appropriate management initiatives that should lead to a reduction or elimination of RF influence.

ARTICLE HISTORY
Received 29 April 2017
Accepted 4 June 2018

KEYWORDS
Economic risk factors; social risk factors; supply chain; risk assessment; fuzzy analytic hierarchical process; fuzzy logic

JEL CLASSIFICATIONS
G31; D8; D80; D81

1. Introduction

Nowadays, effective management of supply chains (SCs) is becoming a critical issue for companies that want to remain competitive and to become leaders in a modern market environment. SC management is influenced by many different external and internal risk factors (RFs). The impact of these RFs has led to the fact that SCs and governments are now more vulnerable, so that there is growing interest for the supply chain risk management domain. Supply chain risk management should be defined as the process of planning, organising, leading and controlling the activities of the organisation in order to reduce the effects of risk on the values of performance by which the effectiveness of an enterprises activities is measured (Stulz, 1996). In the literature, the risk issue is associated with negative consequences and expectations of

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risk. In the past decades, risk management focused on the operational RFs (Tazelaar & Snijders, 2013) and human RFs (Đjapan, Tadić, Mačužić, & Dragojlović, 2015), to ensure profitability and continuity. Regardless, there is no doubt that economic and social sustainability is becoming more important for achieving appointed business goals, than the actual ownership of the particular product.

Risk management presents a part of SC management that is a complex task, especially in SCs, as it includes identification of RFs, risk modelling, and determination of measures that should lead to an overall risk value reduction (Caputo, Pelagagge, & Salini, 2013; Mabrouki, Bentaleb, & Mousrij, 2014; Bounit, Irhirane, Bourquia, & Benmoussa, 2016). Solutions for the risk management problem may be achieved by applying different methods, that can be divided broadly into quantitative, qualitative and hybrid methods (Aqlan & Lam, 2015).

Risk modelling is a procedure used to handle all the identified RFs. Risk modelling is based on the assumption that two dimensions are important when discussing risk: RF consequences and frequency of occurrences. With respect to the fact that SCs operate in ever changing environment, it may be stated that the uncertainties within severities of the consequences, RF frequencies of occurrence, and risk levels are described by pre-defined linguistic expressions whose modelling is based on the fuzzy sets theory (Dubois & Prade, 1980; Zimmermann, 2011). Hence, by applying this modelling approach uncertainties and imprecisions may be quantitatively presented sufficiently precisely. In this paper, existing uncertainties are modelled by triangular fuzzy numbers (TFNs) and trapezoidal fuzzy numbers (TrFNs).

Risk factors' relative importance are stated by a fuzzy pair-wise comparison matrix. Many authors suggest that in this way, decision makers can make a more accurate assessment on the relative importance, than to make a direct assessment (Tadić, Stefanović, & Aleksić, 2014). Determination of relative importance may be based on the application of different multi-criteria decision making methods (MCDM) such as fuzzy AHP (Chang, 1996), best-worst method (BWM) (Rezaei, 2015; Pamučar, Petrović, & Ćirović, 2018), The multi-attribute complex proportional assessment of alternatives (COPRAS) (Zavadskas, Kaklauskas, Turskis, & Tamošaitienė, 2009), multi-attributive border approximation area comparison (MABAC) (Pamučar & Ćirović, 2015), decision making trial and evaluation laboratory (DEMATEL) (Wu & Lee, 2007).

The main objectives of the paper are to quantitatively describe both dimensions of risk with a sufficient precision, to determine on an exact way the overall SC risk level and to determine priorities of management initiatives, which should lead to a reduction of the identified RFs' impact and thus to increase the effectiveness and sustainability in the long-term.

It is important to highlight that the many employees work in automotive industry SC whose income has a significant influence on gross domestic product, in developed, and especially in developing countries. Motivation for this research derives from the above mentioned fact and, also, from the fact that there are no papers published regarding the influence assessment of social and economic RFs on SC effectiveness.

This paper is organised in the following manner. Section 2 presents an evaluation framework. Modelling of uncertainties within severities of consequences, RF frequencies of occurrence, the relative importance of RFs and risk levels are presented in

Table 1 Review on SC risk analysis.

Author	Risk group	RF identification	Risk modelling techniques	Risk level	Result implication
Aqlan & Lam, 2015	Supply chain risk			√	√
Zimmer 2017	Social risks		√	√	√
Djapan, Tadić, Mačužić, & Dragojlović, 2015	Human, technical and technological and organizational risks	√	√	√	√
Pinto, 2014	Occupational safety risk	√	√	√	√
Chopra & Meindl, 2016	Supply chain risks	√			√
Song, Ming, & Liu, 2016	Supply chain risks	√	√	√	√
Giannakis & Papadopoulos, 2016	Social risks	√			√
Eckert & Gatzert, 2017	Operational and reputation risks		√	√	√
The proposed model	Economic and social risks in SC	√	√	√	√

Section 3, as well as the weights vectors of RFs obtained by applying fuzzy analytic hierarchy process (AHP) (Chang, 1996). The proposed algorithm of the model is presented in Section 4. The proposed model with real-life data, which came from automotive industry SC that operates in central Serbia, is illustrated in Section 5. Conclusions are presented in Section 6.

2. Literature review

SC risk management has gained increasing attention in last few years (Heckmann, Comes, & Nickel, 2015; Ho, Zheng, Yildiz, & Talluri, 2015). In the field of risk management, a large number of issues have been the subject of both scientific and practical studies. Table 1 presents a review of papers from the domain of SC risk management.

2.1. RF identification

According to the literature review, qualitative techniques are mostly used for RF identification, such as empirical analysis, literature recommendations (Djapan, Tadic, Macuzic, & Dragojovic, 2015), interview method (Pinto 2014), a checklist which is the simplest and the most frequently used procedure for the identification of RFs in SC. Hence, many authors proposed different RF identification procedures from widely different perspectives (Aqlan & Lam, 2015; Chopra & Meindl, 2007; Song, Ming, & Liu, 2016). Therefore, there is an absence of any consensus on RF identification procedures. It can be emphasised that in order to accomplish balanced effective risk reduction strategy, it is necessary to comprehend diversity and coherence of SC RFs.

In this paper, economic RFs (Hofmann, 2011), and social RFs (Giannakis & Papadopoulos, 2016) in SC are considered. This presents one of the main contributions of the paper.

2.2. Risk modelling techniques

It is well known fact that each RF could lead to the occurrence of several consequences that have different severities. Furthermore, the question may be asked, how to determine the consequences and their severities that are associated to the each RF. This question has been debated in the literature in different ways, consequences could be determined according to literature and evidence data, while their severities may be described by using: risk values (Eckert & Gatzert, 2017), and linguistic variables which are modelled by fuzzy sets (Pinto, 2014; Djapan et al., 2015). Eckert and Gatzert (2017) have dealt with determination of aggregated severity arising from all considered consequences. Input-output modelling may be used to determine the severity of each identified RF (Zimmer, Fröhling, Breun, & Schultmann, 2017). Severity of each identified ergonomic RF (Djapan et al., 2015) and RF (Pinto, 2014) is modelled by TFNs.

Besides severity, a number of authors have considered other uncertainties, for instance the relative importance of RFs and safety barrier effectiveness. A fuzzy pairwise comparison matrix of the relative RFs' importance is stated in (Pinto 2014; Djapan et al., 2015) and determined by applying fuzzy AHP (Chang, 1996). The aggregation of all considered weighted severities may be performed by means of the fuzzy averaging method. Safety barrier effectiveness is defined in (Pinto, 2014) and modelled by TFNs.

In comparison to the papers presented in the literature, there are a certain number of differences in risk modelling procedures. In this paper, uncertainties such as frequencies of RFs' occurrence, severities of consequences, and the RFs relative importance, and the risk level are considered and modelled by TFNs and TrFNs. The relative importance is obtained by applying fuzzy AHP by analogy with (Pinto, 2014; Djapan et al., 2015).

2.4. Risk level

Some author suggested that risk management may be defined as the sustainment of acceptable risk level. Hence, determination of risk level presents important research and practical problems. In Zimmer et al. (2017) the risk level of social RFs in automotive SC is obtained with respect to the weighted RFs' severity values. In Djapan et al. (2015) the ergonomic risk level is obtained by using fuzzy if-then rules. The risk level that may occur due to the materialisation of each RF could depend on three variables: possibility, severity, and safety barrier effectiveness (Pinto, 2014).

The author states that the risk value can be calculated as a product of the severity of all consequences that arise from the materialisation of the RFs and the assessed frequencies of their occurrences. In comparison with other literature sources, the value of this variable, denoted as severity, depends on all identified consequences that are associated with each RF.

2.5. Result implication

Many authors suggest that the relative importance of the factors should be given by comparison pairwise matrix by analogy to fuzzy analytic hierarchy (FAHP) (Chang, 1996) and DEMATEL (Wu & Lee, 2007). FAHP use is widely presented in the literature (Kaya & Kahraman, 2011; Tadic et al. 2017), since it is less demanding than

DEMATEL when it comes to calculations. As it is a well-known fact, when using BWM, the decision makers are bound to predetermine in advance which risk factor has the most, and which has the least significant importance. So the solution obtained by application of BWM is in a high degree burdened with the decision makers' subjectivity. Taking these facts into account, the authors suggest the use of FAHP to determine the risk factor weights.

Management initiatives for risk reduction may be defined in different ways. Aqlan and Lam (2015) have developed a multi-objective optimisation model for determination of optimal strategies for risk mitigation. The main contribution of Zimmer et al. (2017) is the possibility to determinate responsibility of the focal organisation based on the rank of social RFs. In (Đjapan, Tadić, Mačužić, & Dragojlović, 2015) management initiatives for ergonomic risk level reduction are prescribed. By applying the model developed in Pinto (2014) it is possible to use real data and information to assure the safety of a practitioners. The results obtained in (Chopra & Meindl, 2007; Song, Ming, & Liu, 2016; Giannakis & Papadopoulos, 2016) could present the guidance for the identification of RFs in SC.

Based on the results that are obtained by applying the model presented in paper it is possible to determine management initiatives (by analogy to Pinto 2014; Djapan et al., 2015) and their priority for the mitigation of social and economic RFs in SC.

3. Evaluation framework

Determination and improvement of a risk management strategy in complex systems such as PDS presents one of the most important strategic problems. The aim in the proposed classification method is to determine RFs having the highest priority in considered SC. Respecting the priorities of RFs, appropriate management initiatives are perceived by decision makers.

The proposed procedure in this paper is summarised in Figure 1.

As is well known, numerous and diverse RFs may be realised in SCs operating in an uncertain environment. The considered RFs of SC are briefly described. The *volatility of price and cost risk factor* ($i = 1$) is tightly correlated with lack of raw materials, and lack of information. It has been concluded that poor management of these RFs may cause alleged illegal collection of excess vendor markdowns (Tang & Musa, 2011). RF *inflation and currency exchange rates risk factor* ($i = 2$) may include variability and uncertainty in currency exchange rates, economic and political instability, and changes in the regulatory environment (Meixell & Gargeya, 2005). The SC is exposed to RF *market share reduction risk* ($i = 3$) (Christopher & Lee, 2004), i.e., it is possible to miss out business opportunities that may exist in a turbulent market.

To avoid market-share reduction and to recognise the right market signals, SC should be responsive to variable market trends and customer requirements. Shi (2004), stated that SC exposure to a RF *reputation loss or brand damage risk* ($i = 4$) is possible if a series of undetected faulty products have occurred in a different phases of SC processes and reached the market, and therefore would have to be either reworked or withdrawn. According to Giannakis and Papadopoulos (2016) the risk management team should consider the RFs that could imposed by social

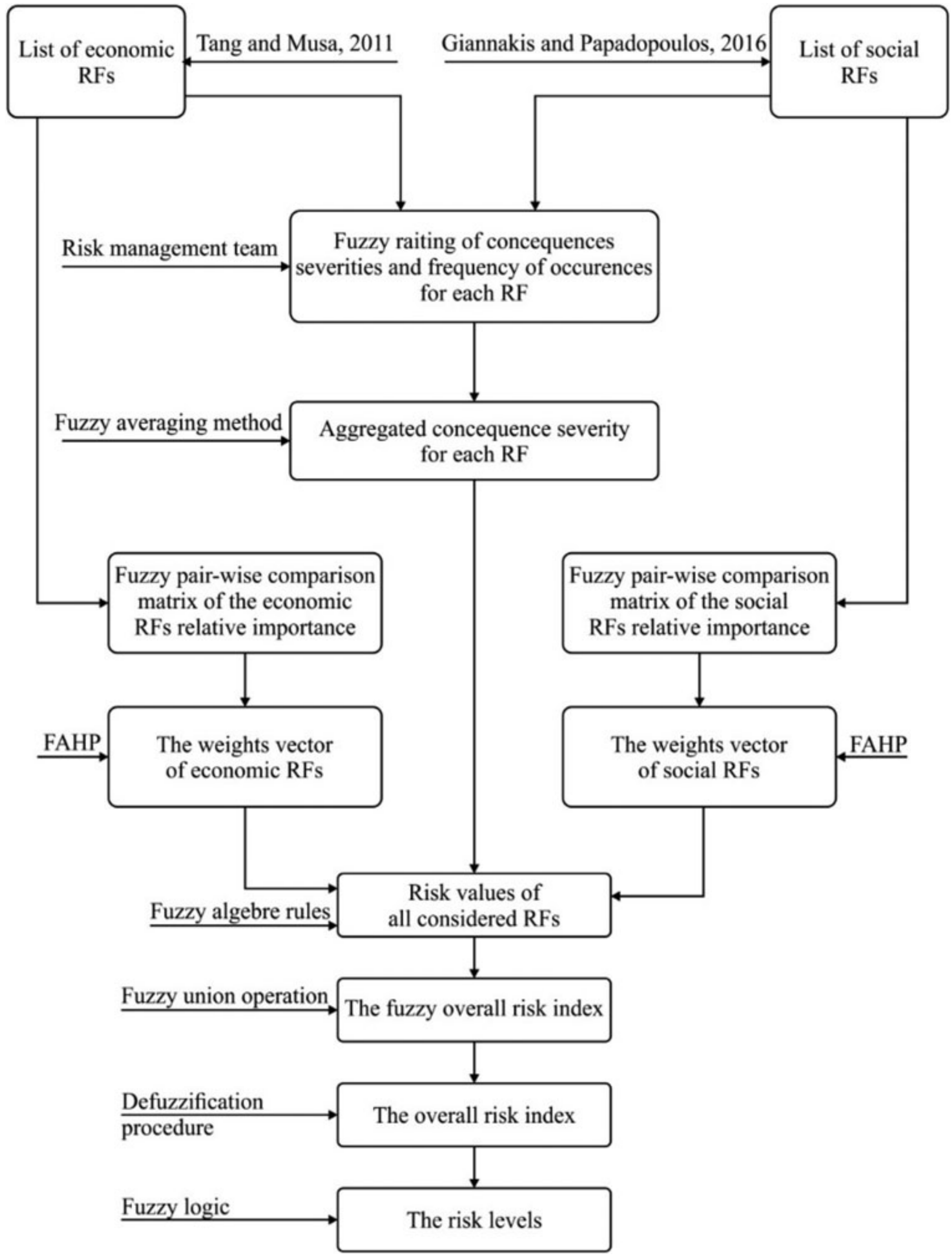

Figure 1. The evaluation procedure.

environments, in addition to the economic risk management that is required to make SC more sustainable. Similarly, but from the social point of view, SC exposed to a RF *unhealthy/dangerous working environment risk factor* (i = 5) influence when working conditions are unhealthy and operations are performed in anon-trusted workplace, with the use of hazardous materials that threaten the employees' health and safety (Giannakis & Papadopoulos, 2016). RF *violation of human rights* (i = 6) includes

(Azapagic & Perdan, 2000): stakeholder inclusion, preservation of cultural values and benefits to communities surrounding SC plants, consistency of employment conditions and health and safety standards for all operations regardless of their location, and leaving the environment in a condition to be acceptable for the future generations wellbeing. In the automotive SC industry, the issues that need to be properly addressed are related to environment, fair trade, health and safety, labour and human rights, and community, and they are frequently derived from RF *failure to fulfill social commitment risk* ($i = 7$) influence (Maloni & Brown, 2006). RF *violating business ethics* ($i = 8$), that could integrate possible corruption, unfair-trading, and privacy invasion, has an influence primarily on the brand reputation and corporate social responsibility.

Following the identification of the economic and social RFs in SC, their weights values are determined by applying the FAHP process (Chang, 1996).

The severity of each consequence at the level of each RF, RFs' frequency of occurrence, and the risk level are assessed by decision makers. They used pre-defined linguistic expressions. Modelling of used linguistic expressions is conducted by means of fuzzy set theory (Zimmermann, 2011).

Calculation of the overall risk index is based on fuzzy algebra rules. To determine the risk level of SC fuzzy IF-THAN rules have been applied. According to the obtained priority of RFs, decision makers should define the appropriate risk management strategy.

4. Modelling of uncertainties

The values of consequence severity, RF frequency of occurrence and RF relative importance are almost impossible to be determined on an exact way. Hence, these values are obtained based on the risk management team (RMT) subjective assessment. Decision makers within RMT have based their assessments on the evidence data, experience, and results of good practice. It is presumed that assessment obtained by decision makers are better stated, if precise numbers instead of linguistic expressions are used.

There are many papers presenting modelling of linguistic variables based on probability theory (Badurdeen et al., 2017), the fuzzy sets theory (Zimmermann, 2011), and theory rough sets (Pawlak, 1998). Fuzzy sets theory use is widely represented in the literature, since it may suitably resemble human reasoning and be useful for information and uncertainty approximation in the processes of decision generation (Kahraman, Ertay, & Büyüközkan, 2006).

In this paper, all existing uncertainties are modelled by the means of fuzzy sets. In the literature, the TFNs and trapezoidal fuzzy numbers (TrFNs) are most widely applied for modelling of different uncertainties and imprecise (Tadic, Aleksic, Mimovic, Puskaric, & Misita, 2016; Sadi-Nezhad & Damghani, 2010). These fuzzy numbers are accurate enough for uncertain data description; and besides that sometimes they don't require complex mathematical calculations. There are no rules and recommendations on how to determine number domains of fuzzy numbers for description of uncertain variable. In this paper, the application of fuzzy numbers that have their domains determined within intervals [0-1] and [0-5] is presented.

Table 2. Notation.

Notation	Description
I	The total number of identified RFs
I	Index of each RF
$J_i, i = 1, .., I.$	The total number of consequences that may arise due to the materialisation of each RF i, $i = 1,..,I$
J	Index of each consequence
$\tilde{C}_i, i = 1, .., I.$	TFN describing the severity of all consequences that may arise due to the materialisation of each RF i, $i = 1,..,I$
$\tilde{f}_i, i = 1, .., I.$	TFN describing the each RF i, $i = 1,..,I$ frequency of occurrence
$w_i, i = 1, .., I.$	The weight of each RF i, $i = 1, \ldots, I$
$\tilde{R}_i, i = 1, .., I.$	TFN describing the weighted risk value which is the result of RF i, $i = 1,..,I$ materialisation whose frequency is estimated in advance
$\tilde{R}$	TFN describing the weighted risk index value
R	The representative scalar of the TFN $\tilde{R}$

4.1. Notation

Notation is used in order to understand the proposed model better and it is presented in Table 2.

4.2. Modelling of the frequencies of occurrence and severities of consequences

The frequencies of occurrence RFs may be determined if the evidence data about production from the previous period are applied. However, often there are not enough adequate evidence data or the data may not be considered as adequate and relevant enough, due to the fact that the changes in the SC environment and within the SC affecting data are occurring frequently and rapidly. Hence, treated RFs frequencies of occurrence are assessed by decision makers that take into account evidence data and the changes that have occurred during the observed time period in which risk management is carried out. The severities of consequences that may arise due to RF materialisation are not measurable variables, and depend on subjective judgments of decision makers. In this case, decision makers base their estimates on their knowledge and experience. In this paper, these uncertainties are described by application of seven pre-defined linguistic variables that are modelled with TFNs. These TFNs are presented as follows:

- very low value (VL): $(x; 0, 0, 0.25)$
- low value (L): $(x; 0, 0.15, 0.3)$
- medium low value (ML): $(x; 0.2, 0.35, 0.5)$
- medium value (M): $(x; 0.35, 0.5, 0.65)$
- medium high value (MH): $(x; 0.5, 0.65, 0.8)$
- high value (H): $(x; 0.7, 0.85, 1)$
- very high value (VH): $(x; 0.75, 1, 1)$

4.3. Modelling and determination of the RFs' relative importance

Song, Ming, and Liu (2017) have divided SC RFs in different groups, so it may be assumed that RFs under each considered group are mutually independent. The RF's relative importance values under each considered RF group are not equal and they are not changed during the considered period. They could not be obtained by direct measurement, or from the evidence data, thus they are described by pre-defined linguistic expressions that are modelled by TFNs, $\widetilde{W}_{ii'}, i, i' = 1, .., I; i \neq i'$. The RF's relative importance within each considered group are stated by fuzzy pair-wise comparison matrices, since decision makers can more easily and accurately make an assessment than by measuring values directly. The weights vectors of RFs under each considered group of RFs is obtained by applying the fuzzy analytic hierarchy process (AHP) (Chang, 1996), which is widely used in the relevant literature to solve similar issues.

In this paper, pre-defined linguistic expressions are modelled by TFNs that are further presented:

- *low importance* (L): $(x; 1, 1, 5)$
- *medium importance* (M): $(x; 1, 3, 5)$
- *high importance* (H): $(x; 1, 5, 5)$.

Domains of these TFNs are defined on the set of real numbers belonging to the interval [1-5]. The value 1 indicates that RF i in regards to RF $i', i, i' = 1, .., I; i \neq i'$ had the equal relative importance within the same group of discussed RF. The value 5 indicates that relative importance of RF i in regards to RF $i', i, i' = 1, .., I; i \neq i'$ had the greatest importance within the same group of considered RFs.

If the relative importance RF i' in regards to RF i is greater under considered RFs group, than the element in the fuzzy pair-wise comparison matrix is presented by TFN:

$$\widetilde{W}_{ii'} = \left(\widetilde{W}_{i'i}\right)^{-1} = \left(\frac{1}{u_{ii'}}, \frac{1}{m_{ii'}}, \frac{1}{l_{ii'}}\right)$$

If the RFs are of equal importance $i = i'$, $i, i' = 1, .., I; i \neq i'$, than the relative importance of RF in regards to RF i', is presented by crisp value 1. According to fuzzy algebra rules the value 1 can be presented by TFN (1,1,1).

In this paper, consistency determination of decision makers' fuzzy ratings are performed according to the proposed procedure which is presented further.

In the first step, the elements of constructed fuzzy pair-wise comparison matrices are transformed into precise numbers by using the moment method (Dubios & Prade, 1980). In this way, the pair-wise comparison matrices are given. The consistency coefficient (C.I.) for each constructed pair-wise comparison matrices is obtained by using eigenvector (Saaty, 1990). If the (C.I.) value is less than 0.1 it may be considered that decision makers have made the accurate assessments. Otherwise, errors in judgments of decision makers are large and can significantly affect the accuracy of the solution.

Once the consistency of decision makers' assessment is determined, the weights vector of RFs under each considered RFs group should be calculated.

4.4. Modelling the risk levels

The each SC may have different risk levels and this paper proposes the defining of the three possible risk levels conditions – low risk level, medium risk level, and high risk level. The proposed risk levels represent the baseline for assessment of the overall risk in SC caused by economic and social RFs. The stated risk levels can be modelled by one of the three predefined linguistic terms. These linguistic expressions are modelled by TrFNs:

- Low risk level - $\tilde{S}_1 = (x; 0, 0.02, 0.05, 0.07)$
- Moderate risk level - $\tilde{S}_2 = (x; 0.01, 0.05, 0.1, 0.15)$
- High risk level - $\tilde{S}_3 = (x; 0.1, 0.5, 1, 1)$

Since the overlaps between each two TrFNs are large, it could be noticed that there is a lack of knowledge about the risk level in SC. The proposed values of the defined risk levels are representing the initial drafts assessed by decision makers in the automotive industry SC in Serbia. These values may be changed and adjusted according to the specific needs of the treated SC.

5. The proposed algorithm

The proposed Algorithm can be carried out in several steps which are presented.

Step 1. Calculate the aggregated severities of the consequences arising from the materialisation of RF i, $i = 1,..,I$ by applying fuzzy averaging method:

$$\tilde{C}_i = \frac{1}{J} \cdot \sum_{j=1}^{J} \tilde{v}_j \tag{1}$$

where:

$$\tilde{C}_i = \left(x; \frac{1}{J} \cdot \sum_{j=1}^{J} l_j, \frac{1}{J} \cdot \sum_{j=1}^{J} m_j, \frac{1}{J} \cdot \sum_{j=1}^{J} u_j \right)$$

Step 2. Calculate the risk value that may arising from the materialisation of RF i, $\tilde{P}_i, i = 1, .., I$:

$$\tilde{P}_i = \tilde{f}_i \cdot \tilde{C}_i = \left(p_i, \mu_{\tilde{P}_i}(r_i) \right) \tag{2}$$

The fuzzy number $\tilde{R}_i$ is obtained by applying expression for fuzzy sets multiplication and it may be approximated TFN such as $\tilde{P}_i = (l_{pi}, m_{pi}, u_{pi})$. The upper and lower bounds are denoted as l_{pi}, u_{pi}, respectively and m_{pi} is modal value.

Step 3. Setting up of the fuzzy pair wise comparison matrices of the social and economic RFs relative importance and determine their consistency.

Step 4. Determination of weights vector of considered RFs, $W = (w_1, .., w_i, ..., w_I)$ by applying concept of extended analysis (Chang, 1996).

The value of fuzzy synthetic extent with respect to the RF i-th under each considered RFs group is defined as:

$$\tilde{S}_k = \left(\sum_{i=1}^{I} l_{ii'}, \sum_{i=1}^{I} m_{ii'}, \sum_{i=1}^{I} u_{ii'}\right) \cdot \left(\frac{1}{\sum_{i=1}^{I}\sum_{i'}^{I} u_{ii'}}, \frac{1}{\sum_{i=1}^{I}\sum_{i'}^{I} m_{ii'}}, \frac{1}{\sum_{i=1}^{I}\sum_{i'}^{I} l_{ii'}}\right) \tag{3}$$

The weights vector:

$$W_p = \left(\left(Bel\left(\tilde{S}_1\right)\right), \ldots, \left(Bel\left(\tilde{S}_i\right)\right), \ldots, \left(Bel\left(\tilde{S}_I\right)\right)\right) \tag{4}$$

Measure of belief that TFN, $\tilde{S}_i$ is greater than or equal to all other TFNs $\tilde{S}_i{}'$, is designated as $Bel(\tilde{S}_i)$ $(i, i' = 1, .., I; i \neq i')$. These values are calculated by means of the method for fuzzy numbers comparison that has been introduced in (Baas & Kwakeernak, 1977; Dubois & Prade, 1980). These values belong to the set of real numbers between 0 and 1.

The normalised vector weights is:

$$W = (w_1, .., w_k, \ldots, w_K) \tag{5}$$

Step 5. Calculate weighted risk values by using fuzzy algebra rules (Zimmermann, 2011):

$$\tilde{R}_i = w_i \cdot \tilde{P}_i = \left(x; w_i \cdot l_{pi}, w_i \cdot m_{pi}, w_i \cdot u_{pi}\right) \tag{6}$$

Step 6. The fuzzy overall risk index is calculated as a union of the weighted risk values:

$$\tilde{R} = \bigcup_{i=1,..,I} \tilde{R}_i \tag{7}$$

Step 7. The representative scalar of TFN $\tilde{R}$, R is calculated by the means of the moment method (Dubois & Prade, 1980):

$$R = \frac{\int r_i \cdot \mu_{\tilde{R}_i}(r_i)}{\int \mu_{\tilde{R}_i}(r_i)} \tag{8}$$

Step 8. The region of risk level in the observed SC can be defined according to the rule:

IF the value of "overall risk index" is equal to R, THEN the region of risk level is described by the linguistic expression, where $\max_{q=1,2,2} \mu_{\tilde{S}_q}(x = R) = \mu_{\tilde{S}_{q^*}}$.

Step 9. Determine the ranks of RFs and the degree of belief that the risk value of one RF is greater than the risk values of the other RFs by applying method developed in (Baas & Kwakernaak, 1977; Dubois & Prade, 1980).

Step 10. Management initiatives which should be undertaken in order to reduce the RFs impact on the business goals achievement are defined in accordance with the obtained overall risk level, ranks of RFs and the obtained degree of beliefs.

6. Application of the proposed model

The considered automotive industry SC presents a part of a large multinational company and exists in Central Serbia and it includes manufacturing plant (focal organisation), its suppliers (suppliers of raw material and semi-finished products), and retailers. In focal organisation, final product is assembled, while suppliers are mainly domestic small and medium enterprises. The income realised by exporting the SC final product has the significant influence on the growth of gross domestic product.

Risk management team is originating from focal organisation, and it is consisted of human resources manager, financial manager, production manager, and supply and sales manager.

The number and the type of possible consequences should be determined by decision makers, who make their decisions by consensus. Their assessments are based on the experience and results of the best practice from the automotive industry. Collection of input data (consequences at the level of each RF, severity of consequences, relative importance of economic and social RFs, and frequency of RFs occurrence) are obtained by questionnaire, which contained the following questions: 1) assess the severity of each predefined consequence; 2) assess the relative importance of each pair of economic RFs; 3) assess the relative importance of each pair of social RFs; and 4) assess the frequency of each defined RFs occurrence.

This questionnaire has been sent to each decision maker. Each input data is associated with the linguistic expression that has been used most often, by the decision makers. If two or more linguistic expression were used in the same number of times, the procedure is repeated.

Economic and social RFs in SC were identified according to literature recommendations (Song, Ming, & Liu, 2016). Consequences that may arise due to the materialisation of each identified RFs, their severities, RFs frequencies of occurrence and the relative importance of RFs within each considered group, separately were assessed by decision makers. They established their assessments on the best practice results and experience. The severities of defined consequences for each RF and frequencies of RF occurrences are presented in Table 3.

Table 3. The severities of defined consequences and frequencies of RF occurrences.

Risk factors	Consequence/severity	Frequency of occurrence
$i = 1$	Liquidity reduction/H; profit decrease/MH; reduction of development/ML; declining of competitiveness/VH	*M*
$i = 2$	Liquidity reduction/; profit decrease/ML; reduction of development /L; declining of competitiveness /MH	*MH*
$i = 3$	Liquidity reduction/M; profit decrease/L; reduction of development /L; declining of competitiveness /M	*H*
$i = 4$	Liquidity reduction/ML; profit decrease/M; reduction of development /ML; declining of competitiveness /H	*ML*
$i = 5$	Inadequate lighting/M; higher level of noise/MH; higher concentration of dust /M; dispersion of working fluid in the working space/ML	*M*
$i = 6$	Inappropriate communication between managers and employees/L; unpaid overtime labour/MH	*VL*
$i = 7$	Lack of continuing education/MH	*L*
$i = 8$	Unethical behaviour of employees/ML	*L*

All calculations have been conducted in the *MatLab* environment. Results that are obtained by applying the developed Algorithm are presented in the next subsection.

6.1. Result section

The developed procedure in each step of the proposed algorithm is illustrated on the data related to *volatility of price and cost risk factor* RF (i = 1), for the rest of RFs final results are presented.

According to the proposed Algorithm (Step 1 to Step 2), the aggregated value of the consequence severities and risk values that may be arising due to the materialisation of the treated RFs are calculated. The aggregated value of consequence severity of RF (i = 1) is calculated by Equation (1):

$$\begin{aligned}\widetilde{C}_1 &= \frac{1}{4}\cdot\sum_{j=1}^{4}\left[(0.7, 0.85, 1) + (0.5, 0.65, 0.8) + (0.2, 0.35, 0.5) + (0.75, 1, 1)\right]\\ &= (0.54, 0.71, 0.82)\end{aligned}$$

The risk value of RF (i = 1) is obtained by applying Equation (2):

$$\widetilde{P}_1 = (0.35, 0.5, 0.65)\cdot(0.54, 0.71, 0.82) = (0.19, 0.36, 0.53)$$

Similarly, the values of risk that may arise from the materialisation of each RF are calculated and these values are:

$$\begin{gathered}\widetilde{P}_2 = (0.13, 0.27, 0.45), \widetilde{P}_3 = (0.12, 0.28, 0.47), \widetilde{P}_4 = (0.07, 0.18, 0.33), \widetilde{P}_5 = (0.12, 0.25, 0.42)\\ \widetilde{P}_6 = (0, 0, 0.14), \widetilde{P}_7 = (0, 0.1, 0.24), \widetilde{P}_8 = (0, 0.05, 0.15)\end{gathered}$$

The relative importance of economic RFs is stated by fuzzy pair-wise comparison matrix:

$$\begin{bmatrix} 1 & 1/L & L & M \\ & 1 & L & H \\ & & 1 & L \\ & & & 1 \end{bmatrix}, C.I. = 0.0987$$

The relative importance of social RFs is stated by fuzzy pair-wise comparison matrix:

$$\begin{bmatrix} 1 & H & 1 & M \\ & 1 & 1/M & 1/H \\ & & 1 & M \\ & & & 1 \end{bmatrix}, C.I. = 0.0999$$

By applying the concept of extended analyses (Step 3 of the proposed Algorithm), the weights vector of economic RFs and social RFs are calculated, respectively.

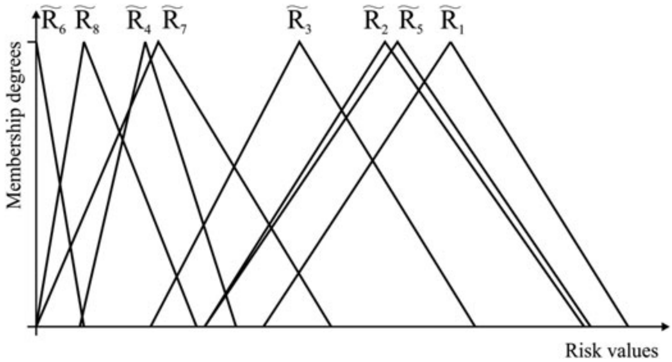

Figure 2. The fuzzy overall risk index value due to materialisation of all considered RFs.

By using Equation (3), the weights vector of the economic RFs is (0.29, 0.32, 0.23, 0.15).

The weights vector of the social RFs is (0.35, 0.09, 0.30, 0.26).

The weighted risk for RF (i = 1) value is calculated according to Step 4:

$$\widetilde{R}_1 = 0.29 \cdot (0.19, 0.36, 0.53) = (0.055, 0.104, 0.154)$$

Similarly, the weighted risk values for the rest of RFs are:

$$\widetilde{R}_2 = (0.042, 0.086, 0.144), \widetilde{R}_3 = (0.028, 0.064, 0.108),$$
$$\widetilde{R}_4 = (0.011, 0.027, 0.049), \widetilde{R}_5 = (0.042, 0.088, 0.147),$$
$$\widetilde{R}_6 = (0, 0, 0.013), \widetilde{R}_7 = (0, 0.03, 0.072), \widetilde{R}_8 = (0, 0.013, 0.039).$$

The fuzzy overall risk index value is obtained by applying the proposed Algorithm (Step 5). Union of the TFNs describing weighted risk values of social and economic RFs in automotive industry SC is calculated by Equation (4) and graphically presented on Figure 2.

By applying Equation (5) defined in (Step 6 of the proposed Algorithm), the overall risk crisp value is obtained, and it is:

$$R = 0.053.$$

By using the fuzzy IF-THAN rules (Step 7 of the proposed Algorithm), the risk level may be given, such as:

$$\mu_{\widetilde{S}_1}(x = 0.053) = 0.85, \mu_{\widetilde{S}_2}(x = 0.053) = 1$$

Since the max value (0.85, 1) =1, it may be stated that overall risk index level of the considered SC could be denoted as *moderate*.

The rank of considered RFs and degree of believe that RF can be placed in the first place in the rank are given by using the procedure (Step 8 of the proposed Algorithm) is presented in the Table 4.

Table 4. The RFs ranks and degree of belief that each RF can be placed at the first place in the rank

RFs	*Rank*	*The degree of belief that RF can be placed at the first place*
$i = 1$	1	1
$i = 2$	3	0.83
$i = 3$	4	0.57
$i = 4$	8	0
$i = 5$	2	0.85
$i = 6$	6	0
$i = 7$	5	0.19
$i = 8$	7	0

Discussion on the obtained results and management initiatives are presented in next subsection.

6.2. Discussion

The obtained result indicates that the risk level in the treated automotive industry SC can be described with the moderate value. Decision makers may define measures that should lead to decrease possible influence of those RFs with the greatest priority. In this case (see Table 3), these RFs are: *volatility of price and cost risk factor* ($i = 1$), *unhealthy/dangerous working environment risk factor* ($i = 5$), *inflation and currency exchange rates risk factor* ($i = 2$), *market share reduction risk* ($i = 3$), and *failure to fulfil social commitment risk* ($i = 7$). In this way, the overall risk level could possibly move to the low risk level domain.

Some of possible management initiatives that should lead to enhancement social and economic sustainability of SC are further analysed (Step 9 of the proposed Algorithm). Based on the presented results (Table 4), it may be concluded that the RF which has the greatest influence on the SC business operations is the *volatility of price and cost risk factor* (i = 1). Decreasing the impact of this RF may be achieved through undertaking of initiatives such as the greater cost control of inputs by applying appropriate cost management system, or greater process control by applying Activity Based Costing. According to results of good practice, it may be concluded that pricing policy development and investigation on how to allocate and relocate capacity of different market segments, as well as the cash flows development in SC may lead to reduction of this RF impact. Decrease of RF influence denoted as *unhealthy/dangerous working environment risk factor* (i = 5) may be accomplished through application of the following concepts such as reverse SC, SC green management, triple bottom line, product stewardship etc. If the reverse SC is incorporated, then the responsibility in SC is divided among SC members. Triple bottom line concept application may provide increased level of SC economical, ecological and social responsibility. Initiatives that lead to reduction of the *inflation and currency exchange rates risk factor* (i = 2) RF impact could not be made by decision makers of automotive industry SC. The degrees of belief that RFs *market share reduction risk* (i = 3), and *failure to fulfil social commitment risk* (i = 7) may be found at the first place in the rank are 0.57, i.e., 0.19, respectively. Based on these values, it may be stated that RFs (i = 3) and (i = 7) have the impact on the economic and social SC sustainability in a long-term period. By applying some management initiatives, such as opening of new markets and innovation improvements the impact of RF (i = 3) may be decreased. The decrease of RF (i = 7) impact could be achieved by implementation of issues referring to corporate social responsibility with many dimensions such as: community, environment, fair trade, etc. RFs denoted as the *reputation loss or brand damage risk* (i = 4), *violation of human rights* ($i = 6$), and *violation of business ethics* (i = 8) have the least possible impact on the economic and social SC sustainability. Impact decrease of these RFs may be based on the use of standard already known procedures.

7. Conclusion

The automotive industry presents one of the most important industrial branches in developed and developing countries. The importance of this industry is reflected through the increase of gross domestic product and through the decrease of unemployment. Having this in mind, the analysis of SC economic and social RFs presents an important management task, with the possible results that are propagated on the business effectiveness of SC and on the economic and social long-term stability of countries in which SC are operating.

Literature review shows that risk analysis could be performed by applying different analytic methods. Hence, it may be stated that each solution obtained in an exact way is less encumbered by the subjective decision makers' perspectives, so it may be considered as accurate. However, the presented methods have some assumptions, such as: all consequences duo to the materialisation of RFs or frequencies of RFs occurrence are not included, or if they are included in certain researches their values are described by crisp numbers.

In comparison to the papers presented in the relevant literature, this paper has certain strengths that may be denoted as the contribution of this paper in theoretical and practical domain.

In theoretical domain: (1) all possible consequences that may occur duo to the materialisation of economic and social RFs are analysed, (2) all existing uncertainties in severities of consequences, relative importance of RFs and frequencies of RFs occurrence are modelled by using fuzzy sets theory, since the SC is operating in turbulent business environment, it is reasonable to assume that evidence data are not reliable enough; the fuzzy sets theory is flexible and tolerant to imprecise and vague data (3) the weights vectors of RFs under each considered group of RFs is obtained by applying fuzzy Analytic Hierarchy Process (AHP), and (4) determination of the risk level of considered SC that is determined by using fuzzy IF-THAN rules, and (5) the proposed fuzzy model is easily understood and user friendly.

The proposed model is flexible, since: (1) all changes, as those in consequences severities or frequencies values and the membership function shape of fuzzy numbers, can be simple and quickly incorporated into the model, and (2) the proposed model could be modified to solve risk problems in different types of organisations, depending on the their size and branch of economy.

In practical domain, decision makers could determine the measures that should lead to reduction of RFs influence and risk level in a short time period. Management initiatives are defined with respect to obtained results and with long term sustainability objectives. Finally, the risk level of SC measuring provides the opportunities for strategic management to: learn and improve, report externally, and control and monitor business processes. In this way, it is possible to achieve social and economic sustainability, both in automotive SC, and a state economy. The proposed model may be useful for the systematic application of economic and social safety principles in SCs.

Besides the advantages, the proposed model has two main weaknesses that can be observed. Firstly, the assumption that there are no mutual dependences between RFs, and secondly, that the proposed model is tested on the real life data, which are obtained from only one automotive industry SC.

Further research should cover analysis of SC risk level originating from social and economic RFs materialisation that may be identified in a larger number of automotive industry SCs. Also, future research would include the development of user friendly software solution based on the proposed model that could provide significantly easier risk analysis and decision making.

Disclosure statement

No potential conflict of interest was reported by the authors.

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