Supply Chain Sustainability Risk Assessment Model Using Integration of the Preference Selection Index (PSI) and the Shannon Entropy

Agung Sutrisno

Department of Mechanical Engineering, Sam Ratulangi University, Manado, Indonesia.

E-mail address: agungsutrisno@unsrat.ac.id.

Vikas Kumar

Bristol Business School, University of The West of England, Bristol, United Kingdom

E-mail address: Vikas.Kumar@uwe.ac.uk.

Purpose

This study proposes a new model for assessing supply chain sustainability risk integrating subjectivity and objectivity of decision- maker. Research has shown the vacancy of study in dealing with above issue. To fill this research gap, a new decision support model considering subjectivity and objectivity of decision makers in assigning the weight of the supply chain risk reprioritization criteria is presented and demonstrated using a case example.

Design/Methodology/Approach

This study adopts a new decision support model for assessing supply chain sustainability risk based on additional Failure Mode and Effect Analysis (FMEA) parameters and its integration with Preference Selection Index (PSI) methodology and The Shannon entropy. A case example of the supply chain SME producing handy crafts has been used in this study.

Findings

The result of our study reveals critical sustainability risk dimensions and their risk elements demanding management attention to support realization to a more sustainable business operation.

Research limitations/implications

The use of a single case study is often associated as a limitation in the research studies, and this study is based on findings from Small and Medium Enterprise (SME) in the handy craft sector in a developing country. Nonetheless, future studies may focus on replicating this study using more samples. This preliminary study provides academics and practitioners with an exemplar of supply chain sustainability risk assessment from the SME in a developing country.

Practical implications

The result of this study is beneficial for practitioners, particularly owner-managers of SMEs who can use this study as guidance on how to identify and select the critical sustainability risks and plan mitigating strategies accordingly.

Originality/value

Scientific effort on appraising supply chain sustainability risk using the integration of the PSI and Shannon entropy method is missing in earlier studies. To the best of our knowledge, this is the first paper applying the PSI and Shannon entropy method and using it for evaluating supply chain risk based on five sustainability pillars. The findings and suggestions for future research initiatives will provide new insights for scholars and practitioners in managing SME supply chain sustainability risks.

1. Introduction

Small and medium enterprises are important contributors to the global economy not only because of their large economic contributions but also due to their role as a job absorbing sector in both developed and developing countries (Hanggraeni *et al.* 2019). However, due to inherent limitations of human and financial resources (Saad *et al.* 2017) it often makes their business prone to termination. Following the work of Tong *et al.* (2018), it is estimated that during the first decade of a business lifetime, only 13% of the SMEs will survive. This indication signals the importance of managing business risks in the context of SMEs to support their business standing in the long-time horizon. Government around the globe are currently enforcing organisations large or small to implement sustainable practices. Hence, improving methodology to aid SMEs to appraise the impact of sustainability risk will provide relevant sustainability risk mitigation strategies that in turn will improve its sustainability. Driven by the need to sustain global economic growth by reducing the adverse impact of business uncertainty, nowadays the theme of supply chain sustainability risk assessment is becoming one of the emerging research areas (Ghadge *et al.* 2012, Ho *et al.* 2015, Fahimnia *et al.* 2015; Kumar *et al.* 2018). Although the importance of sustainability risk assessment within supply chain context is getting more important, research attention devoted to improving methodology in Small and Medium Enterprises (SMEs) supply chain risk assessment approach are still scarce (Qazi and Gaudenzi, 2016), Vishnu *et al.* (2019) and Lima *et al.* (2020). As an aid to decision- makers in dealing with supply chain risk assessment within Small and Medium Enterprises, several studies have utilised various risk reprioritization methods. Anin *et al.* (2015) used traditional FMEA in which the determination of critical supply chain risks is based on multiplication among three risk indices namely, occurrence, detection and severity of risks

without the utilization of any multi- criteria decision- making method. Fuzzy logic -based supply chain risk reprioritization approach has been reported by Rohmah *et al*. (2015) and Muchfirodin *et al*. (2015). Slamet *et al*. (2017) presented the integration of Fuzzy logic and the ANP for ranking critical SME supply chain risks, Mustaniroh *et al*. (2019) used the integration of the AHP and Fuzzy logic to select critical SME supply chain risks. Babu *et al.* (2020) presented the use of the Interpretive Structural Model (ISM)-based supply chain reprioritization approach to improving understanding in selecting the most critical risks considering their interrelationship. Alora and Barua (2021) by using the integration of the AHP and Fuzzy TOPSIS revealed critical SME supply chain risks. Despite versatility on studies applying varying supply chain risk assessment models in aforementioned works, efforts to appraise the impact of risk in above mentioned SME supply chain which use the AHP and ANP approach are still based on decision- makers subjectivity in which pairwise comparison among risk criteria and consistency checking of decision -makers are becoming investigation basis.

Although establishment of decision support model to assess criticality of supply chain risks considering both of subjective and objectivity of decision makers is believed advantageous instead of reliance on subjective or objective stand-alone approach, however to the best of our knowledge such effort is vacant in supply chain risk management studies. Among studies on compiling supply chain risk assessment models presented by Rathore *et al*. (2017), Tran *et al.* (2018) and Vishnu *et al.* (2019) are showing vacancy of studies dealing with the above issue. While efforts to consider decision- makers subjectivity and objectivity in assigning risk priority ranking are already reported by Wen *et al.* 2021 and Pintelon *et al.* 2021, studies intended to consider decision makers subjectivity and objectivity in the supply chain risk assessment area is vacant in references. Subjective evaluation of risk criteria occurred when decision maker uses his or her own preference in assigning the risk criteria score, meanwhile objective risk evaluation process is accomplished by calculating mathematically to the all-risk elements in the decision matrix (Chaitanya and Srinivas, 2021).

In an attempt to support decision- makers determining priority ranking in a multi -criteria decision making environment, Maniya and Bhatt (2010) introduced the Preference Selection Index (PSI) method. Considering its simplicity, this method is getting wider acceptance being used in various applications areas such as evaluating the performance of flexible manufacturing system evaluation (Jain, 2018), determining optimum process parameters (Parizi *et al.* 2017), selecting the best accommodation (Aksoy and Ozbuk, 2017), maintenance planning (Pancholi and Bhatt, 2018). However, the utilisation of this method in supply chain risk evaluation studies, to the best of our knowledge is vacant in literature. Along with the intention to develop

a subjective and objective decision support model simultaneously for supply chain risk evaluation which is also missing in previous studies, this paper intends to develop a new decision support model for evaluating the criticality of supply chain sustainability risk of SME considering subjectivity and objectivity of decision- maker using the integration of the PSI and the Shannon entropy.

The objectives of this paper are as in the followings

- To present the objective and subjective supply chain sustainability risk assessment model based on the integration of the PSI and The Shannon entropy method.
- To determine critical supply chain sustainability risks based on the decision support model using the integration of the PSI and the Shannon entropy based on case example.
- To elaborate the theoretical and practical offering by this study.

The structure of this paper is as follows. In section 2, a short description of supply chain sustainability risks and followed by an overview of supply chain sustainability risks assessment and the state of the art of use of the supply chain risk assessment tool, the FMEA in the supply chain context. Section 3 relates to an overview of the PSI, state of the art in applying this method and establishment of supply chain sustainability risks assessment model based on integrating the PSI and The Shannon Entropy into supply chain FMEA framework. A case example applying the framework using SME Supply chain producing handy crafts based on five pillars of sustainability is presented in section 4. Findings, discussion, and limitations of the model used are presented in section 5. Finally, section 6 concludes this study with directions for future research.

2. Literature review

This section relates to the description of supply chain sustainability risks and compilation of earlier studies in supply chain sustainability risks and the implementation of supply chain FMEA as qualitative tool for assessing supply chain sustainability risks and outlines the research gaps motivating this research.

2.1 Overview of supply chain sustainability risks and its advancement of studies

Correlating to any factor brings negative consequences, risk is possessing two attributes namely, the likelihood of risk event occurrence and its adverse impact (Majumdar *et al*. 2020). In line with the growing importance of managing business operation against impact of business risks, Junaid *et al.* (2019) presented various definition of risk from scholars and yielding conclusion that supply chain risk can be defined as the adverse impact of risk events occurrence when companies doing business with their partners. Within the supply chain management

discipline, supply chain risk assessment is one of the critical enablers of successful supply chain risk management (Prashar and Aggarwal, 2019). In improving understanding on the category of supply chain risks impact, Shafiq *et al.* (2017) presented categorization of supply chain risks into two broad categories; operational and sustainability type supply chain risks. The first supply chain risk category refers to any risk events bring negative impact temporarily to operational of supply chain and usually concentrated on cost, delivery and quality problems and sustainability risk as the risk events occurred bringing adverse environmental and social impacts.   Other scholars, Louis and Pagel (2019) presented categorization of supply chain risk into two classes, ordinary and sustainability risk. The former risk focuses on typology of supply chain risk that have temporary impact on the company and has no consequences on the existential of the company in the long-time horizon. In the opposite, sustainability supply chain risk has longer adverse impact on the firm threatening the existential of business in longer time horizon and closely related with capability to provide the need of future generation. Departing from the adverse impact of sustainability risks, Iddirisu and Bhatarachaya (2015) suggested the expansion of sustainability pillars into five pillars namely, economical, technical, environmental, social, and institutional dimensions. Driven by growing interests in managing supply chain sustainability risk, studies dealing with improving methodology for prioritization of supply chain sustainability risks are growing recently. Table 1 presents scientific efforts which focusing on supply chain sustainability risk assessment.

Table 1. Studies focusing on supply chain sustainability risk assessment

Author(s)	Description	Enterprise type	Author country of origin
Gianakis and Papadopoulos (2016)	Exploring categories of sustainability risks using case example from developed economy setting and proposing risk management approaches based of conventional FMEA	Large enterprise	France and UK
Rostamzadeh et al., (2018)	Evaluating critical supply chain sustainability risk using TOPSIS and CRITIC	Large enterprise	Iran and Denmark
Baseet and Mohammed (2019)	Integrating TOPSIS and CRITIC methods to appraise criticality of sustainability risk	Large enterprise	Egypt
Song et al., (2019)	evaluating the impact of internal-and external supply chain risk factors using DEMATEL (Decision Making Trial and Evaluation Laboratory)	Large enterprise	China

Valinejad and Rahmani (2018)	Determining critical supply chain sustainability risks based on five pillars of sustainability	Large enterprise	Iran
Xu et al., (2019)	Development of a framework to quantify supply chain sustainability risks using risk assessment space and materiality analysis	Large enterprise	China
Rezgdeh and Shoukohyar (2020)	Inclusion of information technology dimension in assessing supply chain sustainability risk	Large enterprise	Iran
Chen et al., (2021)	Investigation on relationship of critical success factors for supply chain risk mitigation in telecommunication industry	Large Enterprise	India
Jianying et al. (2021)	Applying integrated neural network with Genetic Algorithm and Particle Swarm Optimization methods to determine the most critical supply chain sustainability risks	Large enterprise	China
Yang et al. (2021)	Evaluating sustainable SME credit risks within financial supply chain	Small enterprise	China
Raian et al.(2021)	Applying Fuzzy Synthetic method to evaluate sustainability risks in textile supply chain	Large enterprise	Bangladesh
Wang and Rani (2021)	Integrating double normalization-based multiple aggregation (DNMA) model and fuzzy logic for ranking sustainable manufacturing supply chain risk	Large enterprise	China
Haji et al. (2021)	Applying integrated Best-Worst Method (BWM) and fuzzy-WASPAS Methods for ranking sustainable risks in food supply chain	Large enterprise	Iran

At the other side, the use of FMEA as methodological approach to assess criticality of supply chain risk is continuously growing irrespective to the type of supply chain risk factors being evaluated. Table 2 presents compilation of studies on utilising the FMEA as means to evaluate criticality of supply chain risks.

Table 2. Studies pertaining on applying FMEA methodology for supply chain risk assessment

Author(s)	Content	Supply chain risk reprioritization tool	Risk reprioritization parameters	Supply chain type
Ghadge et al. (2017)	Solving root cause of quality risks in global supply chain	Fuzzy logic	Severity, detection and occurrence of risk	Electronics product supply chain
Nakandala et al. (2016)	Analysing criticality of risks in fresh	Fuzzy logic and Hierarchical	Occurrence and severity	Food supply chain

		food supply chain	holographic modelling		
Prakash *et* al.(2017)	Modelling interrelationship among risks in food supply chain	Interpretive structural modelling (ISM)	Occurrence, detection and severity	Food supply chain	
Mohan (2017)	Selecting critical risk exposure index in pharmaceutical industry	AHP	Occurrence, detection and severity	Pharmaceutical products	
Sheshe (2018)	Evaluating criticality of risk factors in humanitarian supply chain	None	Occurrence, detection and severity	Humanitarian operation	
Liu et al., (2018)	Determination of critical safety risk in gas station supply chain	Entropy	Occurrence, detection and severity	Gas station supply chain	
Mangla et al., (2018)	Determining critical risk factors in green supply chain	Fuzzy Logic	Occurrence, detection and severity	Plastic Manufacturing	
Alzubayer et al., (2019)	Evaluating criticality of supply chain risks in ceramic	Fuzzy TOPSIS	Quality of process control, probability of risk event occurrence and severity of risk effect	Ceramic	
Olivos *et al.,* 2019	Assessing criticality of risk factors in tools manufacturing	AHP	Occurrence, detection and severity	Fabricated Tools	
Wu et al., (2019)	Assessing criticality of supply chain in automobile manufacturing	Fuzzy Synthetics evaluation	Occurrence and severity	Automobile product	
Rathore *et al.* (2020)	Assessing critical supply chain risks in food grain supply chain	Fuzzy VIKOR	Occurrence, Detection and Severity	Food	
Mzougui *et al.* (2020)	Identifying Critical supply	AHP and fuzzy DEMATEL	Occurrence, cost,	Automotive product	

	chain risk in Automotive manufacturing supply chain		dependence and strategic impact	
Panahi *et al.* (2020)	Determining critical supply chain risks in Event Weather in the Artic	AHP and Bayesian Network	Occurrence, visibility	Maritime supply chain
Raghuram *et al.* (2020)	Determining supply chain risk maturity index	Ordered Magnitude-AHP	Probability and severity of risk	Distillery industry
Zhu *et al.* (2020)	Identifying critical risks in product deletion and its impact to supply chain	None	Occurrence, detection and severity scale	Consumer products
Moktadir *et al.* (2021)	Identifying critical supply chain sustainability risk	Pareto Analysis-Best Worst Method (BMW)	None	Leather
Anugerah *et al.*, (2021)	Selecting critical sustainable supply chain risks	AHP	Occurrence, Detection and severity scale	Palm oil

Referring to Table 1 dan table 2, it is evident that despite increasing number of studies reported the use of many multi-criteria decision-making approaches in supply chain risk evaluation using FMEA framework, it is clear that supply chain sustainability risks evaluation using the PSI method is vacant and motivating this study. Moreover, integrated model of the PSI and Shannon entropy as new offering approach to assess the magnitude of supply chain is absent in previous references.

2.2. Integrating the PSI and Shannon entropy- the model

The following notations are used to develop decision support model for ranking supply chain sustainability risk using FMEA methodology.

W_O^S = Preference score of the risk occurrence attribute;

W_D^S = Preference score of the detection of risk attribute;

W_S^S = Preference Score of the severity impact of risk attribute;

W_{SN}^S = preference score of the sensitivity of supply chain attribute;

W_R^S = preference score of the recoverability of supply chain attribute;

W_O^O = objective weight of the risk occurrence attribute;

W_D^O = objective weight of the risk detectability attribute;

W_S^O = objective weight of the risk severity attribute;

W_{SN}^O = objective weight of the risk sensitivity attribute;

W_R^O = objective weight of the risk recoverability attribute;

O_i = Risk occurrence Scale of Risk variable i;

D_i = Risk Detectability Scale of Risk variable i;

S_i = Risk Severity Scale of Risk variable i;

SN_i = Sensitivity scale of supply chain under study against impact of risk element i;

R_i = Recoverability scale of supply chain under study against adverse impact of risk element i;

ψ_j = preference score of decision maker against risk reprioritization criteria j;

W_C^j = Compromise weight of supply chain risk prioritization criteria j;

β = adjustment factor;

W_{e_j} = Score of the entropy of the risk reprioritization attribute j;

W_{X_i} = Relative weight of the risk element element i;

μ_i = Mean risk priority number of risk element i ;

τ_i = Standard deviation of risk priority number of risk element i;

Where i= 1,2,3…., m and j=1,2,3,….n.

2.3. Overview of Preference Selection Index (PSI) method and its application area

Preference Selection Index (PSI) methodology is firstly introduced by Maniya and Bhatt (2009). This method is a typology of multi criteria decision making method which simultaneously optimizes two or more conflicting attributes. In the PSI method, determination of the attribute for priority ranking is based on beneficial (profit) and non-beneficial attribute (cost). Beneficial attributes are those kind of attribute in which the larger is score is better. In reverse, the non-beneficial attributes are typical of attributes in which the lower of its score is better.

 Due to its capability to aid decision makers in making less complicated reprioritization in decision-making process, the use of the PSI is becoming more versatile to various areas as reported in Table 3. As can be seen in Table 3, despite growing number of studies applying the

PSI method into varying application area exist, however no previous studies reported it into supply chain risk assessment application.

Table 3. Compilation on studies in the use of PSI methodology

No	Authors	Content	Country
1	Joseph and Sridharan (2011)	Using PSI method for selecting priority scheduling rules in flexible manufacturing system	India
2	Maniya and Bhatt (2011)	Selecting flexible manufacturing System	India
3	Attri et al., (2014)	Ranking cutting fluids using a novel decision-making method: preference selection index	India
4	Paul et al., (2014)	Ranking Priority Dispatching rules for assembly job shop scheduling	India
5	Singh et al., (2015)	Selecting optimum Brake material specification	India
6	Attri and Grover (2015)	Designing life cycle of production system	India
7	Chamoli (2015)	Determining optimal parameter design of Channel Flow	India
8	Sharma and Singhal (2016)	Selecting best plant lay out option	India
9	Chauhan et al.,(2016)	Optimising design parameter of Solar Thermal Collector	India
10	Khorsidhi and Hasani (2013)	Comparing Performance of PSI and TOPSIS method for selecting composite material properties	Iran
11	Mayyas et al., (2013)	Selecting eco-oriented automotive materials	USA
12	Parizi et al., (2017)	Determining process parameters in manufacturing composite materials	Iran
13	Nadda et al., (2018)	Determining the best mechanical design parameters of a solar air heater	India
14	Patel et al. (2018)	Selecting optimum process parameters for Polylactic Acid	India
15	Reddy et al., (2019)	Selecting optimum cementitious material properties	India
16	Ezatpour et al., (2016)	Selecting best combination material properties of Aluminium Nano composites	Iran
19	Borujeni and Gitinavard (2017)	Selecting sustainable mining contractor	Iran
20	Madic et al (2017)	Determining optimum Laser process condition	Serbia and Lithuania
21	Pathak et al., (2019)	Determining optimal scanning conditions	India

22	Jha et al., (2018)	Determining Optimum phase combination of biodegradable composite	India
24	Kumar and Kumar (2020)	Selecting best composite materials	India
25	Singh et al., (2020)	Selecting best composition of Polypropylene composite	Hungary and India
26	Biswas and Anand (2020)	Integrating Preference Selection Index (PSI) and Proximity Value Index (PVI) for evaluating logistics competitiveness scale between BRICS and G7 Countries	India
27	Kumar et al., (2021)	Selecting best composition for optimum performance of metallic alloy	India
28	Jain et al., (2021)	Selecting the rank of Flexible Manufacturing System (FMS) flexibility	India
29	Ulutas et al. (2021)	Combining Preference Selection Index (PSI) and Proximity Value Index (PVI) for warehouse selection	Turkey

Intended to be used as means to determine the score of the subjective weight in appraising the weight of supply chain risk reprioritization criteria, steps to determine the subjective weight of risk reprioritization criteria is as follows.

Step 1. Determining the goal of applying the PSI.

Step 2. Identifying supply chain risk variables R_i (i=1, 2, 3, …., m) and risk reprioritization criteria C_j (j=1, 2, 3, … n).

Step 3. Constructing a risk decision matrix by arranging its column as risk reprioritization attributes and its rows as risk variable alternatives as below:

Table 4. A Typical Supply Chain Risk Decision Matrix

	C1	C2	C3	………	Cn
R1	P_{11}	P_{12}	P_{13}	………	P_{1n}
R2	P_{21}	P_{22}	P_{23}	………	P_{2n}
R3	P_{31}	P_{32}	P_{33}	………	P_{3n}
………	………	………	………	………	………
Rm	P_{m1}	P_{m2}	P_{m3}	………	P_{mn}

Step 4. Normalizing decision matrix. For determining the weight of risk criteria using the PSI, normalization of supply chain risk decision matrix can be accomplished by categorization of

beneficial and non-beneficial attributes. For non-beneficial attribute, normalization of risk alternatives following equation 1.

$$R_{ij} = \frac{P_{ij}}{P_{j,max}} \; ; \; \forall i, j, \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (1)$$

Meanwhile for beneficial type risk reprioritization attribute, equation 2 is used.

$$R_{ij} = \frac{P_{j,min}}{P_{ij}} \; ; \; \forall i, j, \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (2)$$

Step 5. Determining mean value of normalized data for risk attribute $\overline{R_j}$. Computation of the mean value of normalized data $\overline{R_j}$ is accomplished by using equation 3.

$$\overline{R}_j = \frac{1}{m} \sum_{i=1}^{m} RV_{ij}, \; \forall i, j$$
$$\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (3)$$

Step 6. Determining deviation preference value. Computation of the preference deviation value data is accomplished by using equation 4.

$$PV_j = \frac{1}{m} \sum_{i=1}^{n} \left[R_{ij} - \overline{R}_j \right]^2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (4)$$

Step 7. Determining deviation preference value of each risk attribute j using the equation 5.

$$\Phi_j = |1 - PV_j| \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (5)$$

Step 8. Calculating overall preference value of risk attribute j by using equation 6.

$$\Psi_j = \frac{\Phi_j}{\sum_{j=1}^{m} \Phi_j} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (6)$$

The result of step (8) is the preference score of each risk reprioritization attributes which representing the decision maker preference. This preference is functioning as surrogate of the weight of the risk attributes. Let now Ψ_j becoming the preference score against risk reprioritization criteria j.

2.4. Shannon entropy

Following Ouyang et al., (2013), entropy represents the amount of information uncertainty from discrete probability distribution. The entropy method is useful to determine the objective weight of reprioritization criteria. If the data in the decision matrix is known, the weight of the criteria can be counted objectively. Becoming the method to determine the objective weight

of supply chain risk reprioritization criteria, the Shannon entropy is adopted by many studies dealing with priority ranking in various areas such as evaluating the risk of equipment failure (Sachdeva *et al*. 2009), selecting supplier (Liu and Zhang, 2011), managing public rental housing (Wu *et al*. 2017), materials selection (Bakhoum and Brown, 2013 and Hafezalkotob and Hafezalkotob, 2016), managing project (Moarefi *et al*. 2028), Beverage selection (Isik and Adali, 2017), selecting drivers for implementing lean construction (Dehdasht *et al.* 2020). The procedure to determine the objective weight of the supply chain sustainability risk criteria by using the Shannon entropy can be described as in the followings.

Step 1. Determine decision matrix D which is containing n supply chain sustainability risk prioritization criteria and m risk variable.

$$D = \left[X_{ij}\right]_{mxn} = \begin{bmatrix} x_{11} & x_{12} \dots & x_{1n} \\ x_{21} & x_{22} \dots & x_{2n} \\ \vdots & \vdots \ddots & \vdots \\ x_{m1} & x_{m2} & x_{mn} \end{bmatrix} \text{ (i=1,2,3,...m) and j=1,2,3,...n).}$$

x_{ij} presents the performance value of risk variable i for risk reprioritization attribute j.

Step 2. Normalizing the decision matrix. For beneficial risk reprioritization attributes, use equation (7) and for non-beneficial risk reprioritization attributes, use equation (8).

$$r_{ij} = \frac{X_{ij} - min(X_{ij})}{max(X_{ij}) - min(X_{ij})} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(7)$$

$$r_{ij} = \frac{max(X_{ij}) - X_{ij}}{max(X_{ij}) - min(X_{ij})} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(8)$$

Step 3. The entropy of the j risk reprioritization criteria is counted using equation 9.

$$e_j = -\frac{\sum_{i=1}^{m} f_{ij} ln f_{ij}}{ln m} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (9)$$

Where $f_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}$ and $e_j \in (0,1)$.

Step 4. Calculating the objective weight of the risk reprioritization criteria using equation 10.

$$We_j = \frac{1-e_j}{n - \sum_{i=1}^{m} e_j} \text{ and } \sum_{i=1}^{n} W_j = 1 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(10)$$

Pertaining to the use of the Shannon entropy to aid risk reprioritization decision making, Table 5 presents compilation of previous researches devoted to rank criticality of risk.

Table 5. Studies applying Shannon entropy for appraising the weight of risk reprioritization criteria

No	Author(s)	Content	Application Area
1	Xin, J (2008)	Ranking risk of radioactive protective measures	Nuclear Power Plant

2	Yu, C., Zhang,B.,Yao, Y., Meng, F. and Zheng, C. (2013)	Determining most important risk factors of groundwater contamination	Groundwater vulnerability assessment
3	Josi, S.A.,Shafiee, M., Moradimaj, N., and Saffarian, S., (2012)	Determining relative weight on environmental risk reprioritization criteria	Environmental risk assessment
4	Mavi et al., (2016)	Appraising the weight of risk criteria in supplier selection	Motorcycle manufacturing
6	Sutrisno et al. (2018)	Evaluating relative importance of lean waste risk reprioritization criteria	Geothermal power generation Maintenance
7	Liu et al. (2018)	Determining risk relative importance risk criteria	Healthcare
8	Shahin et al. (2019)	Ranking supply chain risks using Shannon entropy and fuzzy TOPSIS	Home appliance
8	Gheib et al. (2019)	Estimating the weight of risk reprioritization criteria	Water treatment plan
9	Eshanifar, M. and Hemesy, M.(2021)	Appraising relative weight of risk variables in construction project	Construction Project
10	Pintelon, et al. (2021)	Determining relative weight of risk reprioritization attribute	Medical device development
11	Wang et al. (2021)	Determining relative weight of risk reprioritization attribute	Mechatronic production process

Among eleven studies applying the Shannon entropy to assess criticality of risk only the works of Mavi *et al*., (2016) and Shahin *et al*., (2019) which deal with subjective determination of relative importance of risk criteria.

2.5. Compromise weighting of risk criteria using preference selection index (PSI) index and the Shannon Entropy

In an attempt to combine both of subjective and objective supply chain risk reprioritization method, subjective risk weightage process based on the PSI method and objective risk

weightage process using the Shannon entropy is accomplished by combining equation 6 and 10. Next, a compromise weighting method used to represent combination of subjective and objective approach and formulated as in equation 11.

$$W_c^j = \beta\psi_j + (1-\beta)We_j \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \ (11)$$

With $\beta \in (0,1)$.

2.6. Inclusion of the relative impact of supply chain risk element using relative weight method

In evaluating the impact of risk, usually one risk element is having relative weight impact against other risk elements affecting the score of the risk priority number. In accommodating the impact of each risk element relative to other risks, the concept of relative weight can be used as an approach to consider the relative impact of risk to support decision making. The concept of relative weight has been used as means to consider the relative impact of factors affecting risk priority decision making. Researches applying the relative weight method is many such as investigating the impact of environmental factors for software development (Zhang *et al.* 2015), investigation on the impact of airline cabin environment (Jia *et al.* 2018), impact of failure factors to the wind turbine (Li *et al.* 2020). Suppose that there are n risk element X_i with i=1,2, 3,..,n; then the risk relative weight from risk element X_i is expressed as equation 12.

$$w_{X_i} = \frac{X_i}{\sum_{i=1}^{i=N} X_i} \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \ (12)$$

2.7. Integrating the Shannon Entropy and The Preference Selection Index (PSI) -the model

2.7.1. Additional supply chain sustainability risk Reprioritization Criteria

Supply chain FMEA is a typical risk assessment method used to evaluate the impact of risk within supply chain scope. In evaluating the impact of risk, in similar with design and process FMEA, supply chain FMEA using three risk reprioritization criteria namely, occurrence, detection and severity of risk. Nevertheless, reliance on these three criteria is insufficient in quantifying the impact of risk element and in line with development of FMEA risk reprioritization model, additional criteria such cost as compiled by Liu *et al.* (2013), substitutability, production capability and profit contribution (Selim *et al.* (2015), experiences and profession hierarchy of decision makers (Fatahi *et al.* 2020) are added to comprehend risk assessment approaches. Considering that enterprise supply chain may have sensitivity against

impact of a certain risk element and also capability to recover from impact of a particular risk, to improve comprehensiveness of supply chain risk assessment, Lahmar et al., (2018) suggest to consider sensitivity against impact of a risk. Following Behzadi et al., (2018), along with occurrence, detection and severity of risk, recoverability from impact of risk shall be taken into consideration in appraising criticality impact of risk becoming more comprehensive. Considering this situation, additional criteria for supply chain risk ranking is then presented in Table 6.

Table 6. Additional supply chain FMEA risk reprioritization criteria

Score	Linguistic Interpretation	Sensitivity of supply chain	Occurrence Of risk variables	Detectability occurrence of risk variables	Severity of risk effect	Recoverability of supply chain
1	Remote	Supply chain is insensitive against impact of risk	The chance of risk event occurrence is remote	The occurrence of risk variables is directly observable by no means of detection tool	The impact of risk is negligible	No effort needed to recover supply chain disruption
2	Small	Supply chain is small sensitive against impact of a risk	The chance of risk event occurrence is small	The occurrence of risk variables is moderate difficult detected using detection tool and method by the company	The impact of risk is little annoyance to the customers	Little effort needed to recover supply chain disruption
3	Medium	Supply chain is medium sensitive against impact of a risk	The chance of risk event occurrence is medium	The occurrence of risk variable is rather difficult to detect by any means of company	The impact of risk is causing very high dissatisfaction to the customers	Medium effort needed to recover supply chain disruption. No need external resource for recoverability

						detection method
4	high	Supply chain is highly sensitive against impact of a risk	The chance of risk event occurrence is high	The occurrence of risk variable is very difficult to detect by any means of company detection method	The impact of risk is having consequence to regulatory violation	Recoverability of supply chain is demanding intervention by external bodies outside of the company
5	Very high	Supply chain is very sensitive against impact of risk occurrence	The chance of risk occurrence is inevitable	The occurrence of risk variable is undetected by any means of company detection method and reported by the customers	The impact of risk is affecting health and safety and may be causing death	Recoverability of supply chain is demanding all out intervention by external bodies outside of the company

A typical supply chain FMEA sheet presenting these additional risk reprioritization parameters is given in Table 7.

Table 7. A typical of Supply Chain FMEA sheet

Supply chain risk dimension	Supply chain risk element	Supply Chain Risk Reprioritization Attributes					Risk priority number
		Risk occurrence (O)	Risk detection (D)	Risk severity (S)	Risk sensitivity (SN)	Risk recoverability (R)	
SRD_1	RF_1	O_1	D_1	S_1	SN_1	R_1	RPN_1
.	RF_2	O_2	D_2	S_2	SN_2	R_2	RPN_2
.	RF_3	O_3	D_3	S_3	SN_3	R_3	RPN_3
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
SRD_m	RF_m	O_m	D_m	S_m	SN_m	R_m	RPN_m

2.7.2. New Risk Priority Number

In representing the metric as measure of risk criticality impact, FMEA using multiplication of the three risk reprioritization parameters namely, occurrence, detection and severity of risk. Mathematically, the metric of risk in FMEA which is named Risk Priority Number (RPN) is formulated by following equation 13.

$$RPN_i = O_i D_i S_i \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (13)}$$

Taking into account to emphasize on effectiveness to detect and prevent the reoccurrence of a risk event, Sahwney et al., (2010) suggest to modify equation 13 into equation 14 where detectability of a risk becomes a denominator in ranking a risk.

$$RPN_i = \frac{O_i S_i}{D_i} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (14)}$$

Next, Braglia (2000), Bevilacqua et al. (2000), Carmignani (2009), Taghipour et al. (2011) and Bojan and Blazic (2015) declared that the criticality of a particular risk can be quantitatively counted as the sum of the impact risk reprioritization criteria. Furthermore, Carmignani (2009) presented that risk priority score is also affected by the score of the relative weight of a risk element against other risks. As a manifestation of negative uncertainty, the company usually will take the form of a risk impact evaluation approach which emphasizes risk detectability to prevent the reoccurrence risk factors or reduce the impact of a risk. Taking into account the effect of the compromise weight of the risk priority criteria from equation 11, the relative weights among risk elements in equation 12 and the emphasis on the ability to detect and control risk as suggested by Sahwney et al., (2010) in equation 14, the new RPN index estimation model of a supply chain risk element is expressed by the equation 15.

$$RPNRF_i = \frac{W_C^O \frac{O_i}{\sum_{i=1}^{m} O_i} + W_C^S \frac{S_i}{\sum_{i=1}^{m} S_i} + W_C^{SN} \frac{SN_i}{\sum_{i=1}^{m} SN_i} + W_C^R \frac{R_i}{\sum_{i=1}^{m} R_i}}{W_D \frac{D_i}{\sum_{i=1}^{m} D_i}} \quad \dots\dots\dots\dots\dots \dots\dots \text{ (15)}$$

As enterprises are having limited resources to mitigate the impact of a risk event, it is necessary to determine the cut off RPN score to delineate among critical risk elements demanding immediate preventative or corrective action and non-critical risks in which their risk mitigation efforts could be postponed later. Following suggestion of Rezgdeh and Shokouhyar (2020), if the mean RPN score is μ with deviation standard τ, then the critical risks and non-critical risk are counted by equation 16 and 17.

$$RPN_{crit} = \mu + \tau \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (16)}$$

$$RPN_{noncrit} = \mu - \tau \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (17)}$$

4. Research Methodology

4.1 Case study description

To demonstrate the use of integrated PSI and The Shannon entropy into Supply Chain FMEA model as new offering method to assess criticality of supply chain sustainability risk, a case study (Yin, 2014). The framework of research approach as presented by Mangla *et al.*, (2015) and Anugerah *et al.* (2021) is used as reference model. A case example focused on the SME sector selling wooden handicraft is chosen. In the context of Indonesia as developing country, among other type of SME operating sectors, handy craft sector is becoming the third rank contributor to the Indonesian GDP and acting role as workforce absorber since the number of handicraft SME is up to 19% from the whole of the number of SMEs in Indonesia (Badruddin and Siregar, 2018, Raya *et al.*, 2021). In accordance to Shafi *et al.*, (2019), this SME sector comparing to other SME sectors are having distinct characteristics' such as creating jobs with least investment costs, consuming least energy and carrying cultural and traditional knowledge to the descendance generation. The locus of the study is located at an SME producing wooden handy crafts for tourism located in West Sumatera Province, Indonesia. The case study employed three stages of supply chain sustainability risk evaluation. The first step pertains to determination on the supply chain sustainability risk elements. Second step related to the determination of each supply chain sustainability risk element and counting the subjective and objective weight of supply chain risk reprioritization criteria. In the third step, determination of the cut of RPN and critical RPN suggested for becoming management attention is presented.

4.1.1. Supply chain sustainability risk element determination

In the first stage, construct validity of the research is determined based on literature reviews to supply chain literature with the aim to determine the category of supply chain sustainability risk dimensions and their risk elements. The result of this first step is categorization of sustainability risk dimensions and risk variables and its supporting references as depicted in Table 8.

Table 8. Categorization of supply chain sustainability risk dimension from various references

Sustainability Risk Dimension	Sustainability Risk category	References	Example of Risk element
Economical	Competition Risk	Schulte and Hallstadt (2017)	Price war

	Knowledge Risk	Durst and Zieba (2020)	Insufficiency on risk management know how
	Reputational Risk	Schulte and Hallstadt (2017)	Bad reputation, sabotage on competitors' brand
	Intellectual Property risk	Gianakis and Papadopoulos (2016)	low awareness on the importance of intellectual property right, Intellectual property piracy
	Quality Risk	Ghadge *et al.* (2017)	Defective products and process
	Corruption Risk	Monteiro *et al.* (2018)	Cost mark up, bribery, unofficial levies
	Market Risk	Puniyamoorthy *et al.* (2013)	The change of customer preference
	Delivery Risk	Gupta *et al.* (2014)	Failure in delivering products and service in timely manner
Environmental	Pollution	Gianakis and Papadopoulos (2016), Oliviera *et al.* (2019)	Air, water and soil pollutions
	Waste	Gianakis and Papadopoulos (2016)	By product waste
	Natural Disasters	Gianakis and Papadopoulos (2016)	Earthquake, hurricane and flood
	Pandemic	Gianakis and Papadopoulos (2016)	Avian Influenza and Covid 19
Social	Relationship Risk	Alamwaleh and Poppelwell (2012)	Distrust among business partners
	Cultural Gap Risk	Jian and Rutherford (2010)	Failure to understand local culture,
	Behavioural Risk	Ragunath and Devi (2018)	Bullying, sexual harassment,
	Human Resource Risk	Cunha *et al.* (2019)	Employee turn over
Institutional	Regulatory / Compliance Risk	Hadiguna (2017)	Inflexible governmental regulations, inconsistency of governmental rules
Technical	Infrastructure Risk	Ebrahimi *et al.* (2019)	Lack of infrastructures,

			failure of infrastructure

The second step of this research is checking relevancy and appropriateness of the supply chain risk variables in the context of the SME. To achieve this goal focus group discussion with SME experts is carried out to determine the elements of operational risk that will be used as the basis for evaluating sustainability risks. Furthermore, the various modes of operational risk variables were verified by interviewing and observing SME entrepreneurs' business operation in the wood craft sector. Based on the five pillars of sustainability, the dimensions and elements of risk are determined by asking SME owner in the case study to determine the sustainability risk scale using an ordinal scale of 1 to 5. The results of determining the dimensions and risks are shown in Table 8. In this paper, subjectivity related to the evaluation of sustainability risk in the case study is the scoring that follows the preferences of MSME actors based on the experience of MSME actors in determining the sustainability risk scale, while the objective data for determining the risk displayed are the risk element scores contained in Table 9.

Table 9. The scale of supply chain risk reprioritization of case example

Supply Chain Risk Dimension	Supply Chain Risk category	Supply Chain Risk Variable	Supply chain risk reprioritization attributes				
			Occurrence	Detection	Severity	Sensitivity	Recoverability
Economical	Reputational Risk	Unattractive product packaging	1	5	1	2	3
		Product brand counterfeiting	1	4	5	5	5
		Product re-packing	1	2	5	5	4
	Competition Risk	Price war among competitors	4	3	5	5	5
		Entrance of New Competitors	4	3	3	5	5

		Change of customer preference	3	5	3	3	3
		Competitors' Unethical behaviour	2	3	3	4	4
	Financial Risk	Avoiding Tax	5	4	4	2	2
		Imitating competitor product	4	3	5	4	4
		Bribery	4	1	4	4	4
		Fix Pricing	5	4	4	4	4
		Fluctuation of raw material price	3	3	3	3	3
		Sudden order cancellation	1	5	5	5	3
Technical /Operational	Technological Risk	Production Facility Risk	5	2	4	4	4
	Supplier Risk	Unreliable suppliers	4	2	3	5	3
	Demand risk	Demand Forecasting error	5	2	4	5	5
	Quality Risk	The use of low-quality grade raw materials	1	2	2	3	3
	Knowledge Risk	Very low awareness on the Intellectual property right	4	4	4	3	3
		Very low knowledge on Risk in running business	5	4	4	3	3
		Perception among SME owners that risk is merely linked to financial loss only	5	4	4	4	4

		Lack of innovation capability	3	5	3	3	3
		Low awareness on the importance of product certificatio n	1	4	2	3	3
	Human Resource Risk	Employ turn over	3	2	2	2	4
		Very low educational level of employees	5	2	1	1	1
		Low interest in upgrading employee skills	4	2	4	2	3
		Scarcity of talent for creative type job	4	2	4	2	3
		Low interest to continue family business	5	2	2	3	4
Environme ntal	Pollutant Risk	Noise	1	1	1	2	1
		soil pollution	1	4	4	4	4
	Waste Risk	By product garbage	1	2	5	5	5
		Electricity wastage	1	2	2	3	3
	Natural Hazard Risk	Pandemic	1	4	5	4	4
		Earthquake	1	5	5	5	5
	Man-made risk (Security Risk)	Burglary	3	1	5	5	5
		Theft	3	3	1	5	5
Social Risk							
	Labour Practice and decent working	Unclean and unsafe production facility	5	1	3	3	4

		condition Risk					
		Sub-standard safety apparatus	5	4	3	2	3
		The use of child workforce	1	1	3	2	3
		Unfair wage	4	4	4	3	3
		The absence of insurance coverage	4	1	2	2	2
Political Risk	Regulatory Risk	Difficulty to obtain banking credit	1	2	1	2	3
		Product certification cost	2	2	2	2	2
		Weak and Inflexible Governmental support	3	2	3	4	4
	Compliance Risk	Regulatory tightness becoming supplier of big company	4	2	3	4	4
		sum	129	126	144	154	156

Under five pillars of sustainability, totally 44 risk elements are identified in this study. Reputational, competition and financial risks are three categories of economic risks. Reputational risk is typical risk closely related to the degrading product or company reputation due to various negative issues like product appearance problem, counterfeiting and product re-packing issues. Within Technical Risk dimension, six risk types are identified which is consisting of facility production risk, Demand Risk, Quality risk, Knowledge risk, supplier risk and human resource risks. In environmental risk, four categories of sustainability risks in the form of pollutant risk, waste, natural hazard and man-made risk are existing. In the social risk dimension, double category of sustainability risks, labour practices and working condition are revealed. At last, in institutional risk, regulatory and compliance risk are found as negative uncertainties affecting business standing of the enterprise under study.

4.4. Determination on the score of the compromise weight of supply chain risk priority number

The first step in determining the composite weight for each risk element is carried out by determining the subjective weighting of risk priority parameters using the PSI method, followed by determining the objective risk priority weights using the Shannon entropy method and combining the relative weights between risk elements. The descriptions of the explanation of the three stages are as follows:

The steps for determining the weight of priority risk subjectively using the PSI method are:

4.4.1. Identification of beneficial and non-beneficial attributes
In the PSI methodology, two categorical attributes, beneficial and non-beneficial are used as basis for calculating preference score. Beneficial attributes relate to supply chain sustainability risk reprioritization is detection and recoverability attributes while risk occurrence scale, severity of supply chain risk impact and sensitivity of risk are categorized as non – beneficial attributes. By using equation (1) until equation (6), the overall preference score for each risk attributes is presented in Table 10.

Table 10. Overall Preference variation value of each risk attribute

No	Preference value of risk occurrence	Preference value of risk detection	Preference value of risk severity	Preference value of risk sensitivity	Preference value of risk recoverability
1	0.361	0.180	0.189	0.108	0.162

The above overall preference scores are representing subjective weight of risk reprioritization parameters of case example. Therefore, the score of $W_O^S = 0.361$, $W_D^S = 0.180$, $W_S^S = 0.189$, $W_{SN}^S = 0.108$ and $W_R^S = 0.162$ respectively.

4.5. Determination on the Objective weight of the supply chain risk reprioritization criteria using the Shannon Entropy

The objective weight of supply chain sustainability risk reprioritization criteria is determined by using the Shannon entropy score. At first, normalization of the risk element scores from Table 8 is accomplished by using equation 7 and equation 8. Then, the entropy score of each risk criteria is counted by following equation 9 and equation 11. The objective weight of the risk criteria is $W_o^o = 0.187$, $W_d^o = 0.159$, $W_s^o = 0.183$, $W_{SN}^O = 0.313$, and $W_R^O = 0.158$.

4.5.1 Determination of the weight of Subjective- Objective supply chain risk reprioritization criteria

Above weight is determined by using equation 12 and the score of each compromise weighting are as in the followings; compromise weight of occurrence $W_C^O = 0.187$, compromise weight of detection $W_C^d = 0.168$, compromise weight of severity $W_C^S = 0.185$, compromise weight of sensitivity $W_C^{SN} = 0.210$, and compromise weight of $W_C^R = 0.139$.

4.6. Comparison on risk priority ranking using Subjective, Objective and Subjective-Objective risk prioritization approaches

Table 11 present the result on appraising supply chain risk score by using four different approaches.

Table 11. Risk priority evaluation comparison among the conventional FMEA, the PSI, the Shannon entropy and integrated Shannon entropy and PSI method.

Supply Chain Risk Dimension	Supply Chain Risk category	Supply Chain Risk Variable	RPN based on Conventional Supply chain FMEA	RPN based on the PSI	RPN based on the Shannon Entropy	RPN-based on Integrated PSI and Shannon Entropy
Economical	Reputational Risk	Unattractive product packaging	5	1.91	1.52	0.79
		Product brand counterfeiting	20	4.03	4.56	2.75
		Product re-packing	10	9.76	8.72	3.10
	Competition Risk	Price war among competitors	60	5.56	7.32	5.71
		Entrance of New Competitors	36	4.09	6.64	5.07
		Change of customer preference	45	4.50	3.365	2.12
		Competitors' Unethical behaviour	18	3.84	4.21	3.80
	Financial Risk	Avoiding Tax	80	3.97	7.24	3.97
		Imitating competitor product	60	5.77	8.70	6.
		Bribery	16	16	19	6.60
		Fix Pricing	80	4.55	4.86	3.81
		Fluctuation of raw material price	27	4.09	4.61	3.55
		Sudden order cancellation	25	2.23	3.30	4.35

Technical /Operational	Technological Risk	Production Facility Risk	40	9.18	9.72	7.37
	Supplier Risk	Unreliable suppliers	24	12.70	9.04	7.63
	Demand risk	Demand Forecasting error	40	9.80	10.12	3.43
	Quality Risk	The use of low-quality grade raw materials	4	6.21	6.16	3.01
	Knowledge Risk	Very low awareness on the Intellectual property right	64	3.91	3.94	2.80
		Very low knowledge on risk in running business	80	4.28	4.24	3.01
		Perception among SME owners that risk is merely linked to financial loss only	80	4.57	4.86	2.0
		Lack of innovation capability	45	3.64	2.71	1.31
		Low awareness on the importance of product certification	8	1.86	2.58	6.46
	Human Resource Risk	Employ turn over	12	5.77	4.0	4.16
		Very low educational level of employees	10	5.97	4.56	3.10
		Low interest in upgrading employee skills	32	7.60	7.08	4.96
		Scarcity of talent for creative type job	32	7.60	7.08	4.36
		Low interest to continue	20	8.10	7.88	2.71

		family business				
Environmental	Pollutant Risk	Noise	1	4.07	6.33	1.13
		soil pollution	16	1.00	3.70	1.47
	Waste Risk	By product garbage	10	6.35	9.12	4.76
		Electricity wastage	4	3.75	5.16	7.92
	Natural Hazard Risk	Pandemic	20	2.82	3.96	3.20
		Earthquake	25	2.057	3.73	2.78
	Man-made risk (Security Risk)	Burglary	15	16.71	5.36	4.53
		Theft	9	4.333	4.12	4.08
Social Risk						
	Labour Practice and decent working condition Risk	Unclean and unsafe production facility	15	17.14	17.5	4.13
		Sub-standard safety apparatus	60	3.91	3.75	2.60
		The use of child workforce	3	7.95	10.16	8
		Unfair wage	64	6.32	3.94	6.93
		The absence of insurance coverage	8	12.21	11.83	8.75
Political Risk	Regulatory Risk	Difficulty to obtain banking credit	2	3.035	3.84	2.26
		Product certification cost	8	6.76	4.52	3.73
		Weak and Inflexible Governmental support	18	6.07	8.08	5.5
	Compliance Risk	Regulatory tightness becoming supplier of big company	24	6.82	8.64	5.93

Comparison of supply chain sustainability risk scoring shown in table 11 with four different approaches shows relatively different results. This is because each risk score is calculated using different approach where in conventional FMEA, the relative weight of the risk criteria is not

taken into account and also ignores the sensitivity and recoverability aspects of the supply chain to the impact of a risk. Meanwhile, in calculating the risk score using the PSI approach, the subjectivity of decision makers is stressed in determining the risk score compared to using the Shannon entropy method which emphasizes the objectivity aspect of the risk contained in the risk criteria score contained in the decision matrix table score. To accommodate the integration of the subjectivity and objectivity aspect of decision makers, the integration between PSI and Shannon entropy methods is used together. This shows that the integration of the PSI and Shannon entropy methods offering advantage where decision makers can simultaneously consider their subjectivity and objectivity of the risk data in determining risk priorities.

4.6. Determination of The Risk Priority Number of Risk Elements of case example

This study intended to determine the score of the critical supply chain sustainability risks using integrated Shannon entropy and the PSI as represented in equation 15. The scale of the risk priority ranking of each risk element is presented in Table 12.

Table 12. The RPN Score of each risk elements

Supply Chain sustainability risk dimension	Supply chain Risk category	Supply chain risk element	Risk priority number
Economical	Reputational	Unattractive product packaging	0.79
		Product brand counterfeiting	2.75
		Product re-packing	3.10
	Competition	Price war among competitors	5.71
		Entrance of new competitors	5.07
		Change of customer preference	2.12
		Competitors' unethical behaviour	3.80
	Financial	Avoiding Tax	3.97
		Product imitation by competitors	6.
		Bribery	6.60
		Fix Pricing	3.81
		Fluctuation of raw material price	3.55
		Sudden order cancellation	4.35

Technical /Operational	Production facility	Production Facility failure	7.37
	Demand	Demand Forecasting error	7.63
	Quality	The use of low-quality grade raw materials	3.43
	Knowledge	Very low awareness on the Intellectual property right	3.01
		Very low knowledge on Risk in running business	2.80
		Perception among SME owners that risk is merely linked to financial loss only	3.01
		Lack of innovation capability	2.0
		Low awareness on the importance of product certification	1.31
	Supplier	Unreliable suppliers	6.46
	Human Resource	Employ turn-over	4.16
		Very low educational level of employees	3.10
		Low interest in upgrading employee skills	4.96
		Scarcity of talent for creative type job	4.36
		Low interest to continue family business	2.71
Environmental	Pollutant	Noise	1.13
		soil pollution	1.47
	Waste	By product garbage	4.76
		Electricity wastage	7.92
	Natural Hazard	Flood	3.20
		Earthquake	2.78
	Man-made	Burglary	4.53
		Theft	4.08
Social Risk			
	Working facility	Untidy and unclean production facility	4.13
		Sub-standard safety apparatus	2.60
	Labour practice	The absence of insurance coverage	8
		The use of child workforce	6.93
		Unfair wage	8.75
Political Risk/Regulation risk	Regulatory	Difficulty to obtain banking credit	2.26
		Product certification cost	3.73
		Weak and Inflexible Governmental policy	5.5

	Compliance	Regulatory tightness becoming supplier of big company	5.93
	N=44 risk variables, mean RPN= 4.25; standard deviation =1.89		

4.5.2. Economical risk

Under economical sustainability risk dimension, reputational, competition and financial risk categories along with their risk elements are revealed. As a typical business which heavy reliance on the attractiveness of product sold to the potential buyer, packing attractiveness is also becoming vital factor which attract attention to other stakeholders such as new investors, partners and new employees (Ambroise and Allaz, 2017). In reputational risk, product re-packing risk is becoming the most serious risk as reflected by its largest RPN score among two other reputational risk categories. This kind of risk is a typical risk occurred when competitors are selling their own product using competitors packing bag/label. This indicates that improving brand name of the company is influencing to the business continuation and shall be considered in making the product sold becoming more marketable against competitor brand. In competition risk category, the riskiest risk element is "price war" as it is having most impacting risk metric among other type of risk elements in competition risk category. This signals on the enterprises under study to keep on producing good quality merchandise while keep it price affordable to be sustained. In the financial risk, the risk type "Bribery" is still perceived as the riskiest risk since this kind of risk is causing high annoyance to the business owners due to the difficulty to estimate how much and how many times shall it should be paid to obtain services.

4.5.3. Technical risks

This second pillar of sustainability risk is concerning on negative uncertainty factors affecting business operability of the company. Under this pillar, six categories of sustainability risk are revealed which showing, that knowledge and human resource risks are having the most risky elements. Attribution of knowledge and human resource risk as one of the important risk elements in SME context is in line with study of Falkner and Hiebl (2015). In terms of its risk impact, "demand risk" is becoming the most critical risk element to the enterprises as that may lead decision makers take wrongly decision on resource allocation.

4.5.4. Environmental risk

The third sustainability risk pillar, the environmental risk refers to the adverse impact of negative uncertainty affecting negatively to the enterprise's environments. The sub risk categories of environmental risk were based on the classification model of Pereira et al., (2020). Within this categorization waste risk, in the form of "by product waste" is perceived as most important risk as reflected by their RPN largest score compared to other categories of environmental risk. On considering situation in developing country, this is not surprising since business owners are less paying attention in dealing with by product wastage produced by their company's operation. Low attention to the environmental impact of business operation is not surprising to the SME in Indonesia. (Fatimah *et al*. 2002). The second environmental risk, security risk is also perceived as the most important risk and one of the common risks in the context of developing country. This typical risk is in line with study of Kagwati et al., (2014) and (Sujka and Schulze, 2012).

4.5.5. Social risk
The social risk as the fourth sustainability pillar is consisting of two risk categories, working facility condition risk and working practice risk. Within social risk, "unfair wage" and "the absence of working insurance" are the riskiest social risks revealed. This type of risk is unsurprise as employee working in family type company as this study take place is not based on formal contract but often based on family relationship.

4.5.6. Institutional risk
The fifth sustainability risk, the institutional risks are consisting of two categories, the regulatory and compliance risk. Between these two categories of institutional risks, compliance with requirements to undertake business relationship with bigger companies is perceived as serious issues consider inherent limitations owned by the small and medium company pertaining to the availability of standard operating procedures etc. As owners of the SMEs are usually using relative loans for funding their operations, the bank ability problem is not perceived as serious issues. As this study found, dealing with around forty-four risk elements is demanding exhaustive effort for risk alleviation. Therefore, categorizing critical and non-critical risks are suggested to save resource owned by the company.

Based on the mean score of the RPN and its standard deviation obtained from Table 12, by using equation 16, the critical supply chain risk element from every risk dimension and each risk category of case example is presented in Table 13.

Table 13. Critical supply chain risk elements of case example

Risk Dimension	Risk category	Supply chain risk element	Risk Priority Number	Priority rank	Cumulative RPN score
Economical	Competition	Price war among competitors	5.71	1	
		Entrance of new competitors	5.07	2	
	Financial	Product imitation by competitors	6.	2	27.66
		Bribery	6.60	1	
		Sudden order cancellation	4.35	3	
Operational	Facility	Production Facility failure	7.37	2	
	Demand	Demand Forecasting error	7.63	1	
	Supply	Unreliable suppliers	6.46	3	30.78
	Human resource	Low interest in upgrading employee skills	4.96	4	
		Scarcity of talent for creative type job	4.36	5	
Environmental	Waste	By product garbage	4.76	2	12.68
		Electricity wastage	7.92	1	
Social	Security	Burglary	4.53	1	
	Labour practice	The absence of insurance coverage	8.0	2	23.68
		The use of child workforce	6.93	3	
		Unfair wage	8.75	1	
Institutional risk	Regulatory	Weak and Inflexible Governmental policy	5.5	2	11.43
	Compliance	Regulatory tightness becoming supplier of big company	5.93	1	

Referring to Table 13, concentration to deal with impact of economical risk, "price war" and "bribery" risk should be assigned as management top priority. Price wars as one of the important risks in the economic dimension are in line with a survey study by Shah and Patel (2017) in the context of developing countries that arises due to the absence of cooperation between handicraft business actors in determining price equality. In the technical dimension, production facility, demand, supply and human resource risks are becoming the four riskiest categories based on their risk impact. This is indicating that the contributing elements

continuing business of the SME in the handicraft type business is strongly affected by reliable suppliers and production facility, error free demand forecasting, and availability of skilled labours. Finding this study is in line with a study from Shafi et al (2020) which noted that cooperating reliable suppliers will increase the continuity of the SMEs operation in the handy draft sector. The lack of human resources to become artisans in the handy craft industry, which is one of the sustainability issues is also in line with the findings of Chudasri *et al*. (2012). The decline in the interest of the younger generation to continue their business as handicrafts SME craftsmen also has a negative impact on the continuity of the craft business (Wondirad *et al*., 2021). The wood craft industry is a typical example of a demand driven industry. Thus, improvement in capability in predicting market demand will greatly affect production planning and supply of raw materials. Efforts to improve the ability to forecast consumer demand can be done by improving proficiency using quantitative demand forecasting tool since generally the SME decision makers only rely on their past experiences in forecasting market demand. Proficiency in using qualitative and quantitative demand forecasting tool will be greatly improving sustainability of the enterprise. In the environmental risk dimension, to support realization of sustainability practice, awareness to keep continuing working place cleanliness of working safety place to improve workers' productivity and saving electrical energy usage shall be in decision makers' mind. The result of scanning social risk element indicating that management of the company shall better improving workers wage scheme and considering allocation of worker working insurance. At last, from institutional risk dimension, capability to fulfil requirements partnering with bigger companies in particular to production capacity risk is becoming the most impacting risk since such requirement will be implying additional costs and technical requirements burdening to the SME. This compliance risk is evidently occurring to the SMEs intending to export its product overseas (Revindo, 2017).

4.6. Contributions to the academic community

Motivated by vacancy of studies on combining of both subjective and objective sustainability risk assessment studies in supply chain risk management field and also scarcity of empirical studies on evaluating supply chain sustainability risk of SME in developing country, this study presented an initial effort to fill in such gap by proposing a new risk assessment approach. The Preference Selection Index (PSI) method is used to estimate the subjective weight of the preference score of the risk reprioritization attributes and the Shannon entropy is employed to appraise the objective weight of supply chain risk reprioritization criteria. Next, complementing to the occurrence, detection and severity scale, sensitivity and recoverability

scale are added as additional risk reprioritization criteria. A case study is presented to illustrate its applicability in practical situation.

Presenting the application of the integrating the PSI and the Shannon entropy method to appraise the weight of supply chain risk reprioritization attributes, this study offering contribution to academic community. The contributions offered by this study are in the followings.

Firstly, as reflected in Table 14, this study presented a new decision support model for appraising the impact of supply chain sustainability risk considering decision maker subjectivity and risk data objectivity in assigning the score of supply chain risk criteria which to the best of our knowledge never investigated by previous scholars.

Table 14 . Classification of studies dealing with weightage approach in determining the supply chain risk reprioritization criteria in the context of supply chain of small and medium enterprise

Supply chain risk criteria weightage approach			
Subjective	Technique(s)	Author(s)	Commodity
	Analytical Hierarchy Process (AHP)	Ornaez and Moreno (2021)	Bakery
	Analytical network priority (ANP)	Slamet *et al* (2017)	Papaya
	Best -Worst Method (BWM)	Moktadir *et al*. (2021)	Leather
Subjective Hybrid	Fuzzy AHP-TOPSIS	Alora and Barua (2020)	Miscellaneous
	AHP-TOPSIS	Silva *et al*. (2021)	Spice
	AHP-PROMETHEE	Venkatesan and Kumanan (2012)	Plastics
Objective	Shannon Entropy-TOPSIS	Shahin *et al*. (2019)	Home appliance
Subjective-Objective	Entropy-PSI	This paper	Wooden Handicrafts

Our model presents an alternative approach to quantify the weight of risk reprioritization attributes instead on the reliance of consistency checking -based supply chain risk ranking reprioritization approach using the stand alone subjective risk prioritization approach using the AHP and or the Best Worst Method (BWM). Or using objective risk ranking approach using the Shannon entropy. Secondly, we have demonstrated that in undertaking supply chain risk criticality assessment, influence of supply chain sensitivity and recoverability from risk as other important risk criteria in risk priority making shall be taken into account which will make supply chain risk assessment process becoming more comprehensive. Thirdly, departing from the study on categorizing supply chain risk assessment methods by Tran *et al*., (2018) it is evident that based on our survey, adoption of the PSI method in supply chain risk assessment is vacant. Moreover, the study also has demonstrated on the promising usage of the PSI as one of simple supply chain risk reprioritization ranking methods can be used by SME practitioners.

4.7. Contribution to the managerial practice

This paper offers contributions to managerial purpose. At first, this paper presented derivation of supply chain sustainability risk variables at practical setting derived from five pillars of sustainability to improve understanding of typical supply chain sustainability risks toward a better risk identification and mitigation planning. At second, this paper also offers a practical use of the recent multi criteria decision making method, the PSI and the Shannon entropy in assigning the preference score of risk reprioritization criteria based on empirical study in the context of developing country. Some other offerings based on this empirical study are concerning on suggestions to improve financial, human resource, knowledge management and working practices to support realization of sustainable operational practice to the SMEs.

4.7. Limitations and Recommendations

Attempting to firstly present an empirical study in applying the integrated PSI and the Shannon entropy method into supply chain sustainability risk assessment based on single case study, validity of the study perhaps is only applicable to wooden handy craft sector only in a developing country. Next, sensitivity analysis to determine the influence of change in the weight of risk criteria and suggestion on sustainable risk mitigation strategies are not covered by this study. Furthermore, subjectivity of the SME owners of the case example which believed affects the accuracy in assigning the risk priority score of the supply chain risk elements is not taken into account. Departing from above limitations, recommendations are advised in the followings.

It is advised to replicate this early study using more respondents and other SME business types to improve its validity and generalisability. As the risk scores obtained from this study is coming from the owner of the enterprise, additional information from other stake holders in the supply chain sustainability risk assessment is suggested to improve comprehensiveness of the study. Also, relative weight of sustainability pillars and impact of practitioners' working experiences which believed affecting the impact of supply chain risks should be considered in the decision support model.

5. Conclusions and New Research Directions

Driven by scarcity of empirical study on assessing supply chain sustainability risk in the context of developing country, this paper presented to use of integrated PSI method into supply chain FMEA to select the most critical risk using case example from creative industry sector. The result of the study pinpoints several critical risk elements from every sustainability pillars indicates that economic, social and operational type sustainability risks are perceived as the three most critical risks affecting business sustainability. Considering as an initial effort to integrate the PSI, the Shannon entropy and the relative weight method into supply chain FMEA method in selecting critical supply chain sustainability risks, future studies can focus on comparing the performance of the proposed model with other multi criteria decision making methods followed by sensitivity analysis. Additionally, future studies can also integrate the PSI, the Grey Relational Analysis (GRA) and the Principal Component Analysis (PCA) methods to reduce the number of risk dimensions and enable decision makers to focus on a few important sustainability risks elements. Determination on the score of supply chain sustainability risk index based on the categorization of supply chain risk elements is another research direction worth to be pursued in future research.

References
Anugerah, A.R., Azfanizam, A.S., Samin, R., Samdin, Z., and Kamarudin, N. 2021. Modified FMEA to mitigate sustainable related supply chain risk in the palm oil supply chain, *Advances in Materials and Manufacturing Technologies*, in press, https://doi.org/10.1080/2374068X.2021.1898180.

Alora, A., and Barua, M.K., 2020. Development of Supply Chain Risk Index for Manufacturing Supply Chains, *International Journal of Productivity and Performance Management*, In press.

Ambroise, L.,and Allaz, I.P., 2017. Reputation Risk : Anticipation and Management of Failure, in Berad, C., and Teyssier, I.P. eds. Risk Management: Lever for SME Development and Stakeholder Value Creation, https://doi.org/10.1002/9781119475002.ch4.

Aksoy,S., and Ozbuk, M.Y. 2017.Multicriteria decision making in hotel selection :does it relate to postpurchase consumer evaluation, *Tourism Management Perspective*, Vol.22, pp:73-81. https://doi.org/10.1016/j.tmp.2017.02.001.

Attri, R., and Grover, S. 2015. Application of Preference Selection Index (PSI) method for decision making over the design stage of production system lifecycle. *Journal of King Saud University-Engineering Science*, Vol.27. Iss.2, pp:207-216. https://doi.org/10.1016/j.jksues.2013.06.003.

Anin, E.K., Alexander, O.F., and Adzimah, D.E. 2015. Managing supply chain risks: A Perspective of exportable pineapple fresh fruits in Ghana, *European Journal of Business and Management*, Vol.7., pp:59-71.

Attri, R., Dev, N., Kumar, K., and Rana, A., 2014. Selection of cutting fluids using a novel multi-criteria method: preference selection index, *International Journal of Information and Decision Sciences*, Vol.6, Iss.4, pp:393-410. DOI: 10.1504/IJIDS.2014.066636.

Alamwaleh, M., and Popolewell, K., 2012. Risk in collaborative Networks: Relationship Analysis, *International Journal of Services and Operations Management*, Vol.12, No.4, pp:431-446. https://doi.org/10.1504/IJSOM.2012.047952.

Babu, H., Bhardwaj, P., and Agrawal, A.K. 2020. Modelling the supply chain risk variables using ISM: a case study on Indian manufacturing SMEs, *Journal of Modelling in Management,* in press. https://doi.org/10.1108/JM2-06-2019-0126.

Biswas, S. and Anand, O.P. 2020. Logistics competitiveness Index-based comparison of the BRICS and G7 Countries, *The IUP Journal of Supply Chain Management*, Vol.17, No.2, pp:32-57. https://ssrn.com/abstract=3809672.

Badrudin, R., Siregar, B. 2018. Creative Economy Development Based on Triple Helix in Indonesia, Theoretical and Practical Research in Economic Field, (Volume IX, Summer), 1(17): 82-91. DOI:10.14505/tpref.v9.1(17).09. from: http://journals.aserspublishing.eu/tpref.

Basset, M. A. B., Gunasekaran, M., Mai, M., and Chilamkarti, N., 2018. A Framework for Risk Assessment, Management and Evaluation: Economic Tool for Quantifying Risk in Supply Chain, *Future Generation Computer System,* Vol.90, pp:489-502. https://doi.org/10.1016/j.future.2018.08.035.

Behzadi, G., O'Sullivan, M.J., Olson, T. L., Zhang, A. 2018." Agribusiness supply chain risk management: a review of quantitative decision model," *Omega*, Vol. 79, pp.21-42. https://doi.org/10.1016/j.omega.2017.07.005.

Borujeni, M.P. and Gitinavard, H. 2017. Evaluating the sustainable mining contractor selection problems:an imprecise last aggregation selection index method. Journal of Sustainable Mining, Vol.16, Iss.4, pp:207-281. https://doi.org/10.1016/j.jsm.2017.12.006.

Bojanc, R., and Blazic, B.J. 2015.A quantitative model for information-security management, *Engineering Management Journal,* Vol.25, Iss.2, pp:25-37.

Bakhoum, E.S., and Brown, D.C. 2013. A hybrid approach using AHP-TOPSIS-Entropy methods for sustainable ranking of structural materials, *International Journal of Sustainable Engineering*, Vol.6, Iss.3, pp:212-224. https://doi.org/10.1080/19397038.2012.719553.

Bevilacqua, M., Braglia, M., and Gabbrieli, R. 2000. Monte Carlo simulation approach for a modified FMECA in a power plant, *Quality and Reliability Engineering International*, Vol.16, Iss.4, pp:313-324.

Chen, W.K., Nalurri, V., Ma, S., Lin, M.M., and Lin, M.T. 2021. An Exploration of the Critical Risk Factors in Sustainable Telecom Service: An Analysis of Indian Telecom Industries, *Sustainability*, Vol.13, No.2, pp:17-22.

Cunha, L.C., Caryno, P., and Leiras, A. 2019. Social Supply Chain Risk Management: A Taxonomy, a Framework and a Research Agenda, *Journal of Cleaner Production*, Vol.220, pp:1101-1110. https://doi.org/10.1016/j.jclepro.2019.02.183.

Chaitanya, K. L. and Srinivas, K. 2019. Sensitive analysis on selection of piston material using madm techniques, *Strojnichy Casupis-Journal of Mechanical Engineering*, Vol.69, No.4,pp:45-56. https://doi.org/10.2478/scjme-2019-0042.

Chauhan, R., Singh, T., Thakur, N.S., and Patnaik, A. 2016. Optimization of parameters in solar thermal collector provided with impinging air jets based upon preference selection index method, *Renewable Energy,* Vol.99, pp: 118-126. https://doi.org/10.1016/j.renene.2016.06.046.

Chudasri, D., Walker, S. and Evans, M. 2012. *An overview of the issues facing the craft industries and the potential for design with a case study in Northen Thailand*, in Israsena, P., Tangsantikul, J. and Durling, D. (eds.), Research: Uncertainty Contradiction Value - DRS International Conference 2012, 1-4 July, Bangkok, Thailand. https://dl.designresearchsociety.org/drs-conference-papers/drs2012/researchpapers/24.

Durst, S., and Zieba, M. 2020. Knowledge Risks inherent in Business Sustainability, *Journal of Cleaner Production*, 251, Vol.251, pp:1-10. https://doi.org/10.1016/j.jclepro.2019.119670.

Eshanifar,M and Hemesy, M. 2021. A new hybrid multi-criteria decision-making model to prioritize risks in the construction process under fuzzy environment (case study: the Valiasr Street underpass project), *International Journal of Construction Management*, Vol.21, Iss.5, pp.508-523. https://doi.org/10.1080/15623599.2019.1569816.

Ebrahimi, M., and Rahmani,D., 2019. Five-dimensional approach to sustainability for prioritizing energy production systems using revised GRA: a case study*, Renewable Energy*, 135, pp: 345-351. https://doi.org/10.1016/j.renene.2018.12.008.

Deshdaht, G., Ferawati, M.S., Zin, R.M., Abidin, N.Z. 2020. A hybrid approach using entropy and TOPSIS to select key drivers for a successful and Sustainable Lean Construction Implementation, PLosONE, Vol.15, No.2,pp:1-32, https://doi.org/10.1371/journal.pone.0228746.

Ezatpour,H.R., Parizi, M.T., Sajadi, S.A., Ebrahimi, G.R., and Chaichi, A. 2016. Microstructure, mechanical analysis and optimal selection of 7075 aluminum alloy based composite reinforced with alumina nanoparticles, *Materials Chemistry and Physics*, Vol.178, pp:119-127. https://doi.org/10.1016/j.matchemphys.2016.04.078.

Fattahi, R., Tavakkoli-Moghaddam, R., Khalilzadeh, M., Shahsavari-Pour, N. and Soltani, R. 2020. A novel FMEA model based on fuzzy multiple-criteria decision-making methods for risk assessment, *Journal of Enterprise Information Management*, Vol. 33 No. 5, pp: 881-904. https://doi.org/10.1108/JEIM-09-2019-0282.

Fahimnia, B., Tang, C.S, Davarzani, H., and Sarkis, J. 2015. Quantitative models for managing supply chain risk: a review, *European Journal of Operational Research*, Vol.247, pp:1-15. https://doi.org/10.1016/j.ejor.2015.04.034.

Falkner, E.M., and Hiebel, M.R.W., 2015. Risk Management in SMEs: a systematic review of available evidence, *The Journal of Risk Finance*, Vol.16, No2., pp:122-144. https://doi.org/10.1108/JRF-06-2014-0079.

Fatimah, Y.A., Biswas,W., Mazhar, I., and Islam, M.N., 2013. Sustainable manufacturing for Indonesian SMEs: the case of remanufactured alternator, *Journal of Remanufacturing*, Vol.3, No.6, pp:1-11. https://link.springer.com/article/10.1186/2210-4690-3-6.

Gheibi,M., Karrabi,M. and Eftekhari,M.2019. Designing a smart risk analysis method for gas chlorination units of water treatment plants with combination of Failure Mode Effects Analysis, Shannon Entropy, and Petri Net Modelling, *Ecotoxicology and Environmental Safety*, Vol.171, pp.600-608. https://doi.org/10.1016/j.ecoenv.2019.01.032.

Giannakis, M., and Papadopoulos, T., 2016. Supply chain sustainability: a risk management approach, *International Journal of Production Economics*, Vol.171, Part 4, pp:455-470. https://doi.org/10.1016/j.ijpe.2015.06.032.

Ghadge, A., Fang, X., Dani, S., and Antony, J., 2017. Supply chain risk assessment approach for process quality risks, *International Journal of Quality and Reliability Management*, Vol.34, No.7, pp: 940-954. https://doi.org/10.1108/IJQRM-01-2015-0010.

Gunasekaran, A., Rai, B.K., and Grifin, M. 2011, Resilience and competitiveness of small and medium sized enterprise: an empirical research, *International Journal of Production Research*, Vol.49, No.18, pp:5489-5509. https://doi.org/10.1080/00207543.2011.563831.

Ho, W., Zheng, T., Yildiz, H., and Talluri, S.,2015. Supply chain risk management: a literature review, *International Journal of Production Research*, Vol 53, Iss.16, pp:5031 – 5069. https://doi.org/10.1080/00207543.2015.1030467.

Isik, A.T. and Adali, E.A.2017. The decision-making approach based on combination of entropy and ROV method for the apple selection problem, *European Journal of Interdisciplinary Studies*, Vol.3, Iss.3, pp:80-86. https://dx.doi.org/10.26417/ejis.v3i3.p80-86.

Iddrisu, I. and Bhattacharya, S.C., 2015. Sustainable Energy Development Index: A Multi-Dimensional Indicator for Measuring Sustainable Energy Development, *Renewable and Sustainable Energy Reviews*, Vol 50, pp: 513- 530. https://doi.org/10.1016/j.rser.2015.05.032.

Hanggraeni, D., Slusarczyk, B., Sulung, L.A.K., and Athor, S., 2019. The Impact of Internal, External and Enterprise Risk Management on the performance of Micro, Small and Mediun Enterprises, *Sustainability*, Vol 11, Iss.7, pp:2-17. https://doi.org/10.3390/su11072172.

Hafezalkotob,A. and Hafezalkotob,A.2016. Extended MultiMOORA Method Based on Shannon Entropy Weight For Material Selection, *Journal of Industrial Engineering International*, Vol.12, Iss.1, pp:1-13. https://link.springer.com/article/10.1007/s40092-015-0123-9.

Hadiguna, R.A. 2012. Decision Support Framework for risk assessment of sustainable supply chain, *International Journal of Logistics, Economics and Globalization*, Vol.4., Iss.1-2, pp.35-54. https://dx.doi.org/10.1504/IJLEG.2012.047213.

Jianying, F., Bianyu, Y., Xin,L., Dang, T., and Weisong, M.2021. Evaluation on Risk of Sustainable Development Supply Chain Based on Optimized BP Neural Network in Fresh Grape Industry, *Computers and Electronics in Agriculture*, Vol.183, in press, https://doi.org/10.1016/j.compag.2021.105988.

Jain V., Iqbal M., Madan A.K. 2021. Preference Selection Index Approach as MADM Method for Ranking of FMS Flexibility. In: Singari R.M., Mathiyazhagan K., Kumar H. (eds) Advances in Manufacturing and Industrial Engineering. *Lecture Notes in Mechanical Engineering*. Springer, Singapore. https://doi.org/10.1007/978-981-15-8542-5_46.

Junaid, M., Xue, Y., Syed, M.W., Li, J.Z., and Ziaullah, M., 2019. A neurosphic AHP and TOPSIS framework for supply chain risk assessment in automotive industry, *Sustainability,* Vol.12, No.1, pp:1-26. https://doi.org/10.3390/su12010154.

Jha, K., Chamoli, S., Tyagi, Y.K., and Mauriya, H.O. 2018. Characterization of biodegradable composites and application of preference selection index for deciding optimum phase combination, *Materialstoday: PROCEEDINGS*, Vol.5, Iss.2, No.1, pp:3353-3360. https://doi.org/10.1016/j.matpr.2017.11.579.

Jain, V. 2018. Application of combined MADM methods as MOORA and PSI for ranking of FMS performance factors, *Benchmarking: An International Journal*, Vol.25, No.6, pp:1903 - 1920. https://doi.org/10.1108/BIJ-04-2017-0056.

Josi, S.A.,Shafiee,M.,Moradimaj, N. and Saffarian, S. 2012. An integrated Shannon entropy-TOPSIS methodology for environmental risk assessment of Helleh protected area in Iran, *Environmental Monitoring and Assessment*, Vol.184, No.11, pp:6913-6922. https://link.springer.com/article/10.1007/s10661-011-2468-x.

Joseph, O.A., and Sridharan, R. 2011. Ranking of scheduling combination rules in a flexible manufacturing using preference selection index, "*International Journal of Advanced Operations Management*, Vol.3, No.2, pp:201-2116. https://doi.org/10.1504/IJAOM.2011.042141.

Jian, F., and Rutherford, C., 2010. Mitigating of Relational Supply Chain Risk caused by Cultural Difference between China and The West, *The International Journal of Logistics Management*, Vol.21, Iss.2, pp:251-270. https://doi.org/10.1108/09574091011071942.

Jia, S., Lai, D., Kang, J., Li, J. and Liu, J. 2018. Evaluation of relative weights for temperature,CO_2, and noise in the aircraft cabin environment, Building and Environment, Vol.131, pp:108-116. https://doi.org/10.1016/j.buildenv.2018.01.009.

Khan, S., Haleem, A.,and Khan, M.I., 2020. Assessment of Supply Chain Risk in the management of Halal Supply Chain Using Fuzzy BWM Method, *Supply Chain Forum: An International Journal*, in press. https://doi.org/10.1080/16258312.2020.1788905.

Kumar, V., Bak, O., Guo, R., Shaw, S., Colicchia, C., Garza-Reyes, J. and Kumari, A. (2018), An empirical analysis of supply and manufacturing risk and business performance: a Chinese manufacturing supply chain perspective, *Supply Chain Management: An International Journal*, Vol. 23 No. 6, pp: 461-479. https://doi.org/10.1108/SCM-10-2017-0319.

Kagwati, G.S., Kamau, J.N., Njau, M.M., and Kamau, M.S., 2017. Risk Faced and Mitigation Strategies Employed by SMEs in Nairobi, Kenya, *IOSR Journal of Business and Management*, Vol.16, Iss.4, pp:1-11. http://www.iosrjournals.org/iosr-jbm/papers/Vol16-issue4/Version-5/A016450111.pdf.

Kumar, M., and Kumar, A. 2020. Application of preference selection index method in performance based ranking of ceramic particulate (SiO2/SiC) reinforced AA2024 composite materials, Materialstoday:PROCEEDINGs, Vol.27, No.2, part.3, pp:2667-2672. https://doi.org/10.1016/j.matpr.2019.11.244.

Kumar, A., Kumar, M., Patnaik, A., Pawar, M.J., Pandey, A., Kumar, A., and Gautam, V.2021. Optimization of sliding and mechanical performance Ti/NI metal powder particulate reinforced Al 6061 alloy composite using preference selection index method, *Materials today: PROCEEDINGS*, in press. https://doi.org/10.1016/j.matpr.2020.10.974.

Kilubi, I., and Haasis, H-D.2016. Supply Chain Risk Management: Avenues for further studies, *International Journal of Supply Chain and Operations resilience*, Vol.2, Iss.1, pp:51-71. https://doi.org/10.1504/IJSCOR.2016.075899.

Khorsidhi,R., and Hassani, A. 2013. Comparative Analysis between TOPSIS and PSI method of material selection to achieve desirable combination of strength and workability in Al/Si Composite, *Materials and Design*, Vol.52, pp:999-1010. https://doi.org/10.1016/j.matdes.2013.06.011.

Lima, P.F.A., Crema, M., and Verbano, C., 2020. Risk Management in SMEs: A Systematic Literature Review and New Research Directions, *European Management Journal*, Vol.38, Iss.1, pp:78-94. https://doi.org/10.1016/j.emj.2019.06.005.

Li, H., Teixeira, A.P., and Soares, C.G.2020. A two-stage FMEA of offshore wind turbines, *Renewable Energy*, Vol.162, pp:1438-1461. https://doi.org/10.1016/j.renene.2020.08.001.

Louis, M., and Pagell, M.,2019. *Categorizing supply chain risk: review, integrated typology and future research, revisiting supply chain risk*, Zhidisin, G., and Henke, M. Eds, Spinger. Series Online. https://link.springer.com/chapter/10.1007/978-3-030-03813-7_20.

Lahmar, A., Chabcoup, H., Galaso, F., Lamothe, J., 2018. The VESP Model: A Conceptual Model of Supply Chain Vulnerability, *International Journal of Risk and Contingency Management*, Vol.7, Iss.2, pp.42-66. DOI: 10.4018/978-1-7998-0945-6.ch021.

Liu, H.C., You, X.Y.,Tsung, F. and Ji, P.2018. An improved approach for failure mode and effect analysis involving large group of experts: an application to the healthcare field, *Quality

Engineering, Quality Engineering, Vol.30, Iss.4, pp:762-775. https://doi.org/10.1080/08982112.2018.1448089.

Liu, Y., Kong, Z., and Zhang, Q. 2018. FMEA for the security of the supply chain system of the gas station in China, *Ecotoxicology and Environmental Safety*, Vol.164, pp: 325 – 330. https://doi.org/10.1016/j.ecoenv.2018.08.028.

Logananthan, A. and Muthuraj, J. 2017. Importance of environmental factors affecting software reliability*, Global and Stochastics Analysis*, Vol.4, No.1, pp: 119-125. https://www.mukpublications.com/resources/12_Jeromia_Muthuraj.pdf.

Liu, H.C., Liu, L., and Liu, N. 2013. Risk evaluation approaches in FMEA: a literature review, *Expert Systems with Applications*, Vol.40, No.2, pp:828-858.

Mzougui, I., Carpitella, S., Certa,A., Felsoufi, Z.E., and Izquierdo, J., 2020. Assessing supply chain risks in the Automotive Industry through a modified MCDM-based FMECA, *Processes*, Vol.8, Iss.5, pp:1-22. https://doi.org/10.3390/pr8050579.

Liu, P. and Zhang, X. 2011. Research on the supplier selection of a supply chain based on entropy weight and improved Electre-III method, *International Journal of Production Research*, Vol.49, No.3, pp:637-646. https://doi.org/10.1080/00207540903490171.

Moktadir,Md., A., Dwivedi, A., Khan, N.S., Paul, S.K., Khan, S.A., Ahmed, S., and Sultana, R., 2020. Analysis of risk factors in sustainable supply chain management in an emerging economy of leather industry, *Journal of Cleaner Production*, Vol.283, https://doi.org/10.1016/j.jclepro.2020.124641.

Mangla, S.K., Luthra, S., and Jakhar, S. 2018. Benchmarking the risk assessment in green supply chain using fuzzy approach to FMEA: insight from an India case study, *Benchmarking: An International Journal,* Vol.25, No.8, pp: 2660 – 2687. https://doi.org/10.1108/BIJ-04-2017-0074.

Moarefi, A. Sweis, R.J., Amiri, S.M.H., AlBalkhy, W. 2018. Shannon entropy weighting technique as a practical weighting decision-making tool in project management, *International Journal of Management Concepts and Philosophy*, Vol.14, No.4, pp:377-392. https://doi.org/10.1504/IJMCP.2018.096054.

Madic, M., Antucheviciene, J., Radovanovic, M., and Petkovic, D.2017. Determination of laser cutting process conditions using the Preference Selection Methodology, *Optics and Laser Technology*, Vol.89, pp:214-220. https://doi.org/10.1016/j.optlastec.2016.10.005.

Mangla, S.K., Kumar, P., and Barua, M.K. 2015. Risk Analysis in green supply chain using fuzzy AHP approach: a case study, *Resource, Conservation, and Recycling*, Vol.104, Part B, pp:375-390.

Mustaniroh, S.A., Ndadari, D.A., Ikasari, D.M., 2018. Mitigation Strategies for supply chain risks in Cassava Chip SME Using House of Risk Method, *Advance in food Science, Sustainable Agriculture and Agro-industrial Engineering*, Vo.1, No.1, pp:25-32. https://afssaae.ub.ac.id/index.php/afssaae/article/view/5

Muchfirodin, M., Guritno, A.D., and Yuliando, H., 2015. Supply Chain Risk Management on Tobbacco Commodity in Temanggung, Central Java (Case study at Farmers and Middleman Level), *Agriculture and Agricultural Science Procedia*, Vol.3, pp.235-241.

Monteiro, M.S., Viana, F.L.E., and Filho, J.M. S. 2018. Corruption and Supply Chain Management: Toward the Sustainable Development Goals Era, *Corporate Governance*, Vol.18, No.6, pp:1207-1219. https://doi.org/10.1108/CG-01-2018-0031.

Mavi, R.K., Goh, M. and Mavi, N.K. 2016. Supplier selection with Shannon entropy and fuzzy TOPSIS in the context of supply chain risk management, *Procedia-Social and Behavioral Science*,Vol.235, pp:216-225. https://doi.org/10.1016/j.sbspro.2016.11.017.

Mohan, V. 2017. Development of a risk exposure method for global pharmaceutical logistics, *MSc Thesis*, Technical University of Eindhoven.

Mayyas, A.T., Qattawi, A., Mayyas A.R., and Omar, R. 2013. Quantifiable measures of sustainability : a case study of material selection for eco light weight auto-bodies, *Journal of Cleaner Production*, Vol.40, pp:177-189. https://doi.org/10.1016/j.jclepro.2012.08.039.

Maniya, K., and Bhatt, M.G. 2011. The selection of flexible manufacturing sytem using Pference Selection Index, *International Journal of Industrial and System Engineering*, Vol.9, Iss.3, pp:330-349. https://doi.org/10.1504/IJISE.2011.043142.

Maniya, K., and Bhatt, M.G., 2009. A selection of material using novel type decision making method : Preference Selection Index Method, *Material and Design*, Vol.1, Iss.4, pp:1784 – 1789. https://doi.org/10.1016/j.matdes.2009.11.020.

Nadda, R., Kumar, R., Kumar, A., and Maithani, R., 2018. Optimization of single arc protrusion ribs parameters in solar air heater with impinging air jets based upon PSI approach, *Thermal Science and Engineering Progress*, Vol.7, pp:146-154. https://doi.org/10.1016/j.tsep.2018.05.008.

Olivos, P.C., Zitlapopoca, R.H., Partida, D.S., Omar, S., Moralles, C., Flores, J.R.M., 2019. Risk Analysis of the supply chain of a tool manufacturer in Puebla-Mexico, *Journal of Contingency and Crisis Management*, Vol.27, Iss.4, pp.406-413. https://doi.org/10.1111/1468-5973.12258.

Oliveira, F.N., Leiras, A., and Ceryno, P., 2019. Environmental Risk Management in Supply Chain: A Taxonomy, Framework and Future Research Avenues, *Journal of Cleaner Production*, Vol. 232, pp:1257-1271. https://doi.org/10.1016/j.jclepro.2019.06.032.

Ouyang, L.Y., Chen, K.S., Yang, C.M. and Hsu, C.H. 2013. Using a QCAC–Entropy–TOPSIS approach to measure quality characteristics and rank improvement priorities for all substandard quality characteristics, *International Journal of Production Research*, Vol.52, Iss.10, pp:3110-3124. https://doi.org/10.1080/00207543.2013.865092.

Ohta, H., and Furutani, T., 2004. Effect of customer order cancellation on supply chain inventory, *Journal of Chinese Institute of Industrial Engineers*, Vol.21, Iss.1, pp:40-45. https://doi.org/10.1080/10170660409509385.

Pintelon, L., Nardo, M.D., Murino,T.,Pileggi, G. and Porten, T.V.2021. A new hybrid multi criteria decision making approach for risk priority number evaluation for medical device prototype, *Quality and Reliability Engineering International*, in press, https://doi.org/10.1002/qre.2852.

Prashar, A., and Aggarwal, S., 2019. Modelling enablers of supply chain quality risk management-: a grey-DEMATEL approach, *TQM Journal*, Vol. ahead of print, Iss. Ahead of print. https://doi.org/10.1108/TQM-05-2019-0132.

Pathak, V.K., Singh, R., and Gangwar, S.2019. Optimization of three-dimensional scanning process conditions using preference selection index and metaheuristic method, *Measurement*, Vol.146, pp:663-657. https://doi.org/10.1016/j.measurement.2019.07.013.

Patel., P.B., Patel, J.D., and Maniya, K.D. 2018. Application of PSI Methods to Select FDM Process Parameter for Polylactic Acid, *Materialstoday: Proceedings*, Vol.5, Iss.2, Part.1, pp:4022-4028. https://doi.org/10.1016/j.matpr.2017.11.662.

Pancholi, N., and Bhatt, M.2018. FMECA-based maintenance planning through COPRAS-G and PSI, *Journal of Quality in Maintenance Engineering*, Vol.24, No.2, pp:224-243. https://doi.org/10.1108/JQME-03-2017-0015.

Parizi, T.M., Habibolahzadeh, A., and Ebrahimi, G.R., 2017. Optimizing and investigating influence of manufacturing techniques on the microstructure and mechanical properties of AZ80-0.5Ca-1.5Al2O3 nanocomposite, *Material Chemistry and Physic*s, Vol.199, pp:485-496. https://doi.org/10.1016/j.matchemphys.2017.07.035.

Patel, R. and Shah, A. 2017. Problems and Challenges Faced by Handicraft Artisans, *Journal of Voice of Research,* Vol.6, No.1, pp:57-61.

Paul, M., Sridharan, R., and Ramanan, T.R. 2016. Multi objective decision-making framework using preference selection index for assembly job shop scheduling, *International Journal of Management Concepts and Philosophy*, Vol.9, Iss.4, pp:361-387. DOI: 10.1504/IJMCP.2016.079843.

Raian, S., Ali, S.M., Sarker, Md. R., Sankaranarayan, B., Kabir, G., Paul, S.K. and Chakrabortty, R.K. 2021. Assessing sustainability risks in the supply chain of the textile industry under uncertainty, *Resource, Conservation and Recycling*, early cite. https://doi.org/10.1016/j.resconrec.2021.105975.

Raya, A. B., Riesma A., Siregar. A.P, Prasada I.Y., Indana F., Simbolon T.G.Y, . Kinasih A.T, and Nugroho, A.D 2021. Challenges, Open Innovation, and Engagement Theory at Craft SMEs: Evidence from Indonesian Batik, *Journal of Open Innovation: Technology, Market, and Complexity*, No.7, no. 2: 121. https://doi.org/10.3390/joitmc7020121.

Rathore, R., Thakkar., Jha, J.K. 2020. Evaluation of risks in food grains supply chain using FMEA and Fuzzy VIKOR, *International Journal of Quality and Reliability Management*, in press. https://doi.org/10.1108/IJQRM-02-2019-0070.

Rezghdeh, K., and Shokouhyar, S. 2020. A six-dimensional model for supply chain sustainability risk analysis in telecommunication network: a case study, *Modern Supply Chain Research and Application*, in press. https://doi.org/10.1108/MSCRA-09-2019-0018.

Rostamzadeh, R., Ghorabaee, M.K., Govindan, K., Esmaeili, A., and Nobar, H.B.K., 2018. Evaluation of sustainable supply chain risk management using an integrated fuzzy TOPSIS-CRITIC approach, *Journal of Cleaner Production*, Vol.125, pp:651-669. https://doi.org/10.1016/j.jclepro.2017.12.071.

Ragunath, K.M.K., and Devi, S.L.T. 2018. Supply Chain Risk Management: An Invigorating Outlook, *International Journal of Information Systems and Supply Chain Management*, Vol.11, No.3, pp:87-103. https://www.igi-global.com/article/supply-chain-risk-management/206164.

Reddy, S.A., Kumar, R.P., and Raj, A.P. 2018. Development of Sustainable Performance Index (SPI) for Self-Compacting Concretes, *Journal of Building Engineering*, Vol.27,10097. https://doi.org/10.1016/j.jobe.2019.100974.

Revindo, M.D. 2017. Types and Severities of Export Barriers: Evidence from Indonesian SMEs, *Economics and Finance in Indonesia*, Vol.63, No.2, pp:160-175. http://efi.ui.ac.id/index.php/efi/article/view/573/594.

Rathore, R., Thakkar, J.J., and Jha, J.K., 2017. A quantitative risk assessment methodology and evaluation of food supply chain, *International Journal of Logistics Management*, Vol.28, No.4., pp.1273-1293. https://doi.org/10.1108/IJLM-08-2016-0198.

Rohmah, D.U., Dania, W.A.P., and Dewi, I.A., 2015. Risk Measurement of supply chain organic rice product using fuzzy FMEA in Mutos Seloliman Trawas Mojokerto, *Agriculture and Agricultural Science Procedia*, Vol.3, pp.108-113. https://doi.org/10.1016/j.aaspro.2015.01.022.

Silva, U.S.K.D., Paul, A., Hasan, K.W., Paul, S.K., Ali, S.M. and Chakraborty, R.K. 2021. "Examining risks and strategies for the spice processing supply chain in the context of an emerging economy", *International Journal of Emerging Markets*, In Press, http://dx.doi.org/10.1108/IJOEM-07-2020-0776.

Singh, T., Tejyan, S., Patnaik, A., Chauhan, R. and Fekete, G. 2020. Optimal design of needlepunched nonwoven fiber reinforced epoxy composites using improved preference selection index approach, *Journal of Materials Research and Technology*, Vol.9, Iss.4, pp:7583-7591. https://doi.org/10.1016/j.jmrt.2020.04.101.

Shafi, M., Yin, L. and Yuan, Y. 2020. Revival of the traditional handicraft enterprising community in Pakistan, *Journal of enterprising Communities: People and Places in the Global Economy*, Vol.15, No.4, pp:477-507. https://doi.org/10.1108/JEC-07-2020-0129.

Sutrisno, A.,Gunawan,I.,Vanany,I., Asjad,M. and Caesarendra,W. 2018. An improved modified FMEA model for prioritization of lean waste risk, *International Journal of Lean Six Sigma*, Vol.11,No.2,pp:762-253. https://doi.org/10.1108/IJLSS-11-2017-0125.

Saad, M., Kumar, V., & Bradford, J. 2017. An investigation into the development of the absorptive capacity of manufacturing SMEs, International *Journal of Production Research*, Vol. 55, No. 23, pp. 6916-6931. https://doi.org/10.1080/00207543.2017.1327728.

Seshe, F. 2018. An investigation into supply chain risk factors and their impact on performance of humanitarian pharmaceutical supply chain in Sub Sahara Africa: a case study of the supply chain system for UNICEF Tanzania, *PhD Dissertation*, Northumbria University.

Shafiq, A., Johnson, F., Klassen, R.D., and Awaysheh, A., 2017. Exploring the Implication of Supply Chain Risk on Sustainability Performance, *International Journal of Operations and Production Management*, Vol.37, No.10, pp.1386-1407. https://doi.org/10.1108/IJOPM-01-2016-0029.

Schulte,J. and Hallstedt,S. 2017. *Challenges for Integrating Sustainability in Risk Management-Current State of Research*, in Proceeding of the 21st International Conference on Engineering Design, Vancouver, Canada. https://www.designsociety.org/publication/39587/Challenges+for+integrating+sustainability+in+risk+management+%E2%80%93+current+state+of+research.

Shahin, A., Kianersi, A., and Shali, A. 2018. Prioritizing Key Supply Chain Risks using the Risk Assessment Matrix and Shanon Fuzzy Entropy-with a case study in the home appliance Industry, *Journal of Advanced Manufacturing Systems*, Vol.17, No.3, pp:333-351. https://doi.org/10.1142/S0219686718500208.

Sunjka, B.P., and Chik, M.S., 2012. Supply chain risk in small and medium enterprises in South Africa, Proceedings of the CIE42, Cape Town, South Africa, pp:199-1 – 199-15. http://conferences.sun.ac.za/index.php/cie/cie-42/paper/download/199/79.

Slamet, A.S., Nakayasu, A., Astuti, R., and Rahman, N.M., 2017. Risk Assessment of Papaya Supply Chain: An Indonesian Case Study, *International Business Management*, Vol.11, No.2, pp: 508-521. http://dx.doi.org/10.36478/ibm.2017.508.521.

Singh, T., Patnaik, A., Gangil, B., and Chauhan, R. 2015. Optimization of tribo-performance of brake friction materials: Effect of nano filler, *Wear*, Vol.324-325, pp:10-16. https://doi.org/10.1016/j.wear.2014.11.020.

Sharma, S.K., and Bhatt, A., 2012. Identification and Assessment of supply chain risk: development of AHP model for supply chain risk prioritization, *International Journal of Agile System*, Vol.5, No.4, pp:350-360. https://dx.doi.org/10.1504/IJASM.2012.050155.

Tong, P., Zhon, C., and Wang, H., 2019. Research of the survival and sustainable development of small and medium enterprises in China under the background of low carbon economy, *Sustainability*, Vo1. 11, pp:3-17. https://doi.org/10.3390/su11051221.

Tran, T.H., Dobrovnik, M., and Kummer, S., 2018. Supply chain risk assessment: a content analysis - based literature review, *International Journal of Logistics Systems and Management*, Vol.31, No.4, pp:562-591. https://doi.org/10.1504/IJLSM.2018.096088.

Taghipour, S., Banjevic, D., and Jardine, A.K.S. 2011. Prioritization of medical equipment for maintenance decision, *Journal of Operational Research Society*, Vol.62, Iss.9, pp:1666-1687. DOI: 10.1057/jors.2010.106.

Qazi, A., and Gaudenzi, B. 2016. Supply chain risk management: creating an agenda for future research, *International Journal of Supply Chain and Operational Resilience*, Vol.2, No.1, pp:12-50. https://dx.doi.org/10.1504/IJSCOR.2016.075896.

Ulutas, A., Balo, F., Sua, L., Demir, E., Topal, A. and Jakovljevic, V. 2021. A new integrated grey multi criteria decision making model: case of warehouse location selection, *Fracta Universitatis, Series: Mechanical Engineering*, Vol.19, No.3, pp:515-535. DOI Number 10.22190/FUME210424060U.

Vishnu, C.R., Shridharan, R., and Kumar, R. P.N.,2019. Supply chain risk management: models and methods, *International Journal of Management and Decision Making*, Vol.18, No.1, pp: 31-75. https://dx.doi.org/10.1504/IJMDM.2019.096689.

Venkatesan, S.Prasanna, and Kumanan, S. 2012. Supply chain risk prioritization using a hybrid AHP and PROMETHEE approach, *International Journal of Service and Operations Management*, Vol.13, No. 1, pp:19-41. https://dx.doi.org/10.1504/IJSOM.2012.048274.

Wen, T.C., Chung, H.Y., Chang, K.H. and Li, Z. S., 2021. A flexible risk assessment approach integrating subjective and objective weights under uncertainty, *Engineering Application of Artificial Intelligent*, Vol.103, in press. https://doi.org/10.1016/j.engappai.2021.104310.

Wang, L. and Rani, P.2021. Sustainable supply chain under risk in the manufacturing firms: an extended double normalization-based multiple aggregation approach under an intuitionistic fuzzy environment, *Journal of Enterprise Information System*, Early View, https://doi.org/10.1108/JEIM-05-2021-0222.

Wondirad, A., Bogale, D., and Li, Y. 2021. Practices and challenges of developing handicrafts as a core tourism product in Chenca and Kongo,Southern Ethiopia, *International Journal of Cultural Policy*, in press, https://doi.org/10.1080/10286632.2021.1938560.

Wang, Z., Ran, Y., Yu, H., Jin, C. and Zhang, G. 2021. Failure mode and effects analysis using function–motion–action decomposition method and integrated risk priority number for mechatronic products, *Quality and Reliability Engineering International*, Vol.37, No.6, pp:2875-2899. https://doi.org/10.1002/qre.2895.

Wu, Y., Jia, W., Li, L., Song, Z., Xu, C., and Liu, F., 2019. Risk assessment of Electric Vehicle Supply Chain using Fuzzy Synthetic Evaluation, *Energy*, Vol.182, pp:397-411. https://doi.org/10.1016/j.energy.2019.06.007.

Wu, G., Duan, K., Zuo, J., Zhao, X. and Tang, D. 2017. Integrating Sustainability assessment of public rental housing community based on hybrid method of AHP-entropy weight and Cloud Model, *Sustainability*, Vol.9, Iss.4, pp:1-25. https://doi.org/10.3390/su9040603.

Xu, M., Cui, Y., Hu, M., Xu, X., Zhang, Z., Liang, S., and Qu, S. 2019. Supply chain sustainability risk and assessment, *Journal of Cleaner Production*, Vol.225, pp:857 – 867. https://doi.org/10.1016/j.jclepro.2019.03.307.

Xin, J.2008. Risk evaluation model for radioactive protective countermeasure based on fuzzy entropy, International Journal of Nuclear Governance, Economy and Ecology, Vol.2, Iss.2,pp:191-198. https://doi.org/10.1504/IJNGEE.2008.018336.

Yang, Y., Chu, X., Pang, R., Liu, F., and Yang, P. 2021. Identifying and predicting the credit risk of small and medium -sized enterprises in sustainable supply chain finance: evidence from China, *Sustainability*, Vol.13, No.10,

Yin, R.K. 2014. *Case study Research: Design and Methods-5th edition,* Sage Publisher, Thousand Oaks, California.

Yu, C., Zhang, B., Yao, M., Meng, F. and Zheng, C. 2013. A field demonstration of the entropy-weighted fuzzy DRASTIC method for underground water vulnerability assessment, Hydrological Science Journal, Vol.57, Iss.7, pp:1420-1432. https://doi.org/10.1080/02626667.2012.715746.

Zhu, Q., Golrizgashti, S., and Sarkis, J., 2020. Product deletion and supply chain repercussions: risk management using FMEA, *Benchmarking: An International Journal*, Vol.82, Iss.2, pp:409-437. https://doi.org/10.1108/BIJ-01-2020-0007.

Zubayer, M.A.A., Ali, S.M., and Kabir, G. 2019. Analysis of supply chain risk in the ceramic industry using fuzzy TOPSIS, *Journal of Modelling in Management*, Vol.4, No.3, pp:792-815. https://doi.org/10.1108/JM2-06-2018-0081.

Zhu, M., Zhang, X., and Pham, H., 2015. A Comparison Analysis of environmental factors affecting software reliability, *The Journal of Systems and Software*, Vol.109, pp:150-160. https://doi.org/10.1016/j.jss.2015.04.083.