Formulation of Manufacturing Strategies Based on an Extended SWARA Method with Intuitionistic Fuzzy Numbers: an Automotive Industry Application

Abstract

Applying any kind of manufacturing strategy requires to evaluate the current situation of the system at the internal and external levels and provide strategies for improving the system performance. Hence, the present study tries to review and design the optimal manufacturing strategy for increasing the efficiency of the automotive industry. In this paper, a three-step manufacturing strategy model using Miltenburg worksheet and concentrating on five manufacturing objectives encompassing the production system, manufacturing outputs, manufacturing leverage, production capabilities, and competitive analysis, is proposed. First, the current production system is determined based on Product\Volume Layout\Flow Matrix (PV-LF) matrix. At the point, six manufacturing levers are analyzed and assessed. In the following step, Step-wise Weight Assessment Ratio Analysis (SWARA) method is extended into the intuitionistic fuzzy environment and manufacturing outputs (delivery, cost, quality, performance) are evaluated to identify criteria of the optimal production system. Eventually, optimal strategies are formulated; thus, the production system could change to the optimal system. The results demonstrated that the case study production system is Equipment Paced Line Flow (EPL) and should change from ELP to Just in Time (JIT). Furthermore, changing manufacturing levers is necessary to execute the proposed framework successfully.

Keywords. Manufacturing Strategy, Miltenburg Worksheet, Intuitionistic Fuzzy Numbers, SWARA method.

1. Introduction

Firms can gain both economic and operational benefits from engaging in environmental and social initiatives. The opportunities emerging from increases the complexity that managers need to deal with in terms of strategy formulation and operationalization (Kulkarni et al., 2019). Today the environment of manufacturing companies has changed dramatically over the past decades; hence, manufacturing companies were facing a constant increase in complexity in recent years (Dombrowski et al., 2016). The theory of manufacturing strategy was first introduced by Selznick (1957). Skinner (1969) developed this theory specifically in the field of production while using the theory of bargaining. The operational strategy began as a field of study (Garrido-Vega et al., 2015). Although research on manufacturing strategy is frequently addressed since Skinner (1969) identified the absence of manufacturing in the business strategy planning process, the topic is still under considerable development. Recently a shift from manufacturing strategy towards the slightly broader concept of operations strategy, including services, can be discerned (Slack, 2005).

One of the essential tools for managing operations in the current businesses is the operational strategy (Qi et al., 2017; Jia et al, 2015). The operational strategy focuses on the organizational activities at the operational levels in line with the competitive priorities of an organization. Using any kind of manufacturing strategy requires identifying and monitoring the present state of the system at internal and external levels and providing strategies to improve the current state of the system (Miltenburg, 2008).

Furthermore, organizations should seek to develop strategies that increase their competitive capabilities (Rahman and Rahman, 2020). Manufacturing strategy involves creating manufacturing capabilities that can differentiate a firm in the market (Kulkarni et al., 2019). Manufacturing strategy may include a sequence of decisions over a period that enables the business unit to achieve the desired industrial manufacturing structure, infrastructures, and a set of specific capabilities (Balić et al., 2017). According to Miltenburg, manufacturing capability is given by the sum of the capabilities of each subsystem (lever) in a particular production system (Miltenburg, 2005). The level of capability (low to high) in each production subsystem (lever) is decided by the decisions taken in that particular subsystem. Therefore, understanding the manufacturing capability is essential for competitiveness. One approach for this is the measurement of manufacturing capability, which is inspired by leanness (Vinod and Balaji, 2011) and agility measurement (Vinod et al, 2010) of an organization for better decision making.

Despite the growing academic research in Manufacturing Strategy with new frameworks, models, and empirical surveys, firms often fail to develop manufacturing capabilities that create a competitive advantage (Kulkarni et al., 2019). Many decision-making methods have been previously employed to formulate manufacturing strategies (Ocampo et al, 2015; Ocampo et al, 2016; Ocampo 2017, 2018, 2019). Even uncertain approaches such as fuzzy are considered in this regard (e.g. Ocampo, 2019). Due to the complex structure of this problem and the conflicting nature of the criteria's leads to impreciseness and vagueness in the data of the corresponding problem. Zadeh (1965) proposed the idea of fuzzy sets to deal with these uncertainties. Ever since many extensions of fuzzy sets are introduced. Intuitionistic Fuzzy Sets (IFSs) (Atanassov, 1986) is one of that extensions being more efficient in dealing with uncertainty and situations that available information is not sufficient for the definition of membership degree for certain elements. By using intuitionistic fuzzy sets instead of fuzzy sets the authors can consider another degree of freedom called non-membership function into decision-making methods with uncertainties in problems that extreme impreciseness and vagueness exist. Therefore, the purpose of this research is to design and develop manufacturing strategy decision making by developing the Miltenburg model by extending the SWARA method into the intuitionistic fuzzy environment. Based on the relevant literature the assessment of manufacturing strategies by considering intuitionistic fuzzy information has not been previously investigated. Additionally, this research follows some other secondary objectives such as identifying the characteristics of the production system and determining the desired situation of the case study in the market and formulating manufacturing strategies.

Automobile manufacturing supply chains are one kind of supply chains that are heavily sensitive to disturbances and formulating operational strategies. Iran's automotive industry is the third-most active industry in the country, after its oil and gas industry, accounting for 10% of Iranian gross domestic product (GDP) and 4% of the Iranian workforce. Since the early 2000s, automobile production in Iran has grown exponentially. According to figures from the International Organization of Motor Vehicle Manufacturers (OICA), Iran was the 12th biggest car market on the planet in 2017, with sales in the region of 1.5 million cars. That number of cars represented an 18% growth in sales, which made Iran the fourth fastest-growing nation in the market, behind Brazil, Portugal, and Russia. Today, Iran is the 18th largest automaker in the world and one of the largest in Asia. The selected case of this paper is one of the leading companies in the Iranian Automobile parts manufacturing sector. This company's purpose is designing and supplying polymeric parts in the automobile, including components of the fuel system, sealing tapes and other injection moldings, extruding, etc., for automobile manufacturers inside and outside of Iran.

Moreover, it is supporting the demand for polymer parts in other markets and industries, while relying on empowered and committed employees and high-tech systems that are following national and international standards. However, since the supply chain of this industry is dependent on the changing and hardly predictable environment of the market (Liu et al., 2018) and factors such as raw materials, supplier's conditions, government policies, sanctions and fluctuations in prices caused by currency volatility; therefore, operational strategies are becoming valuable and they need to formulate the manufacturing strategies to cope with this chaotic business environment.

Following the introduction, section 2 reviews the existing literature. Section 3 sets out the research methodology on extended SWARA and the variables for the case study are discussed in section 4. Section 5 provides the results from the proposed method. Section 6 concludes the study and highlights the managerial implication.

2. Literature review

The manufacturing strategy is a framework for structured and non-structured decisions that determine the capabilities of the production system and determine how the manufacturing sector acts to achieve the commercial goals of the organization. Various definitions of production and manufacturing strategy are provided. Foster and Gibbons (2007) define the production strategy as an adaptive model of decision-making in production functions related to business strategy. Some scholars after Skinner's work have expressed the importance of production as a source of competitive advantage in manufacturing companies. Nonetheless, most researchers have focused on the content of the production strategy and the relationship between multiple variables in this area. In this manner, less attention was paid to identifying the configurations, the typology, and the taxonomy of the strategies (Frohlich and Dixon, 2001; Zhao et al., 2006). The development and creation of configurations and taxonomies is the starting point for research in production strategy, especially when the purpose of the research is to determine the dominant patterns in the organizations or when the goal of a study is to set the relationship between several variables that are separately understandable. However, achieving an overall understanding of them is very complicated (Miller, 1996). Taxonomies provide descriptions of strategic groups, useful for discussion and research, and clarify competitive structures from the operational view (Miller and Roth, 1994). Cox and Blackstone (1998) described the production strategy as a comprehensive model of decisions that emphasize the formulation and use of production resources for maximizing efficiency and must support general strategic decisions and prepare a plan for competitive advantage. Mills et al. (1995) added that the manufacturing or production strategy is a model of related decisions and actions, showing the capability of a production system and how it can achieve a set of production goals. The most important definitions of manufacturing strategy are as follows.

- The industrial manufacturing strategy is a vital part of the business strategy of a company, including a set of practical plans and well-coordinated goals to maintain a sustainable advantage against competitors over time.
- It is a coherent and coordinated approach to achieve consistency between the functional capabilities and policies and the current and future state of competitive advantage of the organization and is necessary for market success (Hill, 2008).

A configuration of manufacturing goals is most often referred to as the configuration of the manufacturing strategy. Various studies are carried out in different countries in this field. Miller and Roth's work is one of the most famous taxonomic studies in the production strategy field. The strategies, introduced by them, were the result of using the 11 manufacturing-competitive priorities (Miller and Roth, 1994). Although different configurations use different dimensions, they are quite similar in practice. Particularly, the classification of competitive priorities, production tasks, and missions seem to fit into four strategic areas. Cagliano et al. (2005) described them as market-based, product, capability, and price-based strategies. Zhao et al. (2006) introduced the taxonomy of China's manufacturing strategies. They identified four clusters. The second category of their strategies only had a significant relationship to Miller and Roth's (Miller and Roth, 1994) market strategies and Frohlich and Dixon (2001). Their clusters were called “quality customizers, low emphasizers, mass servers, and specialized contractors” (Zhao et al., 2006).

Manufacturing strategy formulation is often described through manufacturing strategy frameworks. The concept of manufacturing strategy framework is used to signify any kind of structure or procedure that supports strategy formulation. A manufacturing strategy framework answers the question ‘how to’ and provides an overall way forward (Yusof and Aspinwall, 2000), while a manufacturing strategy tool is the actual implementation of a framework (Säfsten et al., 2014; Oddershede et al, 2019).

Using factor analysis based on a sample of companies with project-oriented systems, Oltra et al. (2005) identified four main components for production goals including cost, the quality of production, delivery, and customization and then three groups were identified that named as cost-oriented strategy, follow-up strategy, and innovation strategy. In-service operation area, Arias Aranda (2003) identified a model based on three basic operational strategies that were consistent with the focus of the company's activities. These strategies were process-oriented, service-oriented, and customer-oriented. Theodorou and Florou (2008) presented a sample of IT companies with advanced information technology applying for their production to study the impact of different types of strategies on financial performance. Their grouping was upon production goals like the strategy of cost, quality, flexibility, and innovation.

Martín-Peña and Díaz-Garrido (2008) provided production targets at the Spanish manufacturing companies. They used cluster analysis and identified two types of strategies. Mohanty and Deshmukh (1999) in their study identified production processes in the form of taxonomy. Miltenburg (2008) introduced a two–dimensional matrix called PV-LF matrix, taking into consideration four features including variety, volume, and layout or material flow. As above mentioned, one of the analytical models in the manufacturing strategy and production system is Miltenburg's Strategy Worksheet. Miltenburg has provided a general framework for analyzing the company's manufacturing strategy alongside with its production system and capabilities (Miltenburg, 2008). The model has two worksheets for the manufacturing strategy and the implementation of the strategy. All existing models can formulate the manufacturing strategy for large companies. Frameworks or procedures for the formulation of manufacturing strategies in small- and medium-sized companies are rare; however, one example is the Miltenburg worksheet. The Miltenburg worksheet identifies the appropriate engineering-technology alternatives to complete the tasks embodied in each product.

The book by Miltenburg (2005) outlines a general process for formulation of manufacturing strategy where three issues are examined, (1) where manufacturing is, (2) where manufacturing needs to be, and (3) what is the best way to move manufacturing from where it is to where it needs to be. Each step interacts with every other step and the interactions can be seen in the worksheet for visualizing the process. The worksheet is used for analyzing a factory, for generation and evaluation of alternative strategies, and to develop a manufacturing strategy. The three-step procedure uses the worksheet in the following way:

1) In step 1, determines the current production system in use and to assess the current level of capability for each manufacturing lever;
2) In step 2, determines market-qualifying and order-winning criteria, to find the best matching manufacturing deliverables compared with manufacturing outputs, to determine a new production system;
3) In step 3, makes adjustments to the manufacturing levers. These adjustments to the manufacturing levers should support changes to the desired production system and the required market-qualifying and order-winning outputs.

The Miltenburg model has six production outputs. These manufacturing outputs of the industry are presented as follows.

[1]. Delivery. The time between ordering and delivery to customers, how do delays occur on most orders,
[2]. Cost. Cost of materials, workforce, overhead and so on,
[3]. Quality. The degree to which the product meets the customer's needs and expectations and the specifications provided by customers,
[4]. Performance. Product features and the degree to that the features allow the product to present values that other products are not able,
[5]. Flexibility. Quick responsiveness to environmental changes and varying customer needs,
[6]. Innovativeness. The ability to rapidly introduce new products with the change.

Production outputs are the very competitive strategies at the business unit or business level. Miltenburg's strategy is a complete framework for analyzing the current state of production as well as developing a strategy for improving the manufacturing system. According to the Miltenburg model, to develop a production strategy, three stages should be followed: identifying the status quo (developing a PV-LF matrix) and determining the current level of manufacturing leverage capabilities, describing the optimal location of production strategy (determining the winner of the order and the best alternative production system) and specifying how should get from the current state to the desired state (adjusting the leverages). As stated earlier, to determine the type of manufacturing system, the PV-LF matrix should be developed. The PV-LF matrix can be created based on the process-product matrix developed by Wheelwright and Hayes (1985). The second step is to determine the manufacturing leverage of the company. Successful manufacturers have categorized the system into six useful sub-systems. These six subsystems refer to manufacturing levers: human resources, organizational structure, and control, resourcing, production planning and control, process technology, and facilities. To determine the capabilities and the level of each of the production levers, one should compare the current status of each leverage with the intended industry. It should be noted that each of the production levers has measurable indicators which can be obtained by a questionnaire to determine the level of the leverage.

Eventually, the strategy implementation worksheet should be designed. The implementation plan is the tool through which the production strategy is executed and it includes what needs to be performed, why, how, when, and who will do it. The next section will review the most important research in the field of strategy development. Singh and Mahmood (2014) determined that there is a significant relationship between manufacturing strategy and export performance of manufacturing small and medium enterprises (SMEs) in Malaysia. Besides, Badurdeen and Jawahir (2017) discussed strategies for value creation through sustainable manufacturing. In this regard, Dombrowski et al. (2016) presented an approach for developing a manufacturing strategy. Their research points out how manufacturing can enable a decisive differentiation from competitors. Furthermore, Pooya and Faezirad (2017) investigated the taxonomy of manufacturing strategies and production systems using a self-organizing map. The results demonstrate the existence of four manufacturing strategies and three production processes among manufacturing companies that are different from those studies conducted in other countries. Besides, Narkhede (2017) assessed the implications of organizational knowledge, the source of information and functional orientation, the resource-based view of the manufacturing and global orientation on manufacturing practices which includes advanced manufacturing strategies. Moreover, Olhager and Feldmann (2018) concerned with the manufacturing strategy decision-making structure in multi-plant networks, i.e. how strategic manufacturing decision-making authority is distributed between the network level (i.e. headquarters) and the plant level. Furthermore, Kulkarni et al. (2019) provided an empirical analysis of the paradox between academic and industry definitions of manufacturing strategies. Narkhede (2018) investigated the linkages in advanced manufacturing strategy by reviewing the literature. Based on a systematic review of published articles from 1982 to 2012, they proposed and discussed a framework that brings together a set of variables related to the manufacturing strategies and advanced manufacturing technologies and the internal contextual factors driving it. Oddershede et al. (2019) employed the concept of House of Quality (HoQ) and Quality Function Deployment (QFD) in formulating manufacturing strategies. Table 1 demonstrates the previous literature with regards to the application of multiple criteria decision making (MCDM) models or any other methods in strategy formulation. In this regard, the relevant researches are classified based upon the method used (e.g. TOPSIS, AHP, systematic literature review, conceptual modeling, etc.), the uncertainty type considered in the research (e.g. grey, fuzzy, interval fuzzy, etc.), the strategy formulation level (e.g. manufacturing strategy, general strategy, environmental strategy, etc.) and the industry or area of study. In this regard keywords including "manufacturing strategy formulation", "strategy formulation", "MCDM in strategy formulation" etc. are searched through databases such as "google scholar", "Scopus", "Sciencedirect", etc. for last five years.

Table 1. The classification of previous relevant research regarding MCDM in strategy formulation

Scholar	Year	method used	Uncertainty type	Strategy formulation type	Industry/ area of study
Kumar et al	2015	ANP, DEA	N/A	Manufacturing	SMEs
Gupta et al	2015	SWOT, QSPM	N/A	General	Corrugate
Ocampo et al	2015	ANP	Fuzzy	Manufacturing	SMEs
Wang et al	2016	PCA	N/A	Manufacturing	SMEs
Khatri & Metri	2016	AHP	N/A	Manufacturing	SMEs
Ocampo et al	2016	ANP	N/A	Manufacturing	SMEs
Ocampo	2017	ANP	Fuzzy	Manufacturing	SMEs
Satyro et al	2017	SLR	N/A	Environmental sustainability	Literature review
Olhager & Feldmann	2018	Statistical analysis	N/A	Manufacturing	107 plant
Ocampo	2018	ANP	Fuzzy	Manufacturing	SMEs
Singh	2018	SLR	N/A	Manufacturing	Automobile
Oddershede et al	2019	HoQ	N/A	Manufacturing	Industrial tanks
Gurbuz	2019	AHP, ANP	N/A	General	Aeronautics
Adobor	2019	SLR	N/A	General	Literature review
Wang et al	2019	Reverse QFD	N/A	Manufacturing	General
Ocampo	2019	TOPSIS, AHP	Fuzzy	Environmental	Food

*Analytical Hierarchical Process (AHP), Analytical Network Process (ANP), Systematic Literature Review (SLR), House of Quality (HoQ), Quality Function Deployment (QFD), Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS), Principle Component Analysis (PCA), Not applicable (N/A), Data Envelopment Analysis (DEA), Small and Medium Enterprises (SMEs)

The above table indicates that the highest degree of uncertainty considered in the existing literature is fuzzy and more recent and modern uncertainty approaches are not addressed by any other scholar. With this fact in mind, in this research by developing and designing an intuitionistic fuzzy version of a decision-making method, a great movement is occurring. Moreover, the literature review showed that for strategy formulation with Miltenburg worksheet no research is performed with a quantitative approach. Since the Miltenburg worksheet has a subjective approach and incorrect use of it can lead to the formulation of non-optimal strategies; therefore, employing quantitative approaches can be very effective to increase the research validity and preventing prejudices in determining the importance of manufacturing levers and outputs. In following the Miltenburg worksheet is developed by a novel multi-criteria decision-making (MCDM) approach. In the current study, the authors proposed a new integrated approach based on the SWARA (an extended SWARA) method, which could be useful to MCDM problems with intuitionistic fuzzy numbers. This combination could lead to more realistic criteria values and manufacturing system weights for strategy formulation. Hence, in this research, an integrated approach based on the SWARA method is developed to deal with manufacturing strategies formulation as an MCDM problem within the intuitionistic fuzzy environment.

3. Research Methodology

The primary data in this research included data collection through interviews and questionnaires. The expert's team in this study included 7 major executives who were familiar with the concept of operational strategy that their background is shown in Table 2. Experts were selected by the snowball sampling method.

Table 2. Background of the expert's team

Expert No.	Position	Work Experience (year)
1	CEO	19
2	Production Manager	12
3	Maintenance Manager	14
4	Head of R&D	7
5	Marketing Director	10
6	Logistics Manager	9
7	Strategic Deputy	11

Secondary data relates to the actual documentary data of the company. In different stages of the research, the Miltenburg model and the SWARA-IFS technique were applied to develop the Miltenburg model. In Figure. 1, the research steps are presented.

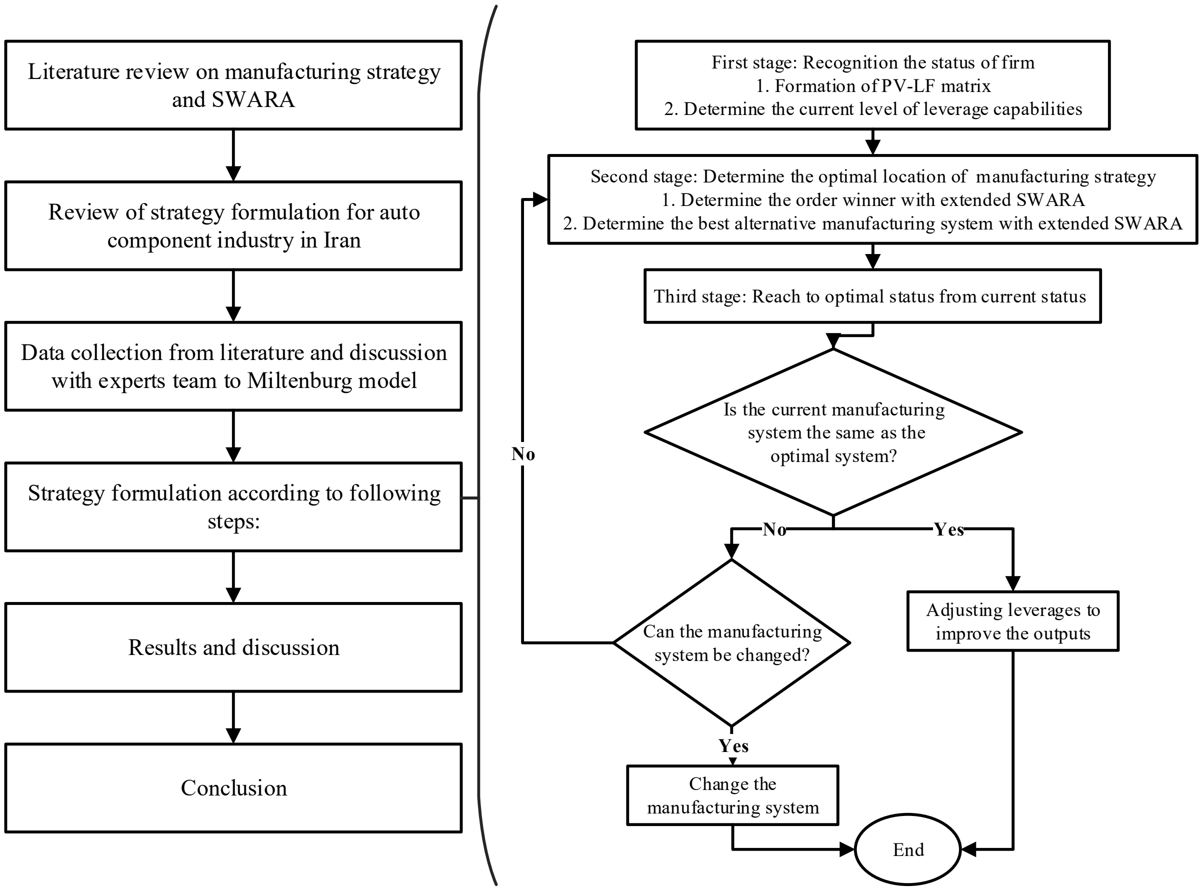

Figure 1. Research steps

3.1. Preliminaries on the Intuitionistic Fuzzy Sets

Atanassov (1986) introduced the Intuitionistic Fuzzy Sets Theory (IFS) which is a generalization of Fuzzy Sets theory introduced by Zadeh (1965). This is characterized by a membership function and a non-membership function. Following are some important concepts of IFS theory:

Definition 1.

Let $X = \emptyset$ be a given set. An Intuitionistic Fuzzy Set X is an object A given by $\tilde{A} = \{< x, \mu_{\tilde{A}}(x), v_{\tilde{A}}(x) >: x \epsilon X\}$ where $\mu_{\tilde{A}}(x), v_{\tilde{A}}(x)$ are membership and none membership degree, $\mu_{\tilde{A}}(x), v_{\tilde{A}}(x) : X \rightarrow [0,1]$, $0 \leq \mu_{\tilde{A}}(x) + v_{\tilde{A}}(x) \leq 1, \forall \epsilon X$ (Çebi and Otay, 2016).

Definition 2.

Membership function $\mu_{\tilde{A}}(x)$ and none membership $v_{\tilde{A}}(x)$ of a triangular intuitionistic fuzzy number (TIFN): $\tilde{A}_{TFIN} = (a^L, a^M, a^U; a'^L, a^M, a'^U)$ is a TIFN if its membership function and none membership are given by Singh and Yadav (2015):

$$u_{\tilde{A}}(x) = \begin{cases} \frac{x-a^L}{a^M - a^L}, a^L < x \leq a^M \\ 1, x = a^M \\ \frac{a^U - x}{a^U - a^M}, a^M \leq x < a^U \\ 0, otherwise \end{cases} \quad (1)$$

$$v_{\tilde{A}}(x) = \begin{cases} \frac{a^M-x}{a^M - a'^L}, a'^L < x \leq a^M \\ 0, x = a^M \\ \frac{x - a^M}{a'^U - a^M}, a^M \leq x < a'^U \\ 1, otherwise \end{cases} \quad (2)$$

Where $a'^L \leq a^L \leq a^M \leq a^U \leq a'^U$ and $\mu_{\tilde{A}}(x) = v_{\tilde{A}}(x) \leq 1$.

Definition 3.

Arithmetic operations of TIFN numbers (Nagoorgani and Ponnalagu, 2012):

If $\tilde{A}_{TFIN} = (a^L, a^M, a^U; a'^L, a^M, a'^U) and$ $\tilde{B}_{TFIN} = (b^L, b^M, b^U; b'^L, b^M, b'^U)$ are two TIFNs, then:

$$\tilde{A} \oplus \tilde{B} = (a^L + b^L, a^M + b^M, a^U + b^U; a'^L + b'^L, a^M + b^M, a'^U + b'^U) \quad (3)$$

$$\tilde{A} \ominus \tilde{B} = (a^L - b^U, a^M - b^M, a^U - b^L; a'^L - b'^U, a^M - b^M, a'^U - b'^L) \quad (4)$$

$$\tilde{A} \otimes \tilde{B} = (a^L b^L, a^M b^M, a^U b^U; a'^L b'^L, a^M b^M, a'^U b'^U) \quad (5)$$

$$\tilde{A} \oslash \tilde{B} = (a^L/b^U, a^M/b^M, a^U/b^L; a'^L/b'^U, a^M/b^M, a'^U/b'^L) \quad (6)$$

$$k \times \tilde{A}_{TFIN} = (K \times a^L, K \times a^M, K \times a^U; K \times a'^L, K \times a^M, K \times a'^U), K > 0 \quad (7)$$

Definition 4.

Score function and accuracy function (Puri and Yadav, 2015; Hajiagha et al, 2015):

Let $\tilde{A}_{TFIN} = (a^L, a^M, a^U; a'^L, a^M, a'^U)$ be a TIFN, the score function for membership and non-membership values define as (8) and (9) respectively:

$$S(\tilde{A}^\alpha) = \frac{a^L + 2a^M + a^U}{4} \quad (8)$$

$$S(\tilde{A}^\beta) = \frac{a'^L + 2a^M + a'^U}{4} \quad (9)$$

Afterward, $(\tilde{A}) = \frac{(a^L + 2a^M + a^U) + (a'^L + 2a^M + a'^U)}{8}$ is defined as an accuracy function of $(\tilde{A})$ to defuzzify the TIFN number.

3.2. An intuitionistic fuzzy SWARA (SWARA-IFS)

Various subjective approaches could be performed to assess the relative importance of criteria weights (Balki et al., 2020) including AHP, ANP, expert method (Zavadskas and Vilutiene, 2006) SWARA, BWM (2016), etc. Different decision-makers of the expert group have different opinions about criteria significance. In this regard, the SWARA method was proposed by Keršuliene et al. (2010).

SWARA is a method where experts apply their implicit knowledge, experiences, and information. Besides, it is not considered to be complicated and time-consuming (Mardani et al., 2017). The main feature of the SWARA method is the possibility to estimate the opinions of experts or stakeholder groups regarding the significance ratio of the criteria in the process of their weight determination (Keršuliene et al., 2010). The experts determine the most considerable criterion by the highest rank, the least considerable criterion by the lowest rank, and then estimate the overall ranks from the average value of ranks. This method is used in different research papers with different applications. Some of the recent works based on the SWARA method are discussed.

Keršuliene et al. (2010) applied SWARA in rational dispute resolution method selection. Mavi et al. (2017) employed fuzzy SWARA for sustainable third-party reverse logistics provider selection in the plastic industry. Keshavarz Ghorabaee et al. (2018) applied SWARA for the evaluation of construction equipment with sustainability considerations. Zarbakhshnia et al. (2018) applied fuzzy SWARA in sustainable third-party reverse logistics provider evaluation and selection problems in the presence of risk criteria. Perçin (2019) used this method for outsourcing provider selection. Balki et al. (2020) applied SWARA in the optimization of engine operating parameters. Heidary Dahooie wt al. (2020) applied the SWARA method to assess the Occupational Hazards in the Construction Industry. Ghenai et al. (2020) utilized SWARA to weighting Sustainability indicators for renewable energy systems. For more studies on the application of this method, you can see Mardani et al. (2017). By extensively analyzing literature review the authors can discover that SWARA-IFS has never been developed in any research and this is one of the most original features of this paper.

Crisp SWARA cannot effectively deal with problems with such imprecise information; hence, in this study fuzzy intuitionistic SWARA method is developed to handle this kind of problem appropriately. The process of evaluating the importance weights of criteria using the SWARA-IFS method is summarized in this section.

Step 1. Each of the decision-makers (DM=1,2,…,m) sort the evaluation criteria (j=1,2,…,n) in descending order of expected significance.

Step 2. According to Table 3, the relative importance of the criterion j concerning the previous (j−1) criterion should be determined by each of the decision-makers.

Table 3. IFS scale (Kaur, 2014)

Linguistic scale	Response scale
Equally important	(0, 0, 0) (0, 0, 0)
Between	(0.8, 1, 2) (0.5, 1, 2.1)
Less important	(1, 2, 2.5) (0.85, 2, 2.7)
Between	(2, 3, 4) (1.5, 3, 4.1)
Very less important	(3, 4, 5) (2.5, 4,5. 2)
Between	(4, 5, 6) (3.5, 6, 6.1)

Linguistic scale	Response scale
Much less important	(6, 7, 8) (6, 7, 8.2)

Step 3. Obtain the coefficient $\widetilde{K}_j$:

$$\widetilde{K}_j = \begin{cases} \tilde{1}\,, j = 1 \\ \tilde{S}_j + \tilde{1}\,, j > 1 \end{cases} \quad (10)$$

Step 4. Calculate the fuzzy weight $\tilde{q}_j$:

$$\tilde{q}_j = \begin{cases} \tilde{1}\,, j = 1 \\ \frac{\tilde{q}_{j-1}}{\widetilde{K}_j}\,, j > 1 \end{cases} \quad (11)$$

Step 5. Calculate the relative weights of the evaluation criteria:

$$\widetilde{w}_j = \frac{\tilde{q}_j}{\sum \tilde{q}_j} \quad (12)$$

Step 6. Calculate the defuzzified weights of the criteria:

$$w_j = \frac{\left(a^{L(\widetilde{w}_j)} + 2a^{M(\widetilde{w}_j)} + a^{U(\widetilde{w}_j)}\right) + \left(a'^{L(\widetilde{w}_j)} + 2a^{M(\widetilde{w}_j)} + a'^{U(\widetilde{w}_j)}\right)}{8} \quad (13)$$

Step 7. Calculate the normalized subjective weights of the criteria:

$$w_j' = \frac{w_j}{\sum w_j} \quad (14)$$

Step 8. Calculate the average normalized subjective weights of the criteria:

$$w_j'' = \frac{1}{m} * \sum_{D=1}^{m} w_j' \quad (15)$$

4. Data analysis and results

In this section, to identify the current status of the manufacturing system of the research case, the authors have employed three methods, including the direct observation of the production process, interviews with experts in the manufacturing field, and the Hayes and Wilfried model (PV-LF matrix). The expert panels were asked to determine the status of the company following such variables as the volume of production, the variety of products, the type of layout, and the flow of materials. In the present study, the four dimensions of the PV-LF matrix are (Miltenburg, 2005; Pooya and Faezirad, 2017):

1) Production volume: High;
2) Product diversity: Very low;
3) Layout: Linear;
4) Material flow: Regular flow.

Considering these dimensions, the type of current system of the case study was Equipment Paced Line Flow (EPL). In the next step, the aim is to determine the manufacturing leverage. The production levers were measured employing the indicators listed in the Miltenburg's standard Model (Miltenburg, 2008) and surveying the expert's opinions regarding questions presented in Table 4. The results are demonstrated in Table 5.

Table 4. Questionnaire of manufacturing levers

Production Lever	No	Items
Human Resource	1	Do employees have the appropriate skill to perform their duties?
	2	Is the wage level suitable for employees?
	3	Are there any suitable training programs for the staff?
	4	Are there appropriate promotion policies for employee promotion?
	5	Do employees have a decent level of security?
	6	Is the policy of termination of employee service appropriate?
	7	Is it appropriate to give employees responsibility and decision?
	8	Are employees involved in solving problems and improving activities?
Control and Organizational Structure	9	What is the status of organizational levels in organizational structure?
	10	What are the importance of different units and the use of teams?
	11	Is the level of responsibility and authority appropriate at the organization?
	12	Are the criteria used to evaluate individuals and sectors appropriate?
	13	Does the organization have appropriate criteria for selecting managers?
	14	Are there any suitable systems for evaluating the employees?
Production Planning	15	How an organization's relationship with suppliers is cooperative?
	16	In supplier selection, how much pay attention to their capabilities?
	17	Are suppliers responsible for design and quality responsibilities?
	18	Is there a proper decision-making process for suppliers to select?
Sourcing	19	Is there a timetabling program for ordering and entering raw materials?
	20	Are there any suitable policies for reducing raw materials?
	21	Is there a good program for support in production processes?
	22	Is there a good way to design new products?
	23	Is there a timetabling program in the production process and equipment?
	24	Is there a good policy for the company's quality control system?
	25	Is there a good program for coordinating different parts of production?
Process Technology	26	Are there sufficient surveys on the equipment layout?
	27	Are there necessary tools at the appropriate volume?
	28	Should attention to the machinery for raising the quality of production?
	29	Are there policies for continuous improvement in layout and technology?
	30	Are there suitable procedures for controlling the quality of production?
	31	Are there any plans to improve the technology of equipment?
Facility	32	Is the location and size of the plant suitable for doing business?
	33	Are the various units of the factory designed in a multipurpose manner?
	34	Are different parts of the factory have the right size for the production process?
	35	Are there suitable programs to improve the capabilities of the infrastructure?
	36	Are the facilities suitable for inventory management?

Table 5. The production levers and the score of the case study in each lever

Production Lever	No	The answer to each expert							Total score
		E_1	E_2	E_3	E_4	E_5	E_6	E_7	
Human Resource	1	3	2	3	3	4	3	2	1.87
	2	3	1	2	2	3	3	1	
	3	2	2	4	3	2	3	2	
	4	1	2	3	2	1	2	2	
	5	4	3	3	1	2	3	2	
	6	2	1	2	3	2	2	3	
	7	2	3	2	2	2	1	2	
	8	3	2	3	3	2	2	3	
Opinions average		2.5	2	2.75	2.37	2.25	2.37	2.12	
Control and Organizational Structure	9	4	2	3	3	2	2	3	2.29
	10	3	3	2	4	4	3	2	
	11	2	3	3	2	3	2	4	
	12	3	2	3	4	2	3	3	
	13	4	3	4	3	3	2	3	
	14	2	3	2	3	2	3	4	
Opinions average		3	2.67	2.83	3.16	2.67	2.5	3.16	
Production Planning and Control	15	4	3	3	2	3	4	3	2.37
	16	3	3	2	4	2	3	4	
	17	3	2	2	4	2	3	4	
	18	4	3	3	2	4	2	2	
Opinions average		3.5	2.75	2.5	3	2.75	3	3.25	
Sourcing	19	3	3	2	3	4	2	2	2.02
	20	2	3	2	3	2	1	3	
	21	3	2	3	2	3	3	2	
	22	2	1	2	2	3	2	1	
	23	4	3	4	3	3	3	4	
	24	2	3	2	3	2	1	2	
	25	3	2	3	2	3	3	3	
Opinions average		2.71	2.42	2.57	2.57	2.85	2.14	2.42	
Process Technology	26	2	2	3	2	2	2	2	2.04
	27	4	3	3	2	3	3	2	
	28	3	2	2	3	3	2	3	
	29	2	2	3	2	1	3	1	
	30	4	3	3	4	3	3	3	
	31	3	2	2	3	3	2	3	
Opinions average		3	2.33	2.67	2.67	2.5	2.5	2.16	
Facility	32	4	3	4	4	3	4	3	2.38
	33	3	2	2	3	3	2	2	
	34	4	3	3	4	4	3	3	
	35	2	3	2	2	3	2	4	
	36	3	3	4	2	2	3	3	
Opinions average		3.2	2.8	3	3	3	2.8	3	
Average of production capabilities									2.16

Given that the competition level of the case study was domestic markets, the results of the investigated levers are presented in Table 6.

Table 6. Type of manufacturing system according to the experts' opinions

Production system	Production Diversity	Production Volume	Material Flow	Layout	Type of Equipment	Costs Fix	Costs Variable	Organization Structure	Organization Style
JS	Very Low	Very Low	Random	Functional	General	Low	High	Flat	Innovative
BF	High	Low	Random	Functional	General	Medium	Medium	Flat	Innovative
OPL	Few	Medium	Constant	Linear	Specialized	High	Low	Long	Innovative
EPL	Standard	High	Constant	Linear	Flexible/ Specialized	Very High	Low	Long	Bureaucratic
CF	Standard	Very High	Unchanged	Linear	Automatic	Very High	Very High	Long	Bureaucratic
JIT	High	Very Low	Constant	Linear	Automatic	Very High	Very Low	Long	Bureaucratic
FMS	High	Medium	Constant	Linear	Specialized	Medium	Low	Flat	Innovative

The results of the first stage are achieved in two steps as follows:

- Having the majority features of the Equipment- Paced Line Flow (EPL), the current manufacturing system of the case study is EPL.
- The average of manufacturing capabilities equals to 2.16.

After determining the current situation, based upon the desired state, competitive analysis involves the following five steps. First, the level of each output is determined for the average market, as well as the strongest rival of the company. The average market and the strongest competitor in the market can help us attain a better understanding of the company's position in the market. For each of the outputs, some criteria are defined to determine the state of them. As a case in point, to evaluate the delivery criteria, three delivery sub-criteria, i.e. average delay, delivery times, and the percentage of delivery in due time, were employed. At this stage, according to the criteria and sub-criteria defined in Table 8, the level of each output is presented for the company, the market, and the strongest competitor.

According to the information attained, the delivery time of production for the case study was 36 hours, which this factor is 49.71 hours at the level of the market average, and for the strongest competitor is 27.43 hours. The firm's timely delivery rate is around 90% while at the average of the market was 82.14% and the strongest competitor was 94.29%. Besides, the company's average delay was 1.5 hours, the average delay of the market was 2.86 hours and the delay for the competitor was 1 hour. According to information attained from the company's experts, the percentage of waste is about 7.14% and the quality of supplier's materials is estimated at 91.29%. Regarding the competitive environment in the market, the open-source qualitative information of the company for wastes and the other competitors was 10% and 5.14%, respectively and for the quality of materials were 86.85% and 94.43%, respectively. Information on other criteria is presented in Table 7.

Table 7. The data of manufacturing output criteria and sub-criteria

Manufacturing Outputs (criteria)	Indicators (sub-criteria)	Average			Company Target
		Compan y	Marke t	Strong Competito r	
Cost, C_1	Unit cost per product (C_{1-1})	83	86	80.57	80
	Inventory return (C_{1-2})	94.14	91.28	96	97%
	Cost of raw material per unit (C_{1-3})	62.28	63.43	59.43	60
Quality, C_2	Waste percentage (C_{2-1})	7.14	10	5.14	3%
	Suppliers material quality (C_{2-2})	91.28	86.86	94.43	95%
Performance, C_3	Number of standard features (C_{3-1})	5	3.86	5.57	6
	Mean time between failures (C_{3-2})	3.76	2.28	5	7 day
Delivery, C_4	Delivery time (C_{4-1})	36	49.71	27.43	24 hour
	Lead Time (C_{4-2})	1.5	2.86	1	1 hour
	Percentage of on-time delivery (C_{4-3})	90	82.14	94.28	95%
Flexibility, C_5	Number of product (C_{5-1})	5	4	4	7
	Minimum order size (C_{5-2})	5	6	4	4
	The average size of production batch (C_{5-3})	130.71	83.57	357.14	200

In the following, production outputs have been classified. Each of the production outputs can be categorized into three classes: 1) Output at the market level, 2) Output above the market, and 3) Less valuable output. At this stage, according to the output level of the company and considering the market and the key rivals, one of the above strategies is adopted. To determine the type of outputs of the production strategy, the Miltenburg model was developed by researchers based on the SWARA-IFS that explained in the previous section.

4.1. SWARA-IFS results

The results of the SWARA-IFS calculation of outputs and their sub-criteria are presented in this section. SWARA-IFS is used for weighting the evaluation outputs. The results of SWARA-IFS for the first Decision Maker (DM_1) of this research are shown in Tables 8–9 for instance. Finally, the average subjective weights demonstrated in Table 10. The prioritization of outputs (Table 10) revealed that the Cost factor (C_1) with the weight (0.54), the Performance factor with the weight (0.21), and the Quality factor with the weight (0.17) selected as the most important outputs in this research respectively. Also, this result showed that among all of the sub-criteria, the Inventory return (C_{1-2}) with the global weight (0.275), Unit cost per product (C_{1-1}) with the global weight (0.205) and the Mean time between failures (C_{3-2}) with the global weight (0.153) introduced as the most important sub-criteria in this research respectively.

Table 8. Weights of outputs for DM_1

Criteria	$\tilde{S}_j$	$\tilde{K}_j$	$\tilde{q}_j$	$\tilde{w}_j$	w_j'
C_1	–	(1, 1, 1) (1, 1, 1)	(1, 1, 1) (1, 1, 1)	(0.49, 0.54, 0.67) (0.42, 0.54, 0.68)	0.55
C_3	(0.8, 1, 2) (0.5, 1, 2.1)	(1.8, 2, 3) (1.5, 2, 3.1)	(0.33, 0.5, 0.55) (0.32, 0.5, 0.66)	(0.16, 0.27, 0.37) (0.13, 0.27, 0.45)	0.27
C_2	(0.8, 1, 2) (0.5, 1, 2.1)	(1.8, 2, 3) (1.5, 2, 3.1)	(0.11, 0.25, 0.3) (0.1, 0.25, 0.44)	(0.05, 0.13, 0.2) (0.04, 0.13, 0.3)	0.14
C_4	(2, 3, 4) (1.5, 3, 4.1)	(3, 4, 5) (2.5, 4, 5.1)	(0.02, 0.06, 0.1) (0.02, 0.06, 0.17)	(0.01, 0.03, 0.06) (0.008, 0.03, 0.12)	0.04
C_5	(2, 3, 4) (1.5, 3, 4.1)	(3, 4, 5) (2.5, 4, 5.1)	(0.0044, 0.015, 0.034) (0.004, 0.015, 0.071)	(0.002, 0.008, 0.023) (0.001, 0.008, 0.049)	0.01

Table 9. Weights of sub-criteria for DM_1

Sub-Criteria	$\tilde{S}_j$	$\tilde{K}_j$	$\tilde{q}_j$	$\tilde{w}_j$	w_j'
Weights of sub-criteria of criterion C_1 for DM_1					
C_{1-2}	–	(1, 1, 1) (1, 1, 1)	(1, 1, 1) (1, 1, 1)	(0.59, 0.62, 0.72) (0.53, 0.62, 0.72)	0.63
C_{1-1}	(0.8, 1, 2) (0.5, 1, 2.1)	(1.8, 2, 3) (1.5, 2, 3.1)	(0.33, 0.5, 0.55) (0.32, 0.5, 0.66)	(0.19, 0.31, 0.4) (0.17, 0.31, 0.48)	0.31
C_{1-3}	(3, 4, 5) (2.5, 4, 5.2)	(4, 5, 6) (3.5, 5, 6.2)	(0.055, 0.1, 0.13) (0.052, 0.1, 0.19)	(0.03, 0.06, 0.1) (0.02, 0.06, 0.13)	0.06
Weights of sub-criteria of criterion C_2 for DM_1					
C_{2-2}	–	(1, 1, 1) (1, 1, 1)	(1, 1, 1) (1, 1, 1)	(0.64, 0.66, 0.75) (0.6, 0.66, 0.75)	0.67
C_{2-1}	(0.8, 1, 2) (0.5, 1, 2.1)	(1.8, 2, 3) (1.5, 2, 3.1)	(0.33, 0.5, 0.55) (0.32, 0.5, 0.66)	(0.21, 0.33, 0.41) (0.19, 0.33, 0.5)	0.33
Weights of sub-criteria of criterion C_3 for DM_1					
C_{3-2}	–	(1, 1, 1) (1, 1, 1)	(1, 1, 1) (1, 1, 1)	(0.66, 0.75, 0.77) (0.64, 0.75, 0.78)	0.73
C_{3-1}	(1, 2, 2.5) (0.85, 2, 2.7)	(2, 3, 3.5) (1.85, 3, 3.7)	(0.28, 0.33, 0.5) (0.27, 0.33, 0.54)	(0.19, 0.25, 0.38) (0.17, 0.25, 0.42)	0.27
Weights of sub-criteria of criterion C_4 *for* DM_1					
C_{4-3}	–	(1, 1, 1) (1, 1, 1)	(1, 1, 1) (1, 1, 1)	(0.47, 0.5, 0.6) (0.42, 0.5, 0.6)	0.51
C_{4-1}	(0.8, 1, 2) (0.5, 1, 2.1)	(1.8, 2, 3) (1.5, 2, 3.1)	(0.33, 0.5, 0.55) (0.32, 0.5, 0.66)	(0.15, 0.25, 0.33) (0.13, 0.25, 0.4)	0.25
C_{4-2}	(0, 0, 0) (0, 0, 0)	(1, 1, 1) (1, 1, 1)	(0.33, 0.5, 0.55) (0.32, 0.5, 0.66)	(0.15, 0.25, 0.33) (0.13, 0.25, 0.4)	0.25
Weights of sub-criteria of criterion C_5 *for* DM_1					
C_{5-1}	–	(1, 1, 1) (1, 1, 1)	(1, 1, 1) (1, 1, 1)	(0.81, 0.84, 0.87) (0.8, 0.84, 0.87)	0.84
C_{5-3}	(6, 7, 8) (6, 7, 8.2)	(7, 8, 9) (7, 8, 9.2)	(0.11, 0.125, 0.142) (0.1, 0.125, 0.142)	(0.09, 0.1, 0.12) (0.08, 0.1, 0.12)	0.10
C_{5-2}	(0.8, 1, 2) (0.5, 1, 2.1)	(1.8, 2, 3) (1.5, 2, 3.1)	(0.03, 0.06, 0.07) (0.03, 0.06, 0.09)	(0.03, 0.05, 0.06) (0.02, 0.1, 0.08)	0.06

Table 10. Average subjective weights of criteria

Criteria	Criteria Weight	Sub-Criteria	Sub-Criteria local weight	Sub-Criteria global weight
C_1	0.54	C_{1-1}	0.38	0.205
		C_{1-2}	0.51	0.275
		C_{1-3}	0.11	0.059
C_2	0.17	C_{2-1}	0.26	0.044
		C_{2-2}	0.74	0.126
C_3	0.21	C_{3-1}	0.27	0.057
		C_{3-2}	0.73	0.153
C_4	0.06	C_{4-1}	0.23	0.014
		C_{4-2}	0.21	0.013
		C_{4-3}	0.56	0.034
C_5	0.02	C_{5-1}	0.73	0.015
		C_{5-2}	0.09	0.002
		C_{5-3}	0.18	0.004

To avoid duplication and Boredom for the reader, the results of SWARA-IFS for the first Decision Maker (DM1) of this research are shown in Tables 8–9. Eventually, average subjective weights are demonstrated in Table 10. For the average weights table, all decision-makers' opinions are considered. The results of the SWARA-IFS calculation for weighting manufacturing systems is presented in this section. The results of SWARA-IFS for Decision maker DM_1 of this research are shown in Table 11 for instance. Finally, average subjective weights are demonstrated in Table 11.

Table 11. Weights of alternative manufacturing systems for DM_1

Production system	$\tilde{s}_j$	$\tilde{K}_j$	$\tilde{q}_j$	$\tilde{w}_j$	w_j'	Subjective weights
JIT	–	(1,1,1) (1,1,1)	(1,1,1) (1,1,1)	(0.61,0.64,0.72) (0.56,0.64,0.73)	0.647	0.483
CF	(0.8,1,2) (0.5,1,2.1)	(1.8,2,3) (1.5,2,3.1)	(0.33,0.5,0.55) (0.32,0.5,0.66)	(0.2,0.32,0.4) (0.18,0.32,0.49)	0.316	0.449
FMS	(6,7,8) (6,7,8.2)	(7,8,9) (7,8,9.2)	(0.03,0.06,0.07) (0.03,0.06,0.09)	(0.02,0.04,0.05) (0.01,0.04,0.07)	0.037	0.068

According to the result of Table 11, The prioritization of Production systems revealed that the JIT System with the weight (0.483), the CF system with the weight (0.449), and the FMS system with the weight (0.068) are the most important production systems respectively. Although, the just-in-time (JIT) system has more advantages in terms of system characteristics shown in Table 12.

Table 12. Optimal strategy and production system

	Outputs	Optimal Strategy	Optimal production system
1	Cost	Order Winner	Just in Time (JT)
2	Delivery, Quality, Performance, Flexibility	Market Qualifying	

The last step of the strategy formulation is different from two earlier ones. Based on the two previous steps, it is necessary to provide a development strategy. According to the results, the factory production system should be switched from the EPL system into a JIT system. In doing so, it is required to make adjustments to each of the manufacturing levers in line with the characteristics of the continuous production system. Hence, for each of the six production levers, the adjustments are suggested as follows:

1) Human Resources: The results of this leverage show that human resource capability and empowerment in this organization is lower than the industry average. In the JIT system, a company should constantly improve the skills of their employees; thus, on the job training can improve their performance. Moreover, due to the routine work, motivating and incentive policies should be used.
2) Control and Organizational Structure: In a JIT system, system costs are typically high. This system is characterized by high manufacturing volume, the centralized production system, the non-functional and hierarchical organizational structure, and so forth. Making changes in these production systems could cost a lot of money and may impede the process of change. Therefore, one effective and beneficial solution is to create a culture of continuous change in the management system and transform the organizational structure into a flat structure. Regarding the current state of the organizational structure, the following actions should be considered to bring some useful changes in the system:
    - Establishing an independent unit of maintenance for periodic and preventive purposes;
    - Using statistical quality control techniques to control and evaluate the performance of the production process and the use of new statistical processes and techniques such as Six Sigma, statistical process control, control charts, etc.;
3) Sourcing: JIT system requires high raw materials in warehouses. This method is highly influenced by suppliers and providers. Selecting suppliers in the continuous production system are based on low cost, high quality, and reliability at delivery time. Information needed such as the amount of product and delivery times, is provided by advanced computer programming and control systems to suppliers. The study of how the resources are provided in the company showed that to change the production system, the below actions should be taken:
    - Company contracts should take a long-term orientation to adapt to this production system;
    - It is suggested that the company assesses its suppliers regularly, ranks them at different levels based on their performance and considers some alternatives for low-level suppliers;
4) Production planning and control: The volume of product inventory in the JIT system is very low, while the raw materials inventory has high volume; therefore, it can use a cash discount. Over and above, it is a guarantee for the company that rarely deals with a shortage of supply. In this case, the following actions should be considered:
    - The production schedule and plan in the JIT system can be changed. In this type of production system, regulating a long-term production schedule is preferred. To achieve these strategic plans, integrated manufacturing systems such as MRP can be applied;
    - By strengthening the planning unit, the factory should be able to achieve strategic plans;
5) Process technology: facilities used in the JIT are specialized based on new and modern technology. Hence:

- The type of machinery needed for JIT systems can be specialized;
- Besides establishing a quality control unit, exerting control over processes should be applied by advanced statistical techniques;

6) Facilities: In a JIT system, the production speed is very high. However, because of regulating the speed of machines, there is no bottleneck and the output volume is high.

Based on the previous result, the overview of the Miltenburg strategy Worksheet for the case study is illustrated in Fig. 2.

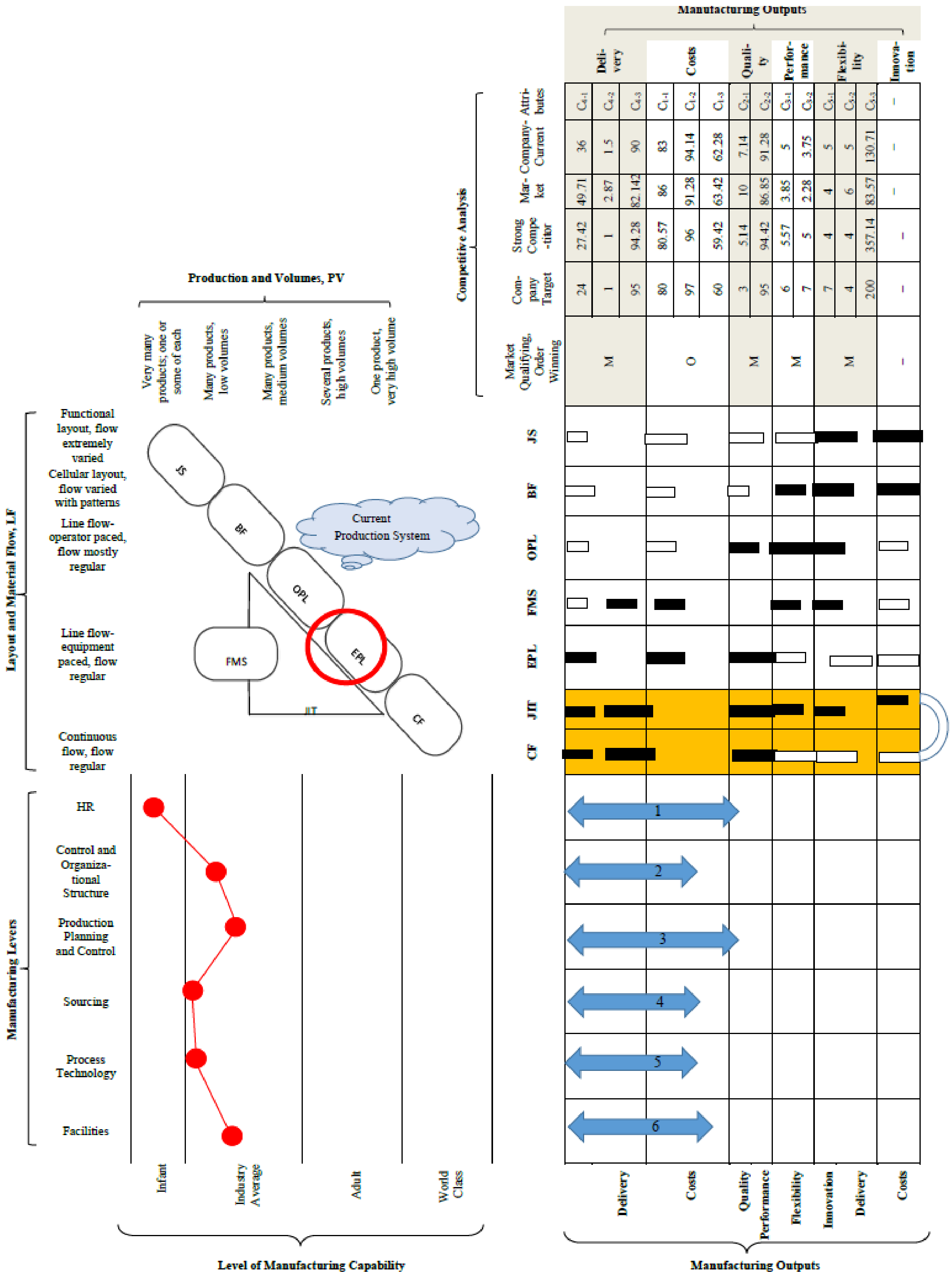

Figure 2. Manufacturing Strategy results in the studied case

5. Implications and Discussion

For a specific SME with limited assets, there could be a real obstacle to overcome to define a manufacturing strategy. In any case, as manufacturing contributes to very important parts of the business, the formulation of manufacturing strategy should be a prioritized area. Regardless of limited researches, this study contributes to the research on adjusting prescriptive frameworks and procedures on manufacturing strategy formulation to SMEs with Miltenburg worksheet and extended SWARA method as an MCDM problem. In traditional MCDM methods, the value of the criteria is known precisely; however, in real problems, the authors deal with the information being sometimes vague or inexact or insufficient. Thereupon, the authors need to deal with these kinds of situations appropriately. IFS is an extension of a fuzzy set and is found to be highly useful to deal with vagueness. IFS considers both the degrees of membership and non-membership of criteria and appropriately can deal with the uncertainty that exists in real decision-making problems.

A famous automobile parts manufacturing company was considered as the main case to employ the proposed approach. The presented method is a new uncertain weighting method to compute the importance of the evaluation outputs based on the expert's opinion. Considering the three-step process of developing a strategy on the Miltenburg worksheet; initially, the current production system of the research case was determined. This system is an EPL with the features of high volume production, low diversity, linear layout and regular flow of materials. Afterward, the position of six manufacturing levers in the market was determined. Subsequently, to determine the company's optimal status, the production outputs of the company were analyzed by the SWARA-IFS method and three outputs of performance, delivery and cost were determined as the strategic output and the order winner. Furthermore, the quality was the second one in terms of importance. Other outputs were considered as standard outputs and consistent with the market. Most researchers believe that it is not practical at the same time to focus on two outputs as the order winner (Miltenburg, 2008). In this study, six subsystems including facility, process technology, resourcing, human resources, control, and organizational structure and production planning were considered as manufacturing levers. Many studies were conducted on the classification of production systems. Most of these studies were emphasized the production subsystems such as resourcing (Fernandez, 2001; Miltenburg, 2008), control and organizational structure (Fernandez, 2001; Miltenburg, 2005), facilities and production planning (Fernandez, 2001; Miltenburg, 2008). Remark that, other researchers studied the various aspects of the production subsystem (Hallgren and Olhanger, 2006).

According to the results of the last step, the factory production system should switch from EPL to the JIT system. In doing so, it is required to make adjustments to each of the manufacturing levers in line with the characteristics of the continuous production system. In the JIT system, the raw material is purchased when it is needed and consumed immediately and made into a finished good. Besides, the finished goods are immediately sent to the customers. This system reduces inventories, prevents using the space and stagnates capital stays and increases productivity. The successful implementation of this system requires the participation of every individual in the organization, the production of high-quality products and timely delivery of products to customers, accurate planning and optimal organizational culture.

The results of this research indicate that applying the Miltenburg strategy model appropriately, not only makes it possible to examine the current situation of the manufacturing system and explore the competitive environment, but also can find contexts that enable organizations to create competitive advantages. Regarding the validation of the proposed approach, it is worth noting here that the results and production status of SWARA-IFS was verified by the experts of the research case.

It is noteworthy that, given the conditions of markets and the high cost of changing the production system, most of the managers tend to maintain the current production system and do not consider essential changes in the type of production system. By using the model of this research, even if the production system is not changed, a comprehensive look at the organization and the threats of their rivals can be found and improve the status quo only by improving production leverage.

Given that the third step in formulating a manufacturing strategy was to provide some suggestions for improving the production system, and for keeping the overall framework of the three-stage model, some implications inevitably were provided as with the manufacturing levers in the previous section and repeating has been avoided. Other useful and practical recommendations were presented as below:

1) The results indicated that formulating the organization's manufacturing strategy is highly influenced by the prioritization of production outputs and setting annual goals. Therefore, it is suggested that establishing an information management system and conducting marketing studies helps experts easily to prioritize production outputs (competitive priorities) and set goals for one year.
2) Given the importance of manufacturing outputs, when choosing the suppliers, it is advisable to focus on the price of materials, and the quality and delivery time, due to the manufacturing system will be heavily influenced by raw materials. Thus, the poor supply of raw materials (in terms of cost, quality, and delivery of materials) will cause detrimental results for the system.

6. Conclusion

The literature review indicated that for strategy formulation with the Miltenburg worksheet so far, no research is performed with a quantitative approach. Moreover, in this research for the first time, the authors developed the SWARA method into an intuitionistic fuzzy SWARA to deal with problems with such imprecise information. The future researchers can develop the proposed model in such a way that it helps analyze the financial statements in the accounting system and use them to evaluate the production leverages.

By the same token, in future researches, scholars can look at other hybrid frameworks that are used to develop competitive strategies. As a case in point, the integration of production strategy with business strategies should be performed and the results compared. The use of other extended multi-criteria decision-making methods in IFS, IVIF, Grey and stochastic environment for dealing with the complex nature of this problem, such as hierarchical analysis, TOPSIS, DEMATEL, etc. can be helpful and productive. From the evaluation method perspective, the authors in this research focused on developing SWARA method with intuitioninstic fuzzy numbers to adjust the original methods uncertainty with reality. In todays challenging environment confronting different uncertainty, adopting a decision making method that conforms the reality is a controversial issue for managers. Thus, future researchers can focus on developing other possible weighing methods such as pairwise comparison (PWC), best worst method (BWM), factor relationship (FARE), etc. with recent development in uncertainty (e.g. IVF, IVIF, HFLTS, etc.). Moreover, the results of this research are based on experts opinion from automobile industry in a developing country. To generalize the results, employing the proposed approach in other industries and other countries for benchmarking is recommended.

References

Adobor, H. (2019). Opening up strategy formulation: Benefits, risks, and some suggestions. *Business Horizons*, *62*(3), 383-393.

Arias Aranda, D. (2003). Service operations strategy, flexibility, and performance in engineering consulting firms. *International Journal of Operations & Production Management, 23*(11-12), 1401–1421. https:// doi.orgDOI: 10.1108/01443570310501907.

Atanassov, K.T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets and Systems, 20*(1), 87–96.

Badurdeen, F., & Jawahir, I. (2017). Strategies for value creation through sustainable manufacturing. *Procedia Manufacturing, 8*, 20–27.

Balić, D., Maljković, D., & Lončar, D. (2017). Multi-criteria analysis of district heating system operation strategy. *Energy Conversion and Management 144*, 414–428. https://doi.org/10.1016/j.enconman.2017.04.072.

Balki, M. K., Erdoğan, S., Aydın, S., & Sayin, C. (2020). The optimization of engine operating parameters via SWARA and ARAS hybrid method in a small SI engine using alternative fuels. *Journal of Cleaner Production*, *258*, 120685.

Cagliano, R., Acur, N., & Boer, H. (2005). Patterns of change in manufacturing strategy configurations. *International Journal of Operations & Production Management, 25*(7), 701–718. https://doi.org/10.1108/01443570510605108.

Çebi, F., & Otay, İ. (2016). A two-stage fuzzy approach for supplier evaluation and order allocation problem with quantity discounts and lead time. *Information Sciences, 339*, 143–157. https://doi.org/10.1016/j.ins.2015.12.032.

Cox, J., & Blackstone, J. (2005). APICS Dictionary 11th edition. Amer Production & Inventory VA, USA.

Dombrowski, U., Intra, C., Zahn, T., & Krenkel, P. (2016). Manufacturing strategy–a neglected success factor for improving competitiveness. *Procedia CIRP, 41*, 9–14.

Dombrowski, U., Intra, C., Zahn, T., & Krenkel, P. (2016). Manufacturing strategy–a neglected success factor for improving competitiveness. *Procedia CIRP*, *41*, 9-14.

Fernandes, P. (2001). *A framework for a strategy-driven manufacturing system design in an aerospace environment: design beyond factory floor* (Doctoral dissertation, Massachusetts Institute of Technology).

Foster, N.F., & Gibbons, S.L. (Eds.) (2007). *Studying students: The undergraduate research project at the University of Rochester*: Assoc of College & Rsrch Libr.

Frohlich, M.T., & Dixon, J.R. (2001). A taxonomy of manufacturing strategies revisited. *Journal of Operations Management, 19*(5), 541–558. https://doi.org/10.1016/S0272-6963(01)00063-8.

Garrido-Vega, P., Jimenez, C.H.O., Pérez Díez de Los Rios, J.L., & Morita, M. (2015). Implementation of technology and production strategy practices: Relationship levels in different industries. *International Journal of Production Economics, 161*, 201–216. https://doi.org/10.1016/j.ijpe.2014.07.011.

Ghenai, C., Albawab, M., & Bettayeb, M. (2020). Sustainability indicators for renewable energy systems using multi-criteria decision-making model and extended SWARA/ARAS hybrid method. *Renewable Energy*, *146*, 580-597.

Ginevicius, R. (2011). A new determining method for the criteria weights in multicriteria evaluation. *International Journal of Information Technology & Decision Making, 10*(6), 1067–1095, https://doi.org/10.1142/S0219622011004713.

Gupta, M. (2015). Strategy formulation for performance improvement of indian corrugated industry: An application of SWOT analysis and QSPM Matrix. *Journal of Applied Packaging Research*, *7*(3), 3.

Gürbüz, T. (2019). Strategy Formulation Using a Hybrid Multi Criteria Decision Making Approach for Strategic Position and Action Evaluation (SPACE) Matrix Method. *Journal of Aeronautics & Space Technologies/Havacilik ve Uzay Teknolojileri Dergisi*, *12*(1).

Hajiagha, S. H. R., Mahdiraji, H. A., Hashemi, S. S., & Zavadskas, E. K. (2015). Evolving a linear programming technique for MAGDM problems with interval-valued intuitionistic fuzzy information. *Expert Systems with Applications*, *42*(23), 9318-9325.

Hajiagha, S. H. R., Hashemi, S. S., Mahdiraji, H. A., & Azaddel, J. (2015). Multi-period data envelopment analysis based on Chebyshev inequality bounds. *Expert Systems with Applications*, *42*(21), 7759-7767.

Hallgren, M., & Olhager, J. (2006). Quantification in manufacturing strategy: A methodology and illustration. *International Journal of Production Economics*, *104*(1), 113-124.

Heidary Dahooie, J., Vanaki, A. S., Firoozfar, H. R., Zavadskas, E. K., & Čereška, A. (2020). An Extension of the Failure Mode and Effect Analysis with Hesitant Fuzzy Sets to Assess the Occupational Hazards in the Construction Industry. *International Journal of Environmental Research and Public Health*, *17*(4), 1442.

Hill, A. (2008). How to organize operations: Focusing or splitting? *International Journal of Production Economics, 112*(2), 646–654. https://doi.org/10.1016/j.ijpe.2007.06.002.

Jia, P., Mahdiraji, H. A., Govindan, K., & Meidutė, I. (2013). Leadership selection in an unlimited three-echelon supply chain. *Journal of business economics and Management*, *14*(3), 616-637.

Jian, W. A. N. G., CHEN, Z. X., & WANG, P. P. (2017). An Empirical Study on Manufacturing Strategy Formulation in Turbulent Environment: Dealing with Changes and Uncertainties. In *Proceedings of the 23rd International Conference on Industrial Engineering and Engineering Management 2016* (pp. 75-79). Atlantis Press, Paris.

Kaur, P. (2014). Selection of vendor based on intuitionistic fuzzy analytical hierarchy process. *Advances in Operations Research, 2014,* Article ID 987690, 10 pages, http://dx.doi.org/10.1155/2014/987690

Keršuliene, V., Zavadskas, E.K., & Turskis, Z. (2010). Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA). *Journal of Business Economics and Management, 11*(2), 243–258. https://doi.org/10.3846/jbem.2010.12.

Keshavarz Ghorabaee, M., Amiri, M., Zavadskas, E.K., & Antucheviciene, J. (2018). A new hybrid fuzzy MCDM approach for evaluation of construction equipment with sustainability considerations. *Archives of Civil and Mechanical Engineering, 18*(1), 32–49. https://doi.org/10.1016/j.acme.2017.04.011.

Khatri, J. K., & Metri, B. (2016). SWOT-AHP approach for sustainable manufacturing strategy selection: A case of Indian SME. *Global Business Review*, *17*(5), 1211-1226.

Kumar, M., Raman, J., & Singh, P. (2015). An unified Analytical Network Process ANP and Data Envelopment Analysis DEA approach for manufacturing strategy decision. *International Journal of Strategic Decision Sciences*, *6*(2), 57-82.

Kulkarni, S., Verma, P., & Mukundan, R. (2019). Assessing manufacturing strategy definitions utilising text-mining. *International Journal of Production Research*, *57*(14), 4519-4546.

Liu, J., Sarkar, S., Kumar, S., & Jin, Z. (2018). An analysis of stock market impact from supply chain disruptions in Japan. *International Journal of Productivity and Performance Management*.

Mardani, A., Nilashi, M., Zakuan, N., Loganathan, N., Soheilirad, S., Saman, M.Z.M., & Ibrahim, O. (2017). A systematic review and meta-Analysis of SWARA and WASPAS methods: Theory and applications with recent fuzzy developments. *Applied Soft Computing, 57*, 265–292. https://doi.org/10.1016/j.asoc.2017.03.045.

Martín-Peña, M.L., & Díaz-Garrido, E. (2008). A taxonomy of manufacturing strategies in Spanish companies. *International Journal of Operations & Production Management, 28*(5), 455–477. https://doi.org/10.1108/01443570810867204.

Mavi, R.K., Goh, M., & Zarbakhshnia, N. (2017). Sustainable third-party reverse logistics provider selection with fuzzy SWARA and fuzzy MOORA in the plastic industry. *The International Journal of Advanced Manufacturing Technology, 91*(5-8), 2401–2418.https://doi.org/10.1007/s00170-016-9880-x

Maylor, H., Turner, N., & Murray-Webster, R. (2015). "It worked for manufacturing…!": Operations strategy in project-based operations. *International Journal of Project Management, 33*(1), 103–115. https://doi.org/10.1016/j.ijproman.2014.03.009.

Miller, D. (1996). Configurations revisited. *Strategic Management Journal, 17*(7), 505–512.

Miller, J.G., & Roth, A.V. (1994). A taxonomy of manufacturing strategies. *Management Science, 40*(3), 285–304.

Mills, J., Platts, K., & Gregory, M. (1995). A framework for the design of manufacturing strategy processes: a contingency approach. *International Journal of Operations & Production Management, 15*(4), 17–49.

Miltenburg, J. (2005). *Manufacturing strategy: how to formulate and implement a winning plan*. CRC Press.

Miltenburg, J. (2008). Setting a manufacturing strategy for a factory-within-a-factory. *International Journal of Production Economics, 113*(1), 307–323. https://doi.org/10.1016/j.ijpe.2007.09.001.

Nagoorgani, A., & Ponnalagu, K. (2012). A new approach to solving an intuitionistic fuzzy linear programming problem. *Applied Mathematical Sciences, 6*(70), 3467–3474.

Nakhaei, J., Bitarafan, M., Lale Arefi, S., & Kapliński, O. (2016). Model for rapid assessment of the vulnerability of office buildings to blast using SWARA and SMART methods (a case study of Swiss Re Tower). *Journal of Civil Engineering and Management, 22*(6), 831–843. https://doi.org/10.3846/13923730.2016.1189457.

Narkhede, B. E. (2017). Advance manufacturing strategy and firm performance: An empirical study in a developing environment of small-and-medium-sized firms. *Benchmarking: An International Journal*, *24*(1), 62-101.

Narkhede, B. E. (2018). Linkages in Advanced Manufacturing Strategy: A Literature Review. In *Operations and Service Management: Concepts, Methodologies, Tools, and Applications* (pp. 359-388). IGI Global.
Ocampo, L. (2018). A probabilistic fuzzy analytic network process approach (PROFUZANP) in formulating sustainable manufacturing strategy infrastructural decisions under firm size influence. *International Journal of Management Science and Engineering Management*, *13*(3), 158-174.
Ocampo, L. A. (2019). Applying fuzzy AHP–TOPSIS technique in identifying the content strategy of sustainable manufacturing for food production. *Environment, Development and Sustainability*, *21*(5), 2225-2251.
Ocampo, L. (2017). The Impact of Firm Size in the Formulation of Sustainable Manufacturing Strategy Infrastructural Decisions Under Uncertainty. *International Journal of Manufacturing, Materials, and Mechanical Engineering (IJMMME)*, *7*(2), 1-18.
Ocampo, L. A., & Promentilla, M. A. B. (2016). Development of a sustainable manufacturing strategy using analytic network process. *International Journal of Business and Systems Research*, *10*(2-4), 262-290.
Ocampo, L. A., Clark, E. E., Tanudtanud, K. V. G., Ocampo, C. O. V., Impas Sr, C. G., Vergara, V. G., ... & Tordillo, J. A. S. (2015). An integrated sustainable manufacturing strategy framework using fuzzy analytic network process. *Advances in Production Engineering & Management*, *10*(3), 125.
Oddershede, A. M., Quezada, L. E., Valenzuela, J. E., Palominos, P. I., & Lopez-Ospina, H. (2019). Formulation of a Manufacturing Strategy Using the House of Quality. *Procedia Manufacturing*, *39*, 843-850.
Olhager, J., & Feldmann, A. (2018). Distribution of manufacturing strategy decision-making in multi-plant networks. *International Journal of Production Research*, *56*(1-2), 692-708.
Oltra, M., Maroto, C., & Segura, B. (2005). Operations strategy configurations in project process firms. *International Journal of Operations & Production Management, 25*(5), 429–448. https://doi.org/10.1108/01443570510593139.
Perçin, S. (2019). An integrated fuzzy SWARA and fuzzy AD approach for outsourcing provider selection. *Journal of Manufacturing Technology Management*.
Pooya, A., & Faezirad, M. (2017). A taxonomy of manufacturing strategies and production systems using a self-organizing map. *Journal of Industrial and Production Engineering*, *34*(4), 300-311.
Puri, J., & Yadav, S.P. (2015). Intuitionistic fuzzy data envelopment analysis: An application to the banking sector in India. *Expert Systems with Applications, 42*(11), 4982–4998. https://doi.org/10.1016/j.eswa.2015.02.014.
Qi, Y., Huo, B., Wang, Z., & Yeung, H.Y.J. (2017). The impact of operations and supply chain strategies on integration and performance. *International Journal of Production Economics, 185,* 162–174. https://doi.org/10.1016/j.ijpe.2016.12.028.
Rahman, M. H., & Rahman, A. (2020). Strategic fit strategy formulation: keys to enhancing competitiveness and improving capabilities of a manufacturing unit. *Production & Manufacturing Research*, *8*(1), 59-79.
Rezaei, J. (2016). Best-worst multi-criteria decision-making method: Some properties and a linear model. *Omega*, *64*, 126-130.
Šaparauskas, J., Zavadskas, E.K., & Turskis, Z. (2011). Selection of facade's alternatives to commercial and public buildings based on multiple criteria. *International Journal of Strategic Property Management, 15*(2), 189–203. https://doi.org/10.3846/1648715X.2011.586532).
Satyro, W. C., Sacomano, J. B., Contador, J. C., Almeida, C. M., & Giannetti, B. F. (2017). Process of strategy formulation for sustainable environmental development: Basic model. *Journal of Cleaner Production*, *166*, 1295-1304.
Singh, H., & Mahmood, R. (2014). Aligning manufacturing strategy to export performance of manufacturing small and medium enterprises in Malaysia. *Procedia-Social and Behavioral Sciences, 130*, 85–95. doi: 10.1016/j.sbspro.2014.04.011.
Singh, S.K., & Yadav, S.P. (2015). Modeling and optimization of multi-objective non-linear programming problems in intuitionistic fuzzy environment. *Applied Mathematical Modelling, 39*(16), 4617–4629. https://doi.org/10.1016/j.apm.2015.03.064.
Singh, C. D. (2018). Competency and Strategy Formulation in Automobile Industry. *International Journal of Industrial and Manufacturing Engineering*, *12*(6), 714-717.
Slack, N. (2005), "Operations Strategy: Will it ever realizes its potential", Invited paper, *Gestão & Produção,* Vol. 12, No 3, pp. 323 -332.
Theodorou, P., & Florou, G. (2008). Manufacturing strategies and financial performance—The effect of advanced information technology: CAD/CAM systems*.* *Omega, 36*(1), 107–121. https://doi.org/10.1016/j.omega.2005.10.005.
Wang, J., Wu, H., & Chen, Y. (2019). Made in China 2025 and manufacturing strategy decisions with reverse QFD. *International Journal of Production Economics*, 107539.
Wheelwright, S.C., & Hayes, R.H. (1985). Competing through manufacturing. Harvard business review, 63(1), 99–109.
Zadeh, L.A., 1965. Fuzzy sets. *Information and Control, 8*(3), 338–353.

Zarbakhshnia, N., Soleimani, H., & Ghaderi, H. (2018). Sustainable Third-Party Reverse Logistics Provider Evaluation and Selection Using Fuzzy SWARA and Developed Fuzzy COPRAS in the Presence of Risk Criteria. *Applied Soft Computing, 65*, 307–319 https://doi.org/10.1016/j.asoc.2018.01.023.
Zavadskas, E.K., Kaklauskas, A., Turskis, Z., & Kalibatas, D. (2009). An approach to the multi-attribute assessment of indoor environment before and after the refurbishment of dwellings. *Journal of Environmental Engineering and Landscape Management, 17*(1), 5–11. https://doi.org/10.3846/1648-6897.2009.17.5-11.
Zavadskas, E.K., Vilutienė, T. (2006). A multiple criteria evaluation of multi-family apartment block's maintenance contractors: I—Model for maintenance contractor evaluation and the determination of its selection criteria. *Building and Environment, 41*(5), 621–632. https://doi.org/10.1016/j.buildenv.2005.02.019.
Zavadskas, E.K., Vilutienė, T., Turskis, Z., Šaparauskas, J. (2014). Multi-criteria analysis of Projects' performance in construction. *Archives of Civil and Mechanical Engineering, 14*(1), 114–121. https://doi.org/10.1016/j.acme.2013.07.006
Zhao, X., Sum, C.-C., Qi, Y., Zhang, H., Lee, T.-S. (2006). A taxonomy of manufacturing strategies in China. *Journal of Operations Management, 24*(5), 621–636. https://doi.org/10.1016/j.jom.2005.07.003.