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Exploring Key Decisive Factors in Manufacturing Strategies in the Adoption of Industry 4.0 by Using the Fuzzy DEMATEL Method

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Abstract: Globalization has created a highly competitive and diverse market, an uncertain and risky business environment, and changing customer expectations. An effective manufacturing strategy reduces complexity and provides organizations with a well-organized manufacturing structure. However, existing research on manufacturing strategies appears scattered, lacking systematic understanding and finding no causal relationship between manufacturing strategies' outputs (MSOs) and their importance. Therefore, this study is a pioneer in identifying the influential factors of MSOs in the adoption of Industry 4.0 (I4.0) technologies utilizing the decision-making trial and evaluation laboratory (DEMATEL) approach. This method is considered an effective method for identifying the cause-effect relationship of complex problems. It evaluates interdependent relationships among MSO factors from the perspective of academic and industry experts. Identifying cause and effect factors leads to increasing the market's competitiveness and prioritizing them. To deal with the vagueness of human beings' perceptions, this study utilizes fuzzy set theory and the DEMATEL method to form a structural model. Results show that customer satisfaction, cost per unit produced, and the number of advanced features are the main factors influencing MSOs.

Keywords: manufacturing strategies; industry 4.0 technologies; competitive capabilities; fuzzy DEMATEL method; smart manufacturing

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1. Introduction

Modern manufacturing has made life easier in terms of accuracy and speed, especially in the last two decades. It fluctuates greatly due to the complexity of customer requirements, the uneven state of resources (machinery and labor), and manufacturing process constraints [1]. Manufacturing strategies (MS) can be defined as long-term plans for the manufacturing system's resources to be used to support the business strategy and, as a result, to accomplish company goals. MS comprises a set of manufacturing policies designed to maximize performance while balancing competing success criteria in order to meet manufacturing objectives. A top management duty is to ensure the manufacturing strategy is coherent, in that all policies are designed to both support and complement the corporate strategy [2]. Manufacturers have developed manufacturing into a strategic competitive element through which they can differentiate themselves from their competitors [3]. As a result, developing a manufacturing strategy for a company has become crucial. MS is critical for establishing a firm's competitive advantage in the market [4].

Manufacturing strategies assist organizations in establishing an efficient manufacturing structure that enables them to stay competitive [5]. Manufacturing competitiveness refers to a business's ability to compete in the markets of other competitors by offering world-class products or services that attract and satisfy customers [6,7]. Competitive advantage is dependent upon the level of manufacturing outputs or priorities that are aligned with customer requirements, such as cost, delivery, flexibility, lead time/delivery, and quality [8]. MSOs are also known as competitive priorities in the literature, and they include cost, quality, delivery, flexibility, performance, and innovativeness [9].

Manufacturing is currently experiencing a paradigm shift in the way that products are designed, produced, and serviced. The industrial revolution refers to the transition in modern history from agrarian and handicraft manufacturing to one dominated by smart manufacturing. The manufacturing industry's historical development is illustrated in Figure 1. This industrial revolution provided new methods of working and living, drastically altering manufacturing. Such developments and changes have mainly been brought about by the extensive use of the internet and digital technologies. As a result of this transformation, a new industrial revolution known as "Industry 4.0" (I4.0) is emerging, promising mass customization at mass production cost [10]. I4.0 contributes to manufacturing's digitalization by promoting industrial flexibility and product customization through automation and data sharing in a variety of settings [11]. I4.0 includes a variety of technologies, such as the internet of things (loT), cloud manufacturing (CM), big data (BD) analytics, augmented reality (AR), automation and industrial robotics (AIR), additive manufacturing (AM), modeling and simulation (MS), cyber-physical systems (CPS), cybersecurity (CS), and blockchain (BC) [9,12–15].

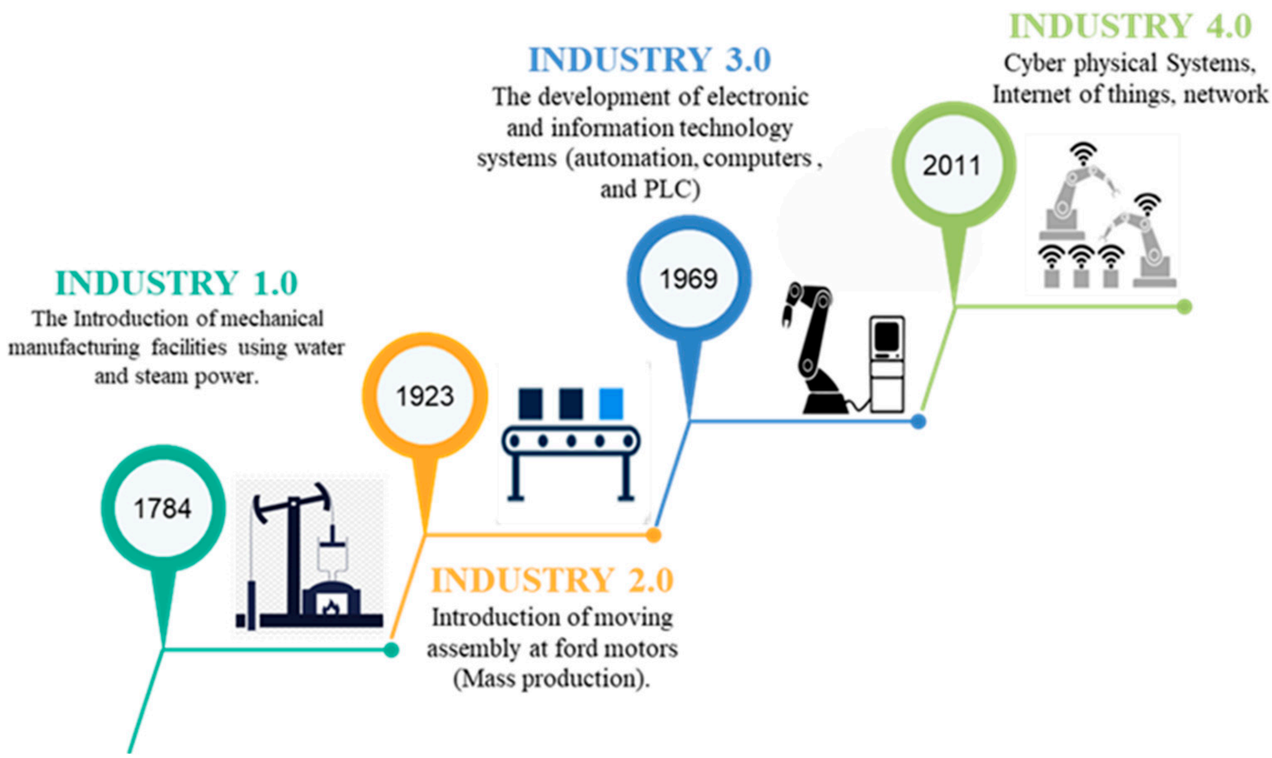

Figure 1. Historical development of the industry.

Manufacturers are increasingly looking for effective decision-making as manufacturing becomes more complex. An effective solution must be based on understanding the causal relationship of the problem, inferring the most effective approach, and ensuring an effective action plan. Generally, DEMATEL is used to obtain a cause-and-effect scheme among the dependent factors. Using this method is a useful way to formulate a structural model for examining the influences among complicated factors in comprehensive studies [16]. These factors are ranked according to the type of relationship they represent and indicate the degree to which they influence one another. This method not only converts interdependencies into a cause and effect group via matrices, but also identifies the critical factors of a complex structure system via impact relationship diagrams. Through this method, all unpredictable characteristics will be verified as interdependent, revealing the character of an essential system and showing the interrelationship between variables by improving the directed graph [17]. DEMATEL helps identify practical solutions, particular problems, and, most importantly, clusters of complicated problems [18,19]. This research utilizes fuzzy techniques in conjunction with DEMATEL (MCDM-based method) for several reasons. First, due to the multidimensional and interactive nature of manufacturing organizations, methods of evaluation that combine quantitative and qualitative perspectives can overcome the limitations of subjective and inaccurate conventional methods. Secondly, in MCDM, the fuzzy theory is widely used. By evaluating the degree of relationship or likelihood of the occurrence of various events, experts can use natural semantics directly in fuzzy theory. Therefore, the evaluator can easily express their subjective value judgments [20]. The DEMATEL method is also used to extract cause-and-effect relationships as well as the intensity of barriers. It also helps to categorize them according to their significance and relationships [21]. Additionally, DEMATEL can be used to determine the interdependence of factors and the relative relationships within them, allowing for the investigation and resolution of complex problems [22].

DEMATEL is more successful than other methods for analysis since it is primarily a theory-driven approach, in contrast to data-driven models that require extensive data collection. Using expert opinion, this study examines and re-examines the causal relationships among factors and dimensions. Through graph theory and matrix calculations, DEMATEL visualizes the importance of relations and their intensity both visually and numerically [23]. It visualizes and quantifies the degree of interrelationship between features of a complex system [24]. DEMATEL allows for a wider and broader judgment of underlying factors in comparison to interpretative structural modeling (ISM). DEMATEL, for example, provides bidirectional multi-number relations, while ISM only offers 0–1 relationships [25]. Human judgments for determining the interrelationship among factors are frequently given by crisp values when DEMATEL is used. On the other hand, crisp values are frequently insufficient in the real world [26]. The necessity for fuzzy logic arises from the fact that human preferences are frequently ambiguous and difficult to evaluate using exact numerical values. To address human perceptions of vagueness, this research utilizes fuzzy set theory with the DEMATEL method to construct a structural model that demonstrates cause-and-effect relationships between criteria [27]. Moreover, the main advantage of fuzzy DEMATEL is that it can take into account the condition of fuzziness and be flexible in dealing with situations that feature vagueness [28].

This research aims to identify the factors that influence MSOs during the adoption of I4.0 technologies. This study aims to develop a structural model for MSOs' development to achieve market competitiveness. MS assists organizations in establishing a well-organized manufacturing structure, thereby reducing the complexity involved. MCDM is a well-known method for analyzing multiple conflicting criteria. By increasing the rationality and efficiency of the decision-making process, the MCDM approach helps to improve the quality of these decisions. DEMATEL is used in this research to ascertain the underlying causes and effects of manufacturing strategy outputs. The judgment of experts is used to propose the interrelationship that corresponds to these root causes. The fuzzy DEMATEL method is applied to address the ambiguity of experts' decisions during the prioritization of the selected improvement efforts. As a result of the knowledge of experts and the interdependencies among MSOs, a suitable improvement road map for MSOs can be created. The main research contributions are listed below.

- To propose smart manufacturing strategies outputs (basic elements) based on a thorough literature review and analysis.
- Defining a deeper understanding of the MS outputs and their basic elements in relation to I4.0.
- The outcomes of DEMATEL cause and effect criteria can greatly contribute to enhancing managerial abilities to achieve market competitiveness through proper decision-making.

- As a comprehensible structural model of the system, it can provide researchers and manufacturers with a better understanding of the structural relationship among MSOs.
- To boost performance, the fuzzy DEMATEL approach can manage interdependent relationships under uncertainty and determine the attributes of priority.

The structure of this research is as follows: Section 2 provides theoretical background and influencing factors' formulation. Section 3 discusses the methodology used to select experts, collect data, and identify factors affecting MSOs during the adoption of I4.0 technologies. Section 4 contains the results and discussion. Finally, the conclusion, implications, and recommendations for future research are presented in Section 5.

2. Theoretical Background and Influencing Factors Formulation

This section presents the MSOs and how they are measured. In addition, I4.0 technologies and how the adoption of these technologies affects manufacturing capabilities are discussed in this section. In this section, the theoretical background for MSOs and their basic elements are discussed. A manufacturing strategy/policy is described as "exploiting the features of manufacturing as a competitive weapon" [29]. Manufacturing strategy outputs, also known as competitive priorities, are concerned with strengthening the targeted competitive capabilities [30]. Manufacturing strategy outputs include cost, quality, delivery, performance, flexibility, and innovativeness, also known as competitive priorities in the literature [9]. MSOs include several measures (basic elements) that are derived from the various functions of manufacturing systems. The competitive priorities of an organization play a significant role in motivating it to leverage its competitors.

A comprehensive literature review is undertaken to construct the MSOs and their basic elements, which are then discussed with academic and industry practitioners. The description of MSOs and their basic elements are as follows.

- Cost (C): provide low overall costs at competitive prices. It can be measured by employee training cost [31,32], cost per unit produced [33], and operating cost [34]. Other measures of cost include unit overhead cost and unit material cost [35].
- Quality (Q): the ability to maintain high standards, quality control, and supervision while increasing customer satisfaction [5,36]. It can be measured by defective products [37], customer satisfaction [38], and the number of customer complaints [38]. Further quality measures include warranty claims [39], scrap rate [40], defective product [37], and customer satisfaction [38].
- Delivery: the time required to collect and deliver an order to a customer. Additionally, it can be defined as the ability to provide shorter lead times throughout the supply chain, which includes logistics, manufacturing, and design [41]. It can be measured by on-time delivery and delivery speed [42]. Additional delivery measures include average lateness, inventory accuracy, and order entry time [43].
- Flexibility: The ability to quickly respond to customer needs by customizing goods and services as well as increasing or decreasing the number of existing products [5,41]. The flexibility measures includes product mix flexibility [44], process flexibility [44], volume flexibility [45], and machine flexibility [45].
- Performance: the features that enable the product to perform tasks that other goods cannot [5]. The performance measures include standard features, advanced features, product resale price, engineering changes, and mean time between failures [43,46].
- Innovativeness: the ability to rapidly introduce new products or redesign existing ones [5]. The number of new products introduced each year, the time required to design new products, the number of engineering change orders placed each year, the level of R&D investment, and the ability to improve existing products are all measures of innovativeness [47].

There are numerous perspectives on the relationships between the MSOs. Previous research has reported that developing one capability can help in the development of another and that all capabilities are positively related. Leading innovators, for example, compete effectively on several operational competencies at the same time to achieve the best company performance [48]. The key decisions in a manufacturing strategy are known as a company's competitive capabilities; as they play a crucial role in helping the entire organization gain an advantage over its competitors.

In summary, the collection and screening of influencing factors should be based on six categories. This was accomplished by collecting and analyzing relevant literature. According to previous studies, the final list of 29 basic elements was classified into six MSOs dimensions, namely cost, quality, delivery, flexibility, performance, and innovativeness. Table 1 presents the summary of twenty-nine basic elements and their descriptions.

Table 1. Factors of manufacturing strategies in the adoption of Industry 4.0 technologies.

Outputs	Factors Names (Basic Elements)	Description	Rep.
Cost (C)	Cost per unit produced	What a company spends on producing every unit of the product it sells.	C1
	Operating cost	Costs associated with running a business or using machines, components, or facilities to prepare a product.	C2
	Unit material cost	The cost of materials used to manufacture a product or perform a service.	C3
	Employee training cost	The cost of training includes both the materials and the time spent training employees.	C4
	Unit overhead cost	It refers to all of a company's direct and indirect operating expenses.	C5
Quality (Q)	Defective products	The entire product/service does not meet the specified criterion. When a product or service is found to have one or more defects, the defect is labeled (s)	C6
	Scrap rate	Some failed materials cannot be repaired or restored and must be discarded.	C7
	Number of customer complaints	A customer complaint is "a consumer's expression of dissatisfaction to a responsible party".	C8
	Customer satisfaction	An indicator measures how satisfied customers are with a company's products, services, and capabilities.	C9
	Warranty claims	A company promises to repair or replace a defective product free if you discover it within a certain period.	C10
Delivery (D)	On-time delivery	An indicator of how often deliveries and finished products are produced on time.	C11
	Speed delivery	Delivered on time or earlier than expected to the consumer.	C12
	Average lateness	The average time between ordering and the due delivery date.	C13
	Inventory accuracy	It is the significant difference between the amount and type of inventory recorded or what is supposed to be ready for delivery.	C14
	Order entry time	A way of keeping order times in a company's system in order to view, modify, and/or execute them on a specific date.	C15
Flexibility (F)	Product mix flexibility	The ability to manufacture a large number of different items or variants with minimal changeover costs.	C16
	Process flexibility	The ability of a manufacturing system to produce multiple parts at once.	C17
	Volume flexibility	It is defined as an organization's ability to change the volume of its operations in response to changing economic conditions.	C18
	Machine flexibility	The system's ability to produce new products and change the order of operations efficiently and effectively.	C19

Table 1. *Cont.*

Outputs	Factors Names (Basic Elements)	Description	Rep.
Performance (P)	Number of standard features	Several features or characteristics of anything are interesting or important for the product.	C20
	Number of advanced features	The new and upgraded features add value to your customers.	C21
	Product resale price	The manufacturer sets a brand's resale price, and retailers cannot lower it.	C22
	Number of engineering changes	It is the number of engineering changes made to a product to improve performance.	C23
	Meantime between failures	Measures how long equipment runs between breakdowns or stops.	C24
Innovativeness (I)	New products introduced each year	The number of products introduced each year	C25
	Lead time to design new products	It describes the time it takes to design, develop, and manufacture a new product.	C26
	Existing-product Improvement	Adding benefits to an existing product, either for new or existing customers.	C27
	Number of engineering change orders per year	A document that details a new product's design or suggests changes to an existing product.	C28
	Level of R&D investment	Investing in R&D develops various solutions to satisfy customer expectations.	C29

3. Research Methodology

The concept of MSOs from the perspective of I4.0 adoption and identifying the final influencing factors through literature research is defined in Section 2. Nonetheless, when there are numerous factors, determining the relative importance of each factor and the causal relationship between them remains difficult. Currently, quantitative evidence is lacking to support a conceptualization of the critical factors affecting MSOs. The fuzzy DEMATEL method was used to identify the main MSO factors influencing the adoption of I4.0 technologies and the basic elements that influence MSO implementation. Additionally, this study acknowledges their criteria interrelationships from industry and academic experts' perspectives. By combining fuzzy set theory and linguistic preferences, this study deals with human judgment vagueness and knowledge loss. In this way, the direct and indirect effects of criteria on MSOs are calculated via their links and strengths.

Experts were chosen for this study based on their level of knowledge and experience [49]. As recommended by the authors of [50], experts with a minimum of ten years of professional experience in academia, industry, or a combination of the two were acceptable. Experts should have a thorough understanding of manufacturing strategies, with a focus on competitive outcomes. Additionally, professionals should have a working knowledge of I4.0 technologies, either through practice or theory, as reported by [51]. The selected experts from the manufacturing organizations were mostly involved in I4.0 technology roles. They were responsible for market strategy and manufacturing, and thus possessed an in-depth understanding of manufacturing strategies. Since these experts had worked in manufacturing firms or provided consulting services to businesses, the data collected through questionnaires were highly reliable. Similarly, the academic experts were chosen from amongst professors and doctorates who had published articles in authoritative journals on manufacturing strategies and Industry 4.0. The selected academic experts had an immense impact in this field.

Individual interviews were conducted with experts to clarify the research, and those who were unable to participate in person due to their location were interviewed online. The authors began by identifying 30 experts who met the criteria outlined above. They received an initial email informing them of the study's purpose and confirming their desire to participate. The email was positively responded to by twenty of them. However, fully completed questionnaires were later received from only fourteen experts.

Fuzzy logic was developed in 1965 by Lotfi A. Zadeh, and is a method for evaluating uncertainty, ambiguity, and human decision-making. Examining the problems of decision-making in real-world transactions reveals that many decisions are caused by constraints and uncertain, imprecise events [52]. It is believed that translating linguistic terms into fuzzy numbers is more advantageous than combining opinions, ideas, or decisions that result from the expertise of individuals or groups. A triangular fuzzy number can be described as a set of three numbers, (l,m,r), with *l* representing the most conservative value closest to the real value and r representing the most optimistic value. The triangular fuzzy number's membership function is illustrated in Equation (2).

$$Z^k = \begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{bmatrix} [0,0,0] & x^k{}_{12} & \cdots & x^k{}_{1n} \\ x^k{}_{21} & [0,0,0] & \cdots & x^k{}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x^k{}_{n1} & x^k{}_{n2} & \cdots & [0,0,0] \end{bmatrix} \tag{1}$$

$$\mu_N(x) = \begin{cases} 0, & x < l \\ \frac{x-l}{m-l}, & l \le x \le m \\ \frac{r-x}{l-m}, & m \le x \le r \\ 0, & x > r \end{cases} \tag{2}$$

where *l* represents the left score, *r* is the right score, and *m* is the medium score of the triangular fuzzy numbers.

The fuzzy DEMATEL method includes collecting indicators for the degree of influence, the degree of cause for each factor, and drawing the causality map. It evaluates the significant relationship path between each factor in terms of the set threshold and concludes with several management implications and recommendations based on additional analysis and discussion. This method establishes a visual structure based on the causal relationship between various factors, calculates the center degree and cause a degree of each factor, draws the causal diagram, classifies factors (cause group or effect group), and then identifies key factors that will help solve problems more effectively [53]. The fuzzy DEMATEL method consists of the following steps [27,54,55]:

Step 1: Define decision objectives, develop a fuzzy scale, and construct a list of criteria (C1, C2 . . . Cn).

Step 2: Select professional experts with relevant knowledge and experience to evaluate the effect of factors using pairwise comparison.

Step 3: Create a semantic evaluation form that divides the level of influence among different factors into five levels: no influence "No" very low influence "VL", low influence "L" high influence "H", and very high influence "VH". The form should be easy to read and understand.

Step 4: Obtain the initial matrix of direct impact. Invite experts to evaluate the direct relationship between the factors based on their comprehension of the semantic evaluation table and to generate a direct effect matrix.

Step 5: Define the fuzzy linguistic scale to deal with the vagueness of human assessments and then convert the direct impact in step 3 to triangular fuzzy numbers as shown in Table 1. The linguistic variable "influence" in conjunction is used with a five-level scale containing the following scale items: no influence, a very low influence, a low influence, a high influence, and a very high influence. Table 1 shows the fuzzy numbers for various linguistic terms.

Step 6: Create the fuzzy direct-relation matrices Z^K by having evaluators construct fuzzy pair-wise influence relationships between components in an *n x n* matrix, where *k* is the number of experts. As a result, the direct-relation matrix $Z^K = [x^K{}_{ij}]$, where Z is an *n x*

n non-negative matrix, x_{ij} reflects the direct influence of component i on factor j; and, when $i = j$, the diagonal elements $x_{ij} = 0$.

Step 7: Use the CSCF (converting fuzzy data into crisp score) method to defuzzify the fuzzy numbers and calculate the weighted average of the membership function's left and right scores to achieve an overall score. Researchers have found that this method is more effective for obtaining precise data [56,57]. The CFCS method is used to determine the fuzzy maximum and minimum values in a fuzzy number range. The total score is calculated using membership functions as a weighted average. Each population score generates a new initial matrix of direct impact. The following are the specific steps:

1. Normalize the triangular fuzzy numbers, where $0 \leq x_{ij} \leq 1$:

$$xl^k{}_{ij} = \frac{l^k{}_{ij} - minl^k{}_{ij}}{\Delta^{max}_{min}} \quad (3)$$

$$xm^k{}_{ij} = \frac{m^k{}_{ij} - minl^k{}_{ij}}{\Delta^{max}_{min}} \quad (4)$$

$$xr^k{}_{ij} = \frac{r^k{}_{ij} - minl^k{}_{ij}}{\Delta^{max}_{min}} \quad (5)$$

$$\Delta^{max}_{min} = maxr^k{}_{ij} - minl^k{}_{ij} \quad (6)$$

2. Calculate the left score (ls) and right score (rs) normalized values:

$$xls^k{}_{ij} = \frac{xm^k{}_{ij}}{(1 + xm^k{}_{ij} - xl^k{}_{ij})} \quad (7)$$

$$xrs^k{}_{ij} = \frac{xr^k{}_{ij}}{(1 + xr^k{}_{ij} - xm^k{}_{ij})} \quad (8)$$

3. Compute the crisp values:

$$x^k{}_{ij} = \frac{xls^k{}_{ij} * \left(1 - xls^k{}_{ij}\right) + xrs^k{}_{ij} * xrs^k{}_{ij}}{(1 - xl^k{}_{ij} + xrs^k{}_{ij})} \quad (9)$$

4. Generate the total normalized crisp values of the expert, k:

$$z^k{}_{ij} = minl^k{}_{ij} + x^k{}_{ij} * \Delta^{max}_{min} \quad (10)$$

5. Obtain the direct relation matrix through aggregating the normalized crisp values from all factors:

$$z_{ij} = \frac{Z^1{}_{ij} + Z^2{}_{ij} + \ldots + Z^n{}_{ij}}{n} \quad (11)$$

6. The standardized direct influence matrix is obtained from the initial direct influence matrix, where $X = [x_{ij}]_{n*n}$, and $0 \leq x_{ij} \leq 1$. The calculation is as follows:

$$X = s * Z \quad (12)$$

$$s = \frac{1}{\max\limits_{1 \leq i \leq n} \sum_{j=n}^{m} z_{ij}}, i, j = 1, 2, \ldots, n. \quad (13)$$

7. Calculate the influence matrix $T = \left[t_{ij}\right]_{n*n}$. The element t_{ij} indicates the indirect influence relationship of factors i and j. The influence matrix T reflects the overall impact relationship between elements. The calculation of the matrix is as follows:

$$T = \lim_{m \to \infty} \left(\ X + \quad X^2 + \quad X^3 \quad \ldots \ X^m \quad \right) = X^*(1 - X)^{-1} \tag{14}$$

8. Calculate the influence degree, affected degree, center degree, and cause degree of each factor as follows:
   i. The degree of influence D_i denotes the extent to which various factors have a cumulative effect on other factors in manufacturing strategies outputs (basic elements).

$$\text{The influence degree}: \ D_i = \sum_{j=1}^{n} t_{ij} \tag{15}$$

   ii. The affected degree R_j indicates the extent to which each factor in a set of manufacturing strategies' outputs (basic elements) is influenced by the other factors.

$$\text{The affected degree}: \ R_j = \sum_{i=1}^{n} t_{ij} \tag{16}$$

   iii. The center degree $\left(R_j - D_i\right)$ indicates that the importance of factors in manufacturing strategies outputs (basic elements).

$$\textit{The center degree} = \left\{ \left(R_j + D_i\right) \middle| i = j \right\} \tag{17}$$

   iv. For the cause degree,
      o when $R_j + D_i$ is positive, the factor belongs to the cause group
      o when $R_j - D_i$ is negative, the factor belongs to the effect group

$$\textit{The cause degree} = \left\{ \left(R_j - D_i\right) \middle| i = j \right\} \tag{18}$$

9. Create a causal diagram. Within the total relation matrix M, the sum of rows and columns are denoted independently by the vectors R_j and D_i. By mapping the dataset of $(R_j + D_i, R_j - D_i)$, a cause and effect graph may be obtained. The horizontal axis vector $(R_j + D_i)$ labeled "Prominence" is created by adding R_j to D_i, indicating the criterion's relevance. Similarly, the vertical axis $(R_j - D_i)$ labeled "Relation" is created by subtracting R_i from D_i, which can be used to organize criteria into a cause category. Alternatively, if $(R_j - D_i)$ is negative, the criterion is assigned to the effect group.

4. Results and Discussions

This section utilizes the MCDM method in order to determine the factors that influence manufacturing strategies while implementing I4.0 technologies. The original data is transformed into a triangular fuzzy numbers as shown in Table 2, and the final initial direct influence matrix is generated. Due to space limitations, this article only includes one expert's original data (see Table 3). The expert's semantic evaluation is converted to a triangular fuzzy number using Excel programming. Finally, the direct impact matrix between the initial influencing elements is generated using the CFCS method (as shown in Table 4, two decimal numbers are retained). The collected data was analyzed by the DEMATEL method, and questionnaires are processed using the triangular fuzzy number approach and defuzzification to generate a matrix of direct influence between elements, as shown in Table 4. The average influence matrix of all experts on elements affecting the MSOs is finally obtained, as shown in Table 5.

Table 2. The fuzzy scale [58–61].

Linguistic Terms	Symbol	Corresponding Triangular Fuzzy Numbers (TFNs)
No influence	NO	(0,0,0.25)
Very low influence	VL	(0,0.25,0.5)
Low influence	L	(0.25,0.5,0.75)
High influence	H	(0.5,0.75,1)
Very high influence	VH	(0.75,1,1)

Table 3. An example of original data from one of the experts.

Elements	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29
C1		H	H	L	H	H	L	VH	H	VH	H	H	L	H	VL	L	L	H	L	H	H	L	H	H	VH	H	H	L	L
C2	VH		NO	H	H	VH	H	H	H	H	L	L	VL	NO	VL	L	H	L	H	H	H	H	H	VL	H	L	L	L	L
C3	VH	L		L	L	VL	VL	H	VH	H	NO	NO	NO	VL	VL	L	VL	L	NO	NO	NO	H	L	NO	L	VL	L	VL	L
C4	L	H	NO		NO	L	L	L	H	L	VL	VL	VL	NO	NO	VL	L	NO	L	L	H	L	L	NO	L	H	H	L	H
C5	H	H	NO	H		L	L	VL	L	L	VL	L	VL	NO	NO	L	H	L	VL	H	VH	L	L	H	L	L	H	L	L
C6	H	VL	NO	H	L		VH	VH	VH	VH	NO	VL	NO	VL	VL	NO	VL	NO	NO	NO	NO	H	H	VH	NO	VL	VL	VL	VH
C7	VH	H	L	H	NO	VH		VH	H	H	VH	VH	H	H	L	VL	VL	VL	VL	L	VL	H	H	L	H	NO	H	H	VH
C8	L	L	VL	H	L	H	L		VH	L	L	H	VL	VL	VL	L	NO	VL	VL	VL	NO	VL	VH	NO	L	L	VH	VH	H
C9	L	NO	NO	VL	VL	VL	NO	VH		H	VL	NO	NO	VL	VL	L	L	L	L	VL	L	H	H	H	VL	NO	VH	H	VH
C10	VH	H	H	H	H	H	L	H	H		NO	NO	NO	NO	NO	NO	NO	NO		VL	NO	L	NO	VH	NO	NO	L	H	H
C11	VL	NO	NO	L	L	NO	NO	VH	VH	NO		VH	VH	L	H	H	H	H	H	VL	NO	L	NO	NO	VL	NO	NO	NO	NO
C12	L	L	NO	VL	L	NO	NO	VH	VH	NO	VH		VH	L	H	NO	VL	NO	NO	NO	NO	NO	NO	NO	VL	NO	NO	NO	L
C13	VL	VL	NO	NO	NO	NO	NO	VH	VH	NO	VH	H		L	H	VL	NO	NO	VL	NO	NO	NO	NO	NO	NO	NO	NO	NO	VL
C14	H	L	VL	NO	VL	NO	NO	H	H	NO	VL	H	H		VL	NO	L	L	L	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
C15	L	L	L	L	NO	NO	NO	VL	NO	VL	VH	VH	H	VL			NO	NO	NO	NO	VL	NO	NO	NO	NO	NO	NO	NO	VL
C16	L	H	NO	H	VH	VL	VL	NO	H	NO	NO	NO	NO	VL	NO		VH	VH	VH	H	L	NO	VL	NO	VL	H	NO	NO	H
C17	L	H	NO	H	VH	VL	VL	NO	H	NO	VL	NO	NO	NO	NO	H		VH	VH	H	VH	VL	VL	NO	NO	H	L	NO	L
C18	VL	H	NO	L	H	VL	VL	NO	VH	NO	NO	VL	VL	VL	NO	H	VH		VH	L	L	H	NO	NO	L	NO	NO	VL	VL
C19	VL	H	NO	VH	VH	VL	VL	NO	H	NO	VL	VL	VL	NO	NO	VH	VH	L		H	H	NO	NO	VL	VL	VL	L	VL	L
C20	H	H	NO	H	H	L	L	VL	H	NO	VL	L	L	NO	NO	L	H	NO	H		VL	NO	VL	VL	NO	VL	L	VL	VL
C21	VH	VH	NO	VH	VH	VL	VL	NO	VH	VH	VL	VL	L	VL	NO	H	H	VL	H	VL		VH	VL	VL	L	L	L	NO	VH
C22	L	NO	NO	VL	NO	NO	NO	NO	L	L	NO	NO	VL	VL	NO	L	L	H	VL	H	VH		L	H	VL	NO	H	VL	VL
C23	H	L	NO	H	VL	H	L	L	H	L	VL	NO	VL	NO	VL	VL	VL	VL	VL	L	L	NO		L	NO	NO	L	NO	H
C24	H	L	NO	VL	NO	H	H	VH	VH	VH	L	L	H	H	L	VL	VL	NO	VL	NO	VL	L	VL		NO	VL	NO	VL	H
C25	NO	H	VL	H	H	H	L	H	VH	H	NO	NO	L	VL	NO	VH	H	L	H	VL	L	NO	H	H		H	L	VH	VH
C26	NO	NO	NO	NO	L	L	H	VL	L	L	VL	VL	VH	L	VL	VL	L	VL	L	H	H	VL	VL	NO	L		NO	VL	L
C27	L	L	NO	VH	H	VL	VL	VL	VH	H	L	L	VL	NO	NO	L	L	NO	L	L	H	L	L	L	H	NO		H	VH
C28	H	H	NO	H	H	L	L	L	H	L	L	VL	VL	NO	NO	VL	VL	NO	NO	VL	L	VL	VL	L	L	L	H		H
C29	H	VL	VL	VH	VH	H	VL	H	VH	L	NO	NO	VL	VL	NO	L	H	L	L	H	VH	L	H	L	H	L	H	H	

Table 4. Initial direct influence matrix after triangular fuzzy conversion.

Elements	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29
C1	0.00	0.73	0.77	0.54	0.77	0.77	0.54	0.99	0.77	0.99	0.77	0.77	0.54	0.77	0.29	0.54	0.54	0.77	0.54	0.77	0.77	0.54	0.77	0.77	0.99	0.77	0.77	0.54	0.54
C2	0.99	0.00	0.03	0.77	0.77	0.99	0.77	0.77	0.77	0.77	0.54	0.54	0.29	0.03	0.29	0.54	0.77	0.54	0.77	0.77	0.77	0.77	0.77	0.29	0.77	0.54	0.54	0.54	0.54
C3	0.99	0.47	0.00	0.54	0.54	0.29	0.29	0.77	0.99	0.77	0.03	0.03	0.03	0.29	0.29	0.54	0.29	0.54	0.03	0.03	0.03	0.77	0.54	0.03	0.54	0.29	0.54	0.29	0.54
C4	0.54	0.73	0.03	0.00	0.03	0.54	0.54	0.54	0.77	0.54	0.29	0.29	0.29	0.03	0.03	0.29	0.54	0.03	0.54	0.54	0.77	0.54	0.54	0.03	0.54	0.77	0.77	0.54	0.77
C5	0.77	0.73	0.03	0.77	0.00	0.54	0.54	0.29	0.54	0.54	0.29	0.54	0.29	0.03	0.03	0.54	0.77	0.54	0.29	0.77	0.99	0.54	0.54	0.77	0.54	0.54	0.77	0.54	0.54
C6	0.77	0.22	0.03	0.77	0.54	0.00	0.99	0.99	0.99	0.99	0.03	0.29	0.03	0.29	0.29	0.03	0.29	0.03	0.03	0.03	0.03	0.77	0.77	0.99	0.03	0.29	0.29	0.29	0.99
C7	0.99	0.73	0.54	0.77	0.03	0.99	0.00	0.99	0.77	0.77	0.99	0.99	0.77	0.77	0.54	0.29	0.29	0.29	0.29	0.54	0.29	0.77	0.77	0.54	0.77	0.03	0.77	0.77	0.99
C8	0.54	0.47	0.29	0.77	0.54	0.77	0.54	0.00	0.99	0.54	0.54	0.77	0.29	0.29	0.29	0.54	0.03	0.29	0.29	0.29	0.03	0.29	0.99	0.03	0.54	0.54	0.99	0.99	0.77
C9	0.54	0.00	0.03	0.29	0.29	0.29	0.03	0.99	0.00	0.77	0.29	0.03	0.03	0.29	0.29	0.54	0.54	0.54	0.54	0.29	0.54	0.77	0.77	0.77	0.29	0.03	0.99	0.77	0.99
C10	0.99	0.73	0.77	0.77	0.77	0.77	0.54	0.77	0.77	0.00	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.00	0.29	0.03	0.54	0.03	0.99	0.03	0.03	0.54	0.77	0.77
C11	0.29	0.00	0.03	0.54	0.54	0.03	0.03	0.99	0.99	0.03	0.00	0.99	0.99	0.54	0.77	0.77	0.77	0.77	0.77	0.29	0.03	0.54	0.03	0.03	0.29	0.03	0.03	0.03	0.03
C12	0.54	0.47	0.03	0.29	0.54	0.03	0.03	0.99	0.99	0.03	0.99	0.00	0.99	0.54	0.77	0.03	0.29	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29	0.03	0.03	0.03	0.54
C13	0.29	0.22	0.03	0.00	0.03	0.03	0.03	0.99	0.99	0.03	0.99	0.77	0.00	0.54	0.77	0.29	0.03	0.03	0.29	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29
C14	0.77	0.47	0.29	0.00	0.29	0.03	0.03	0.77	0.77	0.03	0.29	0.77	0.77	0.00	0.29	0.03	0.54	0.54	0.54	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
C15	0.54	0.47	0.54	0.54	0.03	0.03	0.03	0.29	0.03	0.29	0.99	0.99	0.77	0.29	0.00	0.00	0.03	0.03	0.03	0.03	0.29	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.29
C16	0.54	0.73	0.03	0.77	0.99	0.29	0.29	0.03	0.77	0.03	0.03	0.03	0.03	0.29	0.03	0.00	0.99	0.99	0.99	0.77	0.54	0.03	0.29	0.03	0.29	0.77	0.03	0.03	0.77
C17	0.54	0.73	0.03	0.77	0.99	0.29	0.29	0.03	0.77	0.03	0.29	0.03	0.03	0.03	0.03	0.77	0.00	0.99	0.99	0.77	0.99	0.29	0.29	0.03	0.03	0.77	0.54	0.03	0.54
C18	0.29	0.73	0.03	0.54	0.77	0.29	0.29	0.03	0.99	0.03	0.03	0.29	0.29	0.29	0.03	0.77	0.99	0.00	0.99	0.54	0.54	0.77	0.03	0.03	0.54	0.03	0.03	0.29	0.29
C19	0.29	0.73	0.03	0.99	0.99	0.29	0.29	0.03	0.77	0.03	0.29	0.29	0.29	0.03	0.03	0.99	0.99	0.54	0.00	0.77	0.77	0.03	0.03	0.29	0.29	0.29	0.54	0.29	0.54
C20	0.77	0.73	0.03	0.77	0.77	0.54	0.54	0.29	0.77	0.03	0.29	0.54	0.54	0.03	0.03	0.54	0.77	0.03	0.77	0.00	0.29	0.03	0.29	0.29	0.03	0.29	0.54	0.29	0.29
C21	0.99	0.99	0.03	0.99	0.99	0.29	0.29	0.03	0.99	0.99	0.29	0.29	0.54	0.29	0.03	0.77	0.77	0.29	0.77	0.29	0.00	0.99	0.29	0.29	0.54	0.54	0.54	0.03	0.99
C22	0.54	0.00	0.03	0.29	0.03	0.03	0.03	0.03	0.54	0.54	0.03	0.03	0.29	0.29	0.03	0.54	0.54	0.77	0.29	0.77	0.99	0.00	0.54	0.77	0.29	0.03	0.77	0.29	0.29
C23	0.77	0.47	0.03	0.77	0.29	0.77	0.54	0.54	0.77	0.54	0.29	0.03	0.29	0.03	0.29	0.29	0.29	0.29	0.29	0.54	0.54	0.03	0.00	0.54	0.03	0.03	0.54	0.03	0.77
C24	0.77	0.47	0.03	0.29	0.03	0.77	0.77	0.99	0.99	0.99	0.54	0.54	0.77	0.77	0.54	0.29	0.29	0.03	0.29	0.03	0.29	0.54	0.29	0.00	0.03	0.29	0.03	0.29	0.77
C25	0.03	0.73	0.29	0.77	0.77	0.77	0.54	0.77	0.99	0.77	0.03	0.03	0.54	0.29	0.03	0.99	0.77	0.54	0.77	0.29	0.54	0.03	0.77	0.77	0.00	0.77	0.54	0.99	0.99
C26	0.03	0.00	0.03	0.00	0.54	0.54	0.77	0.29	0.54	0.54	0.29	0.29	0.99	0.54	0.29	0.29	0.54	0.29	0.54	0.77	0.77	0.29	0.29	0.03	0.54	0.00	0.03	0.29	0.54
C27	0.54	0.47	0.03	0.99	0.77	0.29	0.29	0.29	0.99	0.77	0.54	0.54	0.29	0.03	0.03	0.54	0.54	0.03	0.54	0.54	0.77	0.54	0.54	0.54	0.77	0.03	0.00	0.77	0.99
C28	0.77	0.73	0.03	0.77	0.77	0.54	0.54	0.54	0.77	0.54	0.54	0.29	0.29	0.03	0.03	0.29	0.29	0.03	0.03	0.29	0.54	0.29	0.29	0.54	0.54	0.54	0.77	0.00	0.77
C29	0.77	0.22	0.29	0.99	0.99	0.77	0.29	0.77	0.99	0.54	0.03	0.03	0.29	0.29	0.03	0.54	0.77	0.16	0.54	0.77	0.99	0.54	0.77	0.54	0.77	0.54	0.77	0.77	0.00

Complex decision problems often involve several elements influencing each other (placed in the cause group) or influencing other elements (placed in the effect group). Due to the general interdependence of factors, it is not true that improving one element automatically improves the entire manufacturing strategy. To improve MSOs, it is critical to establish a cause-effect relationship, which will allow for the identification of which elements in the cause group can be improved while also improving the elements in the effect group [62]. Customer satisfaction (C9) is the most critical enabler for MSOs to achieve market competitiveness, as shown in Table 6, and previous literature supports this finding [63,64]. Customer satisfaction can be defined as the degree to which a company's products or services meet the expectations of its customers. It is the most important indicator among all MSOs of future purchases and consumer loyalty.

Table 5. The average influence matrix of all experts on elements affecting the MSOs.

Elements	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29
C1	0.00	0.76	0.56	0.38	0.56	0.47	0.41	0.60	0.65	0.56	0.32	0.38	0.35	0.32	0.26	0.45	0.45	0.50	0.38	0.50	0.50	0.62	0.47	0.32	0.40	0.38	0.50	0.48	0.47
C2	0.88	0.00	0.41	0.42	0.65	0.38	0.41	0.32	0.47	0.47	0.41	0.44	0.35	0.22	0.27	0.44	0.50	0.48	0.53	0.53	0.46	0.53	0.53	0.28	0.44	0.38	0.50	0.38	0.47
C3	0.83	0.44	0.00	0.38	0.47	0.32	0.32	0.35	0.52	0.44	0.23	0.26	0.26	0.26	0.21	0.38	0.35	0.35	0.28	0.31	0.28	0.38	0.35	0.25	0.32	0.23	0.32	0.29	0.29
C4	0.60	0.76	0.13	0.00	0.56	0.53	0.62	0.38	0.54	0.56	0.45	0.45	0.48	0.29	0.29	0.44	0.57	0.53	0.44	0.41	0.62	0.47	0.54	0.50	0.38	0.38	0.41	0.47	0.35
C5	0.55	0.38	0.26	0.43	0.00	0.35	0.38	0.32	0.53	0.41	0.42	0.48	0.42	0.29	0.21	0.35	0.47	0.35	0.41	0.47	0.53	0.32	0.35	0.47	0.35	0.32	0.44	0.35	0.50
C6	0.74	0.64	0.68	0.65	0.48	0.00	0.99	0.77	0.94	0.83	0.41	0.41	0.56	0.63	0.24	0.37	0.43	0.37	0.37	0.26	0.35	0.28	0.41	0.43	0.16	0.13	0.25	0.29	0.58
C7	0.62	0.60	0.47	0.23	0.53	0.86	0.00	0.68	0.71	0.52	0.68	0.50	0.50	0.55	0.28	0.47	0.44	0.44	0.44	0.48	0.50	0.57	0.54	0.66	0.22	0.10	0.31	0.32	0.49
C8	0.32	0.26	0.29	0.43	0.51	0.63	0.62	0.00	0.94	0.74	0.41	0.62	0.44	0.28	0.21	0.50	0.44	0.41	0.50	0.55	0.44	0.26	0.50	0.10	0.29	0.35	0.50	0.35	0.44
C9	0.50	0.49	0.44	0.44	0.35	0.51	0.47	0.56	0.00	0.65	0.68	0.61	0.37	0.32	0.21	0.41	0.38	0.47	0.44	0.70	0.68	0.48	0.32	0.26	0.38	0.41	0.50	0.47	0.62
C10	0.62	0.44	0.51	0.49	0.54	0.46	0.59	0.41	0.65	0.00	0.25	0.19	0.29	0.19	0.16	0.32	0.32	0.38	0.32	0.44	0.46	0.48	0.26	0.25	0.16	0.07	0.35	0.25	0.25
C11	0.32	0.26	0.23	0.35	0.45	0.19	0.16	0.49	0.80	0.16	0.00	0.91	0.94	0.67	0.46	0.53	0.44	0.53	0.53	0.32	0.29	0.32	0.19	0.19	0.32	0.25	0.25	0.25	0.32
C12	0.35	0.29	0.19	0.25	0.35	0.23	0.19	0.65	0.83	0.44	0.91	0.00	0.94	0.58	0.46	0.44	0.47	0.44	0.44	0.19	0.22	0.22	0.19	0.10	0.32	0.25	0.25	0.29	0.38
C13	0.32	0.32	0.19	0.25	0.29	0.26	0.19	0.68	0.68	0.44	0.91	0.91	0.00	0.49	0.46	0.35	0.29	0.32	0.32	0.26	0.26	0.29	0.19	0.19	0.32	0.29	0.29	0.25	0.35
C14	0.38	0.31	0.23	0.21	0.29	0.35	0.32	0.44	0.35	0.23	0.66	0.59	0.53	0.00	0.36	0.26	0.29	0.29	0.29	0.13	0.16	0.16	0.13	0.16	0.19	0.16	0.13	0.16	0.19
C15	0.41	0.38	0.32	0.20	0.19	0.16	0.23	0.44	0.32	0.13	0.74	0.80	0.57	0.47	0.00	0.40	0.47	0.49	0.47	0.35	0.41	0.26	0.26	0.29	0.19	0.25	0.19	0.19	0.22
C16	0.60	0.67	0.44	0.57	0.65	0.53	0.53	0.32	0.48	0.32	0.50	0.58	0.47	0.42	0.36	0.00	0.85	0.83	0.82	0.63	0.56	0.29	0.71	0.35	0.68	0.72	0.56	0.65	0.62
C17	0.60	0.63	0.41	0.65	0.60	0.53	0.53	0.32	0.41	0.26	0.53	0.59	0.47	0.45	0.27	0.64	0.00	0.88	0.80	0.63	0.74	0.19	0.56	0.32	0.71	0.77	0.51	0.62	0.56
C18	0.59	0.67	0.35	0.47	0.60	0.50	0.53	0.35	0.44	0.32	0.53	0.62	0.44	0.49	0.28	0.77	0.85	0.00	0.83	0.51	0.60	0.32	0.62	0.28	0.63	0.62	0.41	0.54	0.50
C19	0.60	0.63	0.35	0.59	0.59	0.47	0.47	0.29	0.42	0.38	0.56	0.62	0.53	0.48	0.27	0.64	0.83	0.74	0.00	0.68	0.71	0.23	0.53	0.38	0.77	0.66	0.54	0.56	0.38
C20	0.80	0.51	0.41	0.48	0.42	0.42	0.51	0.55	0.88	0.48	0.53	0.56	0.56	0.06	0.32	0.74	0.77	0.82	0.77	0.00	0.71	0.79	0.57	0.54	0.76	0.57	0.69	0.68	0.56
C21	0.85	0.76	0.44	0.68	0.68	0.54	0.51	0.55	0.94	0.62	0.73	0.59	0.62	0.10	0.38	0.80	0.80	0.88	0.80	0.62	0.00	0.97	0.74	0.54	0.85	0.68	0.72	0.76	0.73
C22	0.41	0.29	0.59	0.14	0.16	0.03	0.13	0.44	0.82	0.23	0.07	0.35	0.10	0.06	0.32	0.16	0.19	0.25	0.13	0.69	0.85	0.00	0.54	0.22	0.68	0.22	0.44	0.56	0.28
C23	0.77	0.70	0.22	0.69	0.50	0.72	0.69	0.56	0.54	0.62	0.59	0.73	0.59	0.37	0.12	0.88	0.68	0.74	0.82	0.69	0.72	0.65	0.00	0.68	0.74	0.62	0.63	0.79	0.74
C24	0.41	0.63	0.16	0.17	0.44	0.74	0.88	0.74	0.59	0.25	0.59	0.73	0.62	0.19	0.22	0.48	0.19	0.19	0.54	0.10	0.48	0.22	0.51	0.00	0.10	0.10	0.10	0.26	0.28
C25	0.68	0.83	0.68	0.74	0.77	0.62	0.56	0.51	0.65	0.62	0.47	0.56	0.54	0.19	0.10	0.68	0.85	0.72	0.88	0.66	0.69	0.62	0.74	0.51	0.00	0.77	0.80	0.77	0.73
C26	0.62	0.51	0.28	0.20	0.60	0.10	0.19	0.57	0.72	0.59	0.47	0.59	0.55	0.32	0.28	0.63	0.51	0.23	0.51	0.57	0.60	0.32	0.41	0.23	0.60	0.00	0.53	0.45	0.51
C27	0.54	0.61	0.19	0.70	0.54	0.62	0.62	0.50	0.71	0.68	0.54	0.54	0.50	0.19	0.10	0.63	0.60	0.59	0.62	0.68	0.69	0.68	0.69	0.26	0.74	0.51	0.00	0.77	0.71
C28	0.63	0.64	0.47	0.77	0.60	0.60	0.48	0.54	0.59	0.53	0.48	0.54	0.57	0.16	0.18	0.71	0.62	0.51	0.50	0.68	0.66	0.57	0.68	0.35	0.72	0.74	0.74	0.00	0.56
C29	0.69	0.53	0.57	0.36	0.83	0.62	0.63	0.47	0.68	0.56	0.22	0.29	0.35	0.19	0.22	0.63	0.66	0.36	0.63	0.68	0.80	0.71	0.68	0.41	0.91	0.74	0.77	0.77	0.00

Table 6. The affected degree (R_j), influence degree (D_i), centrality $(R_j + D_i)$ and cause-effect degree $\left(R_j - D_i\right)$ for each factor.

Factor	R_j	D_i	(R_j+D_i)	$\left(R_j-D_i\right)$	Category
C1	2.373(16)	2.943(2)	5.315(11)	−0.57(25)	Net effect
C2	2.312(18)	2.72(5)	5.032(14)	−0.409(21)	Net effect
C3	1.762(27)	1.932(26)	3.693(27)	−0.171(18)	Net effect
C4	2.406(14)	2.278(23)	4.684(19)	0.129(12)	Net cause
C5	2.045(20)	2.597(9)	4.641(20)	−0.553(23)	Net effect
C6	2.415(13)	2.329(22)	4.743(17)	0.086(15)	Net cause
C7	2.453(12)	2.394(20)	4.847(15)	0.059(16)	Net cause
C8	2.267(19)	2.498(14)	4.764(16)	−0.232(19)	Net effect
C9	2.403(15)	3.227(1)	5.629(4)	−0.825(28)	Net effect
C10	1.844(24)	2.406(18)	4.249(24)	−0.563(24)	Net effect
C11	1.979(21)	2.587(11)	4.566(21)	−0.608(26)	Net effect
C12	1.925(23)	2.778(3)	4.702(18)	−0.854(29)	Net effect
C13	1.832(25)	2.52(13)	4.352(23)	−0.688(27)	Net effect
C14	1.401(29)	1.696(28)	3.096(29)	−0.296(20)	Net effect
C15	1.756(28)	1.38(29)	3.135(28)	0.377(8)	Net cause
C16	2.911(8)	2.649(8)	5.56(6)	0.263(9)	Net cause
C17	2.825(9)	2.698(7)	5.522(7)	0.127(13)	Net cause
C18	2.712(11)	2.593(10)	5.304(12)	0.119(14)	Net cause
C19	2.758(10)	2.709(6)	5.467(8)	0.05(17)	Net cause
C20	3.049(4)	2.531(12)	5.58(5)	0.518(7)	Net cause
C21	3.463(1)	2.729(4)	6.192(1)	0.734(3)	Net cause
C22	1.793(26)	2.246(24)	4.039(25)	−0.453(22)	Net effect
C23	3.274(3)	2.416(17)	5.69(3)	0.858(1)	Net cause
C24	1.966(22)	1.743(27)	3.709(26)	0.223(10)	Net cause
C25	3.307(2)	2.462(15)	5.769(2)	0.846(2)	Net cause
C26	2.333(17)	2.171(25)	4.504(22)	0.162(11)	Net cause
C27	2.931(6)	2.342(21)	5.272(13)	0.59(4)	Net cause
C28	2.927(7)	2.396(19)	5.323(10)	0.532(6)	Net cause
C29	2.973(5)	2.421(16)	5.394(9)	0.553(5)	Net cause

As a result, this factor boosts economic development and provides significant competitive advantages to an organization, resulting in increased profitability and growth and the company achieving market competitiveness. In relation to I4.0 adoption, the factories and products are smart, and customers demand to be served with all-around great customer satisfaction [65].

Cost per unit produced (C1) is the second important enabler for MSOs in order to achieve market competitiveness. The cost per unit produced is what a company spends on producing each unit of a product it sells. Manufacturing organizations should provide lower total costs with market-competitive pricing [66]. Customer satisfaction, low-cost strategies, and differentiation are the most effective ways for companies to maintain their competitive advantage. To preserve or enhance its market competitiveness, a low-cost company can do a variety of things.

It can invest heavily in marketing. In comparison to its higher-cost competition, it can pay for better positions in retail outlets. A company also has the ability to lower prices, reducing its competitor's margins and earnings. Manufacturing driven by I4.0 frequently results in operational gains through lower unit production costs. I4.0 technologies have increased production line efficiencies, resulting in more material consumption and less waste, as well as new ways to reuse and recycle waste to bring it back into production processes and lower package sizes, all of which leads to reducing production costs [67].

The third important enabler for MSOs in order to achieve market competitiveness is delivery speed (C12). The ability to meet delivery dates with the correct quantities and specifications is commonly referred to as delivery reliability [68]. Delivery speed refers to the capacity to fulfill a customer's order quickly [69]. The ability to accelerate time-to-market is a significant competitive advantage for manufacturers as it can immediately increase market share and profits. There are several competitive advantages associated with service differentiation, including product accessibility, speed of delivery to the customer, and reliability [70]. Manufacturing firms can introduce new products to the market faster and more flexibly with Industry 4.0. In response to technological advances and increasingly flexible and fast delivery services, customer expectations are changing.

The number of advanced features (C21) is the fourth MSO enabler required in order to achieve market competitiveness. Flexibility refers to the ability to provide customized goods and services as well as increase or decrease the availability of products to meet customer demands [71]. Advanced product features are traits or attributes of a product that add value to end-users and differentiate it from its competitors. The importance of an I4.0 implementation is due to its potential to lead to improved quality, lower prices, and increased product flexibility. As a result, other enablers appear to have a moderate to minor impact on MSOs' adoption of I4 technologies, as illustrated in Table 6.

To gain a thorough understanding of the most prevalent critical MSOs, it is necessary to concentrate on their root causes, which should be treated with extreme caution. For this purpose, a cause-effect relation diagram is plotted and shown in Figure 2. Figure 2 reveals that the number of engineering changes (C23) has the highest $R_i - D_i$ value (0.858) among all elements in the cause group. This indicates that C23 has more impact on the MSOs. With the implementation of I4.0 technologies, it is possible to enhance (improve) or transform (renovate or innovate) a manufacturing process in response to product changes during development in order to create new advanced features and maintain market competitiveness. As result, the number of engineering changes is the most critical MSO element that should be taken into consideration to provide an organization with huge competitive advantages. Thereafter, new products introduced each year (C25) is the second most important causal factor among the manufacturing strategies in the adoption of I4.0 technologies followed by the number of advanced features (C21) which comes the third most critical factor among all elements since its $R_i - D_i$ value is 0.58. This sequence continues with existing-product improvements (C27) and level of R&D investment (C29). As a result, other factors appear to have a moderate effect on MSOs' adoption of I4 technologies, as illustrated in Figure 2.

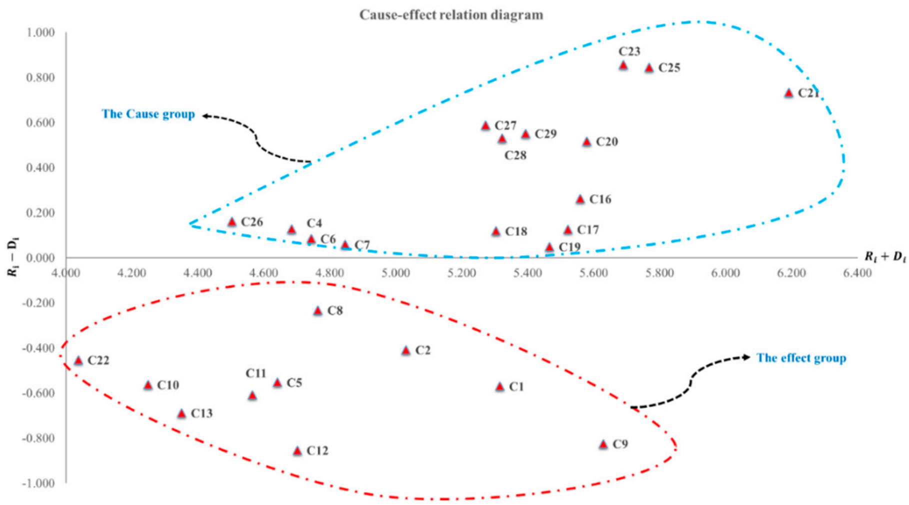

Figure 2. Cause-effect strategy map.

The factors that are easily influenced by other factors can be called effect factors. However, it is still necessary to analyze the effect factors that could lead to serious consequences in manufacturing strategies' outputs (basic elements). According to the cause-effect relation diagram in Figure 2, it is very clear that customer satisfaction (C9) has the highest $R_j + D_i$ value (5.629) among all effect groups. Furthermore, among all elements, its influenced impact index (D_i) has the highest value (3.227). Moreover, cost per unit produced (C1) and operating cost (C2) have a great influence on the manufacturing strategies as effect factors. Other effects seem to have a moderate to low effect on the MSOs in the adoption of I4 technologies, as shown in Figure 2.

5. Conclusions and Future Study

This research uses the fuzzy DEMATEL method to analyze MSOs' adoption of I4.0 technologies. This method discovers the root causes-effects of MSOs and creates a strategy map based on those factors. The strategy map reveals interdependencies and their strengths among MSOs' outputs. This research raises market competitiveness through well-organized and planned manufacturing strategies. The effect of MSOs was measured, and the cause-effect relationship between MSOs was clarified. Additionally, this research can assist organizations in considering the root causes and effects of MSOs, emphasizing how the right decisions can play a significant role in motivating the company to maintain a competitive advantage. Several conclusions have been drawn about the effect of MSOs based on expert opinion:

- Among all the factors, customer satisfaction is the most important enabler for manufacturing strategy outputs. Then comes the cost per unit, delivery speed, and advanced features.
- Regarding the root causes of manufacturing strategy outputs, the number of engineering changes has the highest influence among all elements in the cause element group. Other important causes are the number of new products introduced each year, the improvement of existing products, the number of engineering change orders per year, and the number of advanced features.
- The results reveal that customer satisfaction has the highest influence of all the elements in the effect element group. Moreover, the cost per unit produced and operating cost have a great influence on manufacturing strategies as effect factors.

There are certain limitations and shortcomings in this paper. Firstly, due to a shortage of respondents, future studies should perform more surveys in order to gain a deeper understanding of the topic. Secondly, as no case study or empirical study has been conducted to evaluate how factors influence MSOs' adoption of I4.0 technologies, future research should conduct an empirical study in specific industries. Thirdly, WINGS (weighted influence non-linear gauge system), which is an improvement on the DEMATEL method, could be used in the future to find out how strong a factor is, instead of the intensity of its influence.

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References

1. Park, K.; Kremer, G.E.O. Assessment of static complexity in design and manufacturing of a product family and its impact on manufacturing performance. *Int. J. Prod. Econ.* **2015**, *169*, 215–232. [CrossRef]
2. Badurdeen, F.; Jawahir, I.S. Strategies for Value Creation Through Sustainable Manufacturing. *Procedia Manuf.* **2017**, *8*, 20–27. [CrossRef]
3. ElMaraghy, H.; Schuh, G.; ElMaraghy, W.; Piller, F.; Schönsleben, P.; Tseng, M.; Bernard, A. Product variety management. *CIRP Ann.* **2013**, *62*, 629–652. [CrossRef]
4. Dohale, V.; Gunasekaran, A.; Akarte, M.M.; Verma, P. Twenty-five years' contribution of "Benchmarking: An International Journal" to manufacturing strategy: A scientometric review. *Benchmarking Int. J.* **2020**, *27*, 2887–2908. [CrossRef]
5. Miltenburg, J. Setting manufacturing strategy for a factory-within-a-factory. *Int. J. Prod. Econ.* **2008**, *113*, 307–323. [CrossRef]
6. Patil, P.P.; Narkhede, B.E.; Akarte, M.M. Pattern of manufacturing strategy implementation and implications on manufacturing levers and manufacturing outputs and business performance. *Int. J. Indian Cult. Bus. Manag.* **2015**, *10*, 157–177. [CrossRef]
7. Flynn, B.B.; Schroeder, R.G.; Flynn, E.J. World class manufacturing: An investigation of Hayes and Wheelwright's foundation. *J. Oper. Manag.* **1999**, *17*, 249–269. [CrossRef]
8. Ketokivi, M.; Schroeder, R. Manufacturing practices, strategic fit and performance: A routine-based view. *Int. J. Oper. Prod. Manag.* **2004**, *24*, 171–191. [CrossRef]
9. Parhi, S.; Joshi, K.; Akarte, M. Smart manufacturing: A framework for managing performance. *Int. J. Comput. Integr. Manuf.* **2021**, *34*, 227–256. [CrossRef]
10. Wagner, T.; Herrmann, C.; Thiede, S. Industry 4.0 Impacts on Lean Production Systems. *Procedia CIRP* **2017**, *63*, 125–131. [CrossRef]
11. Sung, T.K. Industry 4.0: A Korea perspective. *Technol. Forecast. Soc. Chang.* **2018**, *132*, 40–45. [CrossRef]
12. Alcácer, V.; Cruz-Machado, V. Scanning the industry 4.0: A literature review on technologies for manufacturing systems. *Eng. Sci. Technol. Int. J.* **2019**, *22*, 899–919. [CrossRef]
13. Ghobakhloo, M. The future of manufacturing industry: A strategic roadmap toward Industry 4.0. *J. Manuf. Technol. Manag.* **2018**, *29*, 910–936. [CrossRef]
14. Ko, M.; Kim, C.; Lee, S.; Cho, Y. An Assessment of Smart Factories in Korea: An Exploratory Empirical Investigation. *Appl. Sci.* **2020**, *10*, 7486. [CrossRef]
15. Dohale, V.; Gunasekaran, A.; Akarte, M.M.; Verma, P. 52 Years of manufacturing strategy: An evolutionary review of literature (1969–2021). *Int. J. Prod. Res.* **2022**, *60*, 569–594. [CrossRef]
16. Wu, G.-C.; Ding, J.-H.; Chen, P.-S. The effects of GSCM drivers and institutional pressures on GSCM practices in Taiwan's textile and apparel industry. *Int. J. Prod. Econ.* **2012**, *135*, 618–636. [CrossRef]
17. Tamura, H.; Nagata, H.; Akazawa, K. Extraction and systems analysis of factors that prevent safety and security by structural models. In *SICE Annual Conference Program and Abstracts SICE Annual Conference 2002*; The Society of Instrument and Control Engineers: Tokyo, Japan, 2002; p. 387. [CrossRef]
18. Huang, C.-Y.; Shyu, J.Z.; Tzeng, G.-H. Reconfiguring the innovation policy portfolios for Taiwan's SIP Mall industry. *Technovation* **2007**, *27*, 744–765. [CrossRef]
19. Tzeng, G.-H.; Chiang, C.-H.; Li, C.-W. Evaluating intertwined effects in e-learning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL. *Expert Syst. Appl.* **2007**, *32*, 1028–1044. [CrossRef]
20. Li, J.; Wu, C.-H.; Chen, C.-W.; Huang, Y.-F.; Lin, C.-T. Apply Fuzzy DEMATEL to Explore the Decisive Factors of the Auto Lighting Aftermarket Industry in Taiwan. *Mathematics* **2020**, *8*, 1187. [CrossRef]

21. Boutkhoum, O.; Hanine, M.; Nabil, M.; El Barakaz, F.; Lee, E.; Rustam, F.; Ashraf, I. Analysis and Evaluation of Barriers Influencing Blockchain Implementation in Moroccan Sustainable Supply Chain Management: An Integrated IFAHP-DEMATEL Framework. *Mathematics* **2021**, *9*, 1601. [CrossRef]
22. Si, S.-L.; You, X.-Y.; Liu, H.-C.; Zhang, P. DEMATEL Technique: A Systematic Review of the State-of-the-Art Literature on Methodologies and Applications. *Math. Probl. Eng.* **2018**, *2018*, 3696457. [CrossRef]
23. Manafzadeh, E.; Ramezani, A. Identifying and prioritizing the effect of marketing mix from the customer's perspective (4C) on the competitiveness of insurance companies using DEMATEL technique: A case study of Tehran Insurance Companies. *Mark. Brand. Res.* **2016**, *3*, 86–96. [CrossRef]
24. Lee, Y.-C.; Hsieh, Y.-F.; Guo, Y.-B. Construct DTPB model by using DEMATEL: A study of a university library website. *Program Electron. Libr. Inf. Syst.* **2013**, *47*, 155–169. [CrossRef]
25. Shao, J.; Taisch, M.; Ortega-Mier, M. A grey-DEcision-MAking Trial and Evaluation Laboratory (DEMATEL) analysis on the barriers between environmentally friendly products and consumers: Practitioners' viewpoints on the European automobile industry. *J. Clean. Prod.* **2016**, *112*, 3185–3194. [CrossRef]
26. Devadoss, A.V.; Felix, A. A Fuzzy DEMATEL approach to study cause and effect relationship of youth violence. *Int. J. Comput. Algorithm* **2013**, *2*, 363–372.
27. Lin, R.-J. Using fuzzy DEMATEL to evaluate the green supply chain management practices. *J. Clean. Prod.* **2013**, *40*, 32–39. [CrossRef]
28. Wu, W.-W. Choosing knowledge management strategies by using a combined ANP and DEMATEL approach. *Expert Syst. Appl.* **2008**, *35*, 828–835. [CrossRef]
29. Skinner, W. Manufacturing-missing link in corporate strategy. *Harv. Bus. Rev.* **1969**.
30. Boyer, K.K.; Lewis, M.W. Competitive priorities: Investigating the need for trade-offs in operations strategy. *Prod. Oper. Manag.* **2002**, *11*, 9–20. [CrossRef]
31. Chen, C.; Liu, Y.; Kumar, M.; Qin, J.; Ren, Y. Energy consumption modelling using deep learning embedded semi-supervised learning. *Comput. Ind. Eng.* **2019**, *135*, 757–765. [CrossRef]
32. Abdullah, F.M.; Saleh, M.; Al-Ahmari, A.M.; Anwar, S. The Impact of Industry 4.0 Technologies on Manufacturing Strategies: Proposition of Technology-Integrated Selection. *IEEE Access* **2022**, *10*, 21574–21583. [CrossRef]
33. Stoyanov, S.; Ahsan, M.; Bailey, C.; Wotherspoon, T.; Hunt, C. Predictive analytics methodology for smart qualification testing of electronic components. *J. Intell. Manuf.* **2019**, *30*, 1497–1514. [CrossRef]
34. Castellano, D.; Gallo, M.; Grassi, A.; Santillo, L.C. Batching decisions in multi-item production systems with learning effect. *Comput. Ind. Eng.* **2019**, *131*, 578–591. [CrossRef]
35. Youssef, M.A.; Youssef, E.M. The synergisitic impact of time–based technologies on manufacturing competitive priorities. *Int. J. Technol. Manag.* **2015**, *67*, 245–268. [CrossRef]
36. Ward, P.T.; Duray, R. Manufacturing strategy in context: Environment, competitive strategy and manufacturing strategy. *J. Oper. Manag.* **2000**, *18*, 123–138. [CrossRef]
37. Kucukoglu, I.; Atici-Ulusu, H.; Gunduz, T.; Tokcalar, O. Application of the artificial neural network method to detect defective assembling processes by using a wearable technology. *J. Manuf. Syst.* **2018**, *49*, 163–171. [CrossRef]
38. Petrillo, A.; De Felice, F.; Zomparelli, F. Performance measurement for world-class manufacturing: A model for the Italian automotive industry. *Total Qual. Manag. Bus. Excel.* **2019**, *30*, 908–935. [CrossRef]
39. Alqahtani, A.Y.; Gupta, S.M.; Nakashima, K. Warranty and maintenance analysis of sensor embedded products using internet of things in industry 4.0. *Int. J. Prod. Econ.* **2019**, *208*, 483–499. [CrossRef]
40. Rajput, S.; Singh, S.P. Industry 4.0—Challenges to implement circular economy. *Benchmarking Int. J.* **2019**, *28*, 1717–1739. [CrossRef]
41. Krause, D.R.; Pagell, M.; Curkovic, S. Toward a measure of competitive priorities for purchasing. *J. Oper. Manag.* **2001**, *19*, 497–512. [CrossRef]
42. Salam, M.A. Analyzing manufacturing strategies and Industry 4.0 supplier performance relationships from a resource-based perspective. *Benchmarking Int. J.* **2019**, *28*, 1697–1716. [CrossRef]
43. Leong, G.K.; Snyder, D.L.; Ward, P.T. Research in the process and content of manufacturing strategy. *Omega* **1990**, *18*, 109–122. [CrossRef]
44. Delbrügger, T.; Meißner, M.; Wirtz, A.; Biermann, D.; Myrzik, J.; Rossmann, J.; Wiederkehr, P. Multi-level simulation concept for multidisciplinary analysis and optimization of production systems. *Int. J. Adv. Manuf. Technol.* **2019**, *103*, 3993–4012. [CrossRef]
45. Oh, J.; Jeong, B. Tactical supply planning in smart manufacturing supply chain. *Robot. Comput. Manuf.* **2019**, *55*, 217–233. [CrossRef]
46. Kamble, S.S.; Gunasekaran, A.; Ghadge, A.; Raut, R. A performance measurement system for industry 4.0 enabled smart manufacturing system in SMMEs-A review and empirical investigation. *Int. J. Prod. Econ.* **2020**, *229*, 107853. [CrossRef]
47. Dziallas, M.; Blind, K. Innovation indicators throughout the innovation process: An extensive literature analysis. *Technovation* **2019**, *80–81*, 3–29. [CrossRef]
48. Kilic, K.; Ulusoy, G.; Gunday, G.; Alpkan, L. Innovativeness, operations priorities and corporate performance: An analysis based on a taxonomy of innovativeness. *J. Eng. Technol. Manag.* **2015**, *35*, 115–133. [CrossRef]

49. Tortorella, G.L.; Pradhan, N.; Macias de Anda, E.; Trevino Martinez, S.; Sawhney, R.; Kumar, M. Designing lean value streams in the fourth industrial revolution era: Proposition of technology-integrated guidelines. *Int. J. Prod. Res.* **2020**, *58*, 5020–5033. [CrossRef]
50. Baker, J.; Lovell, K.; Harris, N. How expert are the experts? An exploration of the concept of 'expert' within Delphi panel techniques. *Nurse Res.* **2006**, *14*, 59–70. [CrossRef]
51. Tortorella, G.L.; Fettermann, D. Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies. *Int. J. Prod. Res.* **2018**, *56*, 2975–2987. [CrossRef]
52. Zadeh, L.A.; Klir, G.J.; Yuan, B. *Fuzzy Sets, Fuzzy Logic, and Fuzzy Systems: Selected Papers*; World Scientific: River Edge, NJ, USA, 1996; Volume 6.
53. Ocampo, L.A.; Tan, T.A.G.; Sia, L.A. Using fuzzy DEMATEL in modeling the causal relationships of the antecedents of organizational citizenship behavior (OCB) in the hospitality industry: A case study in the Philippines. *J. Hosp. Tour. Manag.* **2018**, *34*, 11–29. [CrossRef]
54. Tsai, S.-B.; Chien, M.-F.; Xue, Y.; Li, L.; Jiang, X.; Chen, Q.; Zhou, J.; Wang, L. Using the Fuzzy DEMATEL to Determine Environmental Performance: A Case of Printed Circuit Board Industry in Taiwan. *PLoS ONE* **2015**, *10*, e0129153. [CrossRef] [PubMed]
55. Muhammad, M.N.; Cavus, N. Fuzzy DEMATEL method for identifying LMS evaluation criteria. *Procedia Comput. Sci.* **2017**, *120*, 742–749. [CrossRef]
56. Opricovic, S.; Tzeng, G.-H. Defuzzification within a multicriteria decision model. *Int. J. Uncertain. Fuzziness Knowl.-Based Syst.* **2003**, *11*, 635–652. [CrossRef]
57. Zhou, F.; Wang, X.; Lim, M.K.; He, Y.; Li, L. Sustainable recycling partner selection using fuzzy DEMATEL-AEW-FVIKOR: A case study in small-and-medium enterprises (SMEs). *J. Clean. Prod.* **2018**, *196*, 489–504. [CrossRef]
58. Chang, B.; Chang, C.-W.; Wu, C.-H. Fuzzy DEMATEL method for developing supplier selection criteria. *Expert Syst. Appl.* **2011**, *38*, 1850–1858. [CrossRef]
59. Mohammadi, H.; Nouri, I.; Ehsanifar, M. Applying fuzzy DEMATEL method to analyze supplier selection criteria (Case study: WagonPars Company). *Int. Res. J. Financ. Econ.* **2013**, *115*, 76–86.
60. Feng, C.; Ma, R. Identification of the factors that influence service innovation in manufacturing enterprises by using the fuzzy DEMATEL method. *J. Clean. Prod.* **2020**, *253*, 120002. [CrossRef]
61. Abbasi, M.; Hosnavi, R.; Tabrizi, B. Application of Fuzzy DEMATEL in Risks Evaluation of Knowledge-Based Networks. *J. Optim.* **2013**, *2013*, 913467. [CrossRef]
62. Vinodh, S.; Devadasan, S.; Vasudeva Reddy, B.; Ravichand, K. Agility index measurement using multi-grade fuzzy approach integrated in a 20 criteria agile model. *Int. J. Prod. Res.* **2010**, *48*, 7159–7176. [CrossRef]
63. Bayazit, O. Use of AHP in decision-making for flexible manufacturing systems. *J. Manuf. Technol. Manag.* **2005**, *16*, 808–819. [CrossRef]
64. Qi, Y.; Mao, Z.; Zhang, M.; Guo, H. Manufacturing practices and servitization: The role of mass customization and product innovation capabilities. *Int. J. Prod. Econ.* **2020**, *228*, 107747. [CrossRef]
65. Bollard, A.; Larrea, E.; Singla, A.; Sood, R.J. The next-generation operating model for the digital world. *McKinsey Digit.* **2017**, 1–8.
66. Wang, J.; Cao, D.-B. Relationships between two approaches for planning manufacturing strategy: A strategic approach and a paradigmatic approach. *Int. J. Prod. Econ.* **2008**, *115*, 349–361. [CrossRef]
67. Genc, T.S.; De Giovanni, P. Closed-loop supply chain games with innovation-led lean programs and sustainability. *Int. J. Prod. Econ.* **2020**, *219*, 440–456. [CrossRef]
68. Sarmiento, R.; Byrne, M.; Contreras, L.R.; Rich, N. Delivery reliability, manufacturing capabilities and new models of manufacturing efficiency. *J. Manuf. Technol. Manag.* **2007**, *18*, 367–386. [CrossRef]
69. Lin, Y.; Ma, S.; Zhou, L. Manufacturing strategies for time based competitive advantages. *Ind. Manag. Data Syst.* **2012**, *112*, 729–747. [CrossRef]
70. Köksal, M.H.; Özgül, E. The export competitive advantages of Turkish manufacturing companies. *Mark. Intell. Plan.* **2010**, *28*, 206–222. [CrossRef]
71. Wang, J.; Wu, H.; Chen, Y. Made in China 2025 and manufacturing strategy decisions with reverse QFD. *Int. J. Prod. Econ.* **2020**, *224*, 107539. [CrossRef]