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# Identifying Comprehensive Key Criteria of Sustainable Development for Traditional Manufacturing in Taiwan

**Zon-Yau Lee [1], Mei-Tai Chu [2], Shiuann-Shuoh Chen [3] and Chih-Hung Tsai [3,*]**

1 Department of International Business, Kainan University, No. 1 Kainan Road, Luzhu District, Taoyuan City 33857, Taiwan; zylee.mt88g@mail.knu.edu.tw
2 Department of Entrepreneurship, Innovation and Marketing, La Trobe University, Melbourne, VIC 3086, Australia; m.chu@latrobe.edu.au
3 Department of Business Administration, National Central University, No. 300, Zhongda Rd., Zhongli District, Taoyuan City 32001, Taiwan; kenchen@mgt.ncu.edu.tw
* Correspondence: 103481018@cc.ncu.edu.tw

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**Abstract:** The traditional manufacturing industry has suffered from changing global demands and rapid technology upgrades. It is critical to incorporate innovation into contemporary manufacturing for sustainable development. A comprehensive interpretation of the determinants and directions of technical change is greatly needed. Therefore, this study aims to explore innovative applications that can enhance the value of manufacturing and examine the key factors associated with these innovations. In this paper, three traditional manufacturing industries are analyzed using the research methodologies analytic hierarchy processing (AHP) and Decision Making Trial and Evaluation Laboratory (DEMATEL), resulting in a set of six key criteria for innovative manufacturing. The causal relationships considering the six criteria in three industries are analyzed. The main contribution of this study is to establish a new framework for the sustainable development of traditional manufacturing industries. This could help to support conceptual innovation in these industries and establish a pragmatic approach to increase sustainable development. From the research results, the following suggestions can be made. The traditional manufacturing industries in Taiwan should focus on design and innovation. This can enhance the value-added and international competitiveness of industrial chains, enterprises, and products. Ultimately, it can lead to the sustainable development of Taiwan's traditional industries.

**Keywords:** innovation; value added manufacturing; multiple-criteria decision making (MCDM)

## 1. Introduction

Many enterprises are struggling in the face of globalization and rapid technological advancement. Especially, traditional manufacturing industries have struggled during this transition [1] and many face bankruptcy. The main reason for this is that industrial development cannot keep up with global developments. The economies of many developing countries are based on traditional manufacturing. If the traditional manufacturing industry is not sustainably developed, it will cause an unemployment crisis and severely affect the economy. Successfully achieving the sustainable development goals (SDGs) proposed by the United Nations is an extremely important issue at present. In response to such issues, researchers have attempted to find innovative ways to make traditional manufacturing industries sustainable. Schumpeter [2] believes that innovation is an important factor for enterprises in using all available ways to meet the needs of the target market and promote economic growth. The role of innovation is regarded as a critical capability of enterprises that enhances competitive advantages and allows enterprises to survive in an increasingly changing environment. For example, enterprises may consider building their own brand instead of conventional original equipment manufacturing (OEM) to face the reality of the transformation [3]. Most countries in the world are eager to explore the future development of the manufacturing industry at the national level. For example, German industrialization 4.0 was proposed in 2011 and finalized in 2013 to address this issue [4] and mainly focused on various industrial-related technologies to establish so-called smart factories and the integration of various partnerships. These innovations were implemented to provide firms with the ability to gain competitive advantages and thus earn profits that are systematically higher than those gained by non-innovating companies [5,6]. However, the traditional thought that as long as you have a good product, a market will be created by word of mouth is weakly supported now [7]. In other words, if the manufacturing industry cannot be innovative, it will be difficult for it to survive or excel.

The extensive role of design and its influences on innovation have been studied in the context of manufacturing because of the decline of the industry despite its significant contributions to economic growth and rising living standards [8]. The innovation of enterprises can help to differentiate firms from their competitors, provide more value for customers, and maintain industry competitiveness [9,10]. Raffa and Zollo [11] also pointed out that when a company does not innovate and change, its competitive power and economic profits decline. If companies wish to get rid of traditional manufacturing challenges, then innovation can be a critical transformative factor [12]. Therefore, there is a need to combine technology and innovation to add value to firms' products considering customer value, technical feasibility, and market feasibility. This paper aims to discover key innovation criteria and their causal relationships in traditional manufacturing industries. The main contribution of this study is to establish a new modeling framework for the sustainable development of traditional manufacturing industries.

There are many complex factors or elements of innovation that need to be addressed and analyzed, as there are causal relationships between these elements in the real world to be discovered. In the past, in dealing with such complex issues, many scholars have taken a multiple-criteria decision making (MCDM) approach to solve the problem. Decision Making Trial and Evaluation Laboratory (DEMATEL) can be used to analyze the causal relationship between elements [13]. Analytical hierarchy processing (AHP) does well to identify the appropriate weight of the factors or elements [14] before using DEMATEL. In terms of methodology, this paper uses AHP and DEMATEL to conduct a quantitative analysis to measure how conventional manufacturing converts itself to an innovation-oriented industry and thus adds more value.

As a result, this research establishes a model to discuss the causal relationship between the various factors in traditional manufacturing industries. It focuses on the elements in relation to innovation. This model can be used to understand the trends and orientations of these elements and then discover the key success factors. The contribution of this research not only serves as the basis of future research and policy-making, but also helps the traditional manufacturing industry to find and grasp the advantages of growth and enhance the value of the industry in the future.

The remainder of this paper is organized as follows. Section 2 explains the literature review outcomes, including the key factors considering innovation for traditional manufacturing and the justification of research methods. Section 3 outlines the steps and procedures based on the methodology design. Section 4 demonstrates the results from a serial analysis. Section 5 discusses the research results. The final section concludes this paper with managerial implications.

## 2. Literature Review

The purpose of this section is to discover the key elements of how traditional manufacturing can create more value with innovation. In other words, the industry eagerly needs to choose innovation as a key factor in its transformation. Furthermore, the key elements derived from the literature review can help to build a meaningful model to be analyzed.

### *2.1. Innovation for Traditional Manufacturing*

Traditional Manufacturing tends to have a small scale of operation, high production costs, and weak competitiveness, generally. While facing dramatic and rapid changes in global competition and the economic environment, the manufacturing industry also confronts problems such as an aging workforce, shorter product lifecycle, more customized needs, and rising labor costs. Many activities have been initiated in this industry to increase production value and accelerate industrial restructuring and upgrading to strengthen competitiveness and sustainability. Thus, the issue of innovation regarding manufacturing has attracted much attention in terms of how to increase manufacturing response speed, production efficiency, and flexibility. Moreover, manufacturing is suggested to meet the increasingly competitive global product quality and production costs. Many companies have managed to close the gap between productivity and quality. Established manufacturing companies also recognize that many customers are reluctant to pay high prices for quality improvements. For example, adjusting production through innovation in the German manufacturing industry focused on customized products and quicker market introduction [15]. In addition to introducing new products and modes of production, research and development (R&D) departments also support the opening up of new markets and reinventing their businesses to provide the best possible service to these markets [16]. Thus, some scholars have stated that innovation can come from two main sources: (1) in-house R&D using the company's accumulated knowledge and (2) imitating the innovations of others to make increase competitiveness and hopefully reinforce any advantages [17,18].

Innovation means focusing on creativity for better or new products to increase consumer satisfaction and ensure a higher return of investment [19]. It is important for businesses to compete effectively in the market through higher economic value and happier customers [20]. One of the key components of innovation is value creation. Creating value in innovation stimulates enterprises to produce benefits for the environment and society to make them sustainable. Design-driven innovation aims at a branding strategy and hopes to find a niche in the market [21,22]. Hence, design-driven innovation can be considered as an effective strategy for success in organizational business models.

Several factors can affect a company's research allocation, such as fluctuations in raw material and energy prices, rapid changes in interest rates and exchange rates, and the increase in working conditions and social welfare costs. Continuous product innovation seems to improve new product development performance during challenges. Value proposition can be used as a means to eliminate waste and improve product development to provide value for end consumers [23]. An organization's capabilities and intangible assets effectively provide value, which is vital in a competitive environment [24]. Constrained by limited resources, the consideration of the economic return rate generated by products/services based on the value proposition has a better opportunity to boost the profitability of enterprises [25]. The value proposition is then regarded as an important key factor in this research.

In recent years, many companies have begun to involve customers in different goods and service-related processes. This integration of customer needs and preferred business models is believed to be a new trend for the future [26]. This means that companies create and develop appropriate business models that enable their customers to fully integrate into their business activities to increase their competitiveness [27]. Therefore, in the process of enterprise innovation, customers also play an important role. No matter how much the external environment faced by the company changes, it is extremely important to integrate the consumer's business strategy. Recognizing the value of integrating customer needs creates a strong influence on corporate innovation, especially the importance of customer perception of resource value. This is why customers and companies work together to define the creation of corporate value [28,29].

In terms of supply and demand, consumption and production often go hand in hand. Changing one component in a product may create a chain reaction [30,31]. Companies are constantly affected by market trends when designing innovative products. For example, when most consumers are positive towards sustainable products, it encourages a company to produce more environmentally friendly products. Consumers interested in environmentally friendly products have also formed a green consumer market value [32,33]. Consumers use their consumption behavior to express support for the company's production. This results in companies continuing to innovate and combine the desired products of customers. Therefore, in order to prevail in a highly competitive market, producers must respond to customer needs and increase customer satisfaction in different situations [34]. Proper production, marketing, and resource utilization strategies become very important as a result.

For companies, the development of new products is an important factor in sustainable operations; thus, product design is seen as necessary for innovation and success [35]. However, the design and development of new products require considerable time, capital, and other costs, which is not an issue that traditional manufacturing can easily overcome. In addition, the uncertain risks faced by new product development may drag down the entire business operation. Therefore, some scholars have suggested knowledge sharing between suppliers and customers can help to improve the success rate of new product development [36–38]. When suppliers share knowledge at all stages of product development, this promotes insights and technologies in components, system processes, or project management. This helps to create new product value, reduce design risk, and gain competitive advantages in design [39–41]. When customers share their own experience in the development of the product and participate in the design concept and decision-making process, this increases suppliers' success dramatically [42]. Past research has also pointed out that knowledge integration is important for enabling buyers and sellers to share and use knowledge and create new knowledge. Hence, how to provide a good knowledge integration mechanism is essential to improve efficiency and innovation. It can not only enhance integration efficiency but also promote innovation. Thus, capacity and knowledge play extremely important roles in helping companies innovate.

In reality, many traditional manufacturing industries are currently short of funds, which makes companies unable to ideally innovate. Therefore, proper funding is greatly needed, especially for traditional manufacturing. For example, investors in developed countries providing financial and management support to many innovative companies has helped bring innovative products, services, and business models to the international market. As pointed out in past scholars' research, such investments could improve economic growth, increase labor force quality, and reduce barriers to entrepreneurship [43–45]. Such a strategy has proven to be effective if domestic and foreign investors can provide sufficient funds to companies ready to innovate [46,47]. Thus, adequate funding and support is believed to be critical to a company's long-term development and innovation capabilities.

In view of the significance of the key success factors for innovation, this study considers the key success factor to be the work that a firm wants to achieve in order to fulfill its business objectives. If an enterprise cannot execute the key factor well, the consequences not only impact enterprise goals but also their overall survival. Innovative design is the prerequisite to improve industrial value and manage competition in traditional manufacturing. Therefore, we propose the key success factor combined with the importance of innovation should be placed on top of all goals, strategies, and objectives of an enterprise. If a firm can master these important factors, it ensures that it can remain competitive and innovative. The six constructs supported by the literature review are as follows:

#### 2.1.1. Design-Driven Innovation (Criteria One, $C_1$)

It is difficulty to master the design-driven approach to innovation. Making design through R&D an integral part of the business process can add value to products and create potential markets. The interplay between functional and semantic aspects of a product illustrates the role of technology in design-driven innovation [48]. Design-driven innovation focuses on the innovation of product meanings, and companies all need to create value for multiple stakeholders [49]. It is not only a key factor in the development of technology and products but also has a comprehensive impact on the overall performance of the product [50]. Verganti [51] proposed a design-driven innovation approach that is based on the combination of design information as a source of innovation. It shows a model that is more valuable to the industry and it is believed that complex social cultural factors constituting the design pattern can even drive market demand. Several modern technology developments are derived from the process of such demand. Therefore, the design-driven innovation of the industry, as well as future development, is an important indicator to determine whether the industry has the ability to innovate.

#### 2.1.2. Value Proposition (Criteria Two, $C_2$)

Afuah [52] pointed out that innovation can be divided into product innovation and process innovation. Innovation can then be defined as a valuable new idea and the result of adoption by the whole organization as a value proposition. The value proposition can include technology, design, new product marketing, or a new manufacturing process. Press and Cooper [50] also argued that innovation is an industry's value proposition that does not only work in a single part, such as product innovation, process innovation, management innovation, market innovation, and organizational innovation. One can provide new values to customers, redefine customer needs, and provide new services which are the sources of competitive advantages and create differentiation [53]. To sum up, a user-centered value proposition can develop more successful innovative business models.

#### 2.1.3. Integration (Criteria Three, $C_3$)

Recognizing the consumer's interest in innovative products allows companies to focus on the real needs of consumers to meet innovation. Value creation and integration for consumers is at the heart of demand-side strategy research and is a core element of almost any business model [54]. Integrating technology and customers' real demands as a solution can create the context for the evolution of innovative development and growth [55]. Integration is necessary to achieve ambidexterity for most firms, allowing them to use available organizational knowledge to meet the needs of existing customers [56]. Thus, an innovative product-based solution does not only provide excellent quality and perfect performance to achieve a competitive advantage but also provides products that integrate with consumer needs.

#### 2.1.4. Production and Market Resources (Criteria Four, $C_4$)

The concept of innovation allows organizations to invest in R&D activities. These organizations invest heavily to provide customers with the most advanced products through production and other resources from the market [57,58]. Such products are developed after extensive research to identify the potential for destructive innovation [59]. By exploring the true meaning of radical innovation, an organization gives itself the ability in the process of production to realize technological breakthroughs. Therefore, the capability of production to utilize resources from the market naturally occurs in the process of high growth of the organization and ultimately makes it a market leader. Therefore, industrial innovation needs to assess its own production and market resources as another critical factor.

#### 2.1.5. Capacity and Knowledge (Criteria Five, $C_5$)

In the past, industry members believed that the key capacity to success was the dissemination of specific knowledge via media. Potentially, this can be done with internal and external partners (suppliers, customers, and internal stakeholders) to produce innovative products. Knowledge sharing has thus been well recognized in this context [60]. For manufacturing, it depends upon how colleagues disseminate knowledge such as design information to pursue collective knowledge and realize a desired product. As Hoopes and Postrel [61] stated, the unique patterns of knowledge-sharing that result from such integrating practices can create a potential source of competitive advantage. Therefore, it is necessary to assess whether the industry has the capacity and knowledge to lead the industry to innovation.

#### 2.1.6. Funding and Support (Criteria Six, $C_6$)

Since the mid-1980s, the world economy has evolved into a knowledge-based economy driven by rapidly changing technologies and markets [62]. Small- and medium-sized enterprises (SMEs) play an important role in economic performance. However, many SMEs, such as traditional manufacturing, often lacked financial support, which makes it difficult to exploit new technology and boost productivity. In order to link the innovation concept to the technology industry, most governments have set up research laboratories to support innovation or have given specified funding. Financial, policy, and research support is considered significant for innovation [63]. Therefore, there is a need to assess whether the industry has extra funding and support for innovation.

### *2.2. The Justification of Adopted Research Methods*

As this research aims to explore the key success factors of sustainable management in traditional industries, it is necessary to find out the important priorities of these factors and their causal relationship. The literature has reported that the DEMETAL and AHP methods can solve the abovementioned problems. Therefore, the present study adopted these two methods.

Decision Making and Trial Evaluation Laboratory (DEMETAL) is an efficient way to establish and analyze structural models and is often used in the search for social phenomena and the relationship between multiple factors in complex problems [13]. We can understand from the structural model established by DEMETAL that we can prioritize problems among multiple strategies and proceed with this order of priority and improve the overall structure. The result of this hybrid process can help top managers of technology-based companies or policy makers of governments to more objectively and effectively determine future research and development directions and the interdependent relationships of the key factors [64,65]. This research utilized this method to clarify the relationships among traditional manufacturing industries as well as to discover the key factors that affect traditional manufacturing's innovation development. The AHP assists in making sound judgments on a problem by assisting in decision-making by combining cognition, feelings, judgments, and memory. AHP technology is one way to help identify the relative importance of problem attributes or standards in order to solve complex multistandard problems [14].

## 3. Methodology

DEMETAL was developed by the Battelle Institute in Geneva in 1971 to develop a solution for technology and human affairs. It has been used to study complex and inter-related problems (such as race, hunger, environmental protection, energy, etc.) to clarify the nature of the problem and contribute to decision-making. This method can effectively understand the complex causal relationship structure and the significance between the two indicators of the relationship. It uses matrixes and related mathematical principles to calculate the causal relationship between all indicators and the impact of influence. In fact, DEMETAL not only transforms the causal relationship between criteria into a clear structural model but is also an appropriate method to deal with a series of internal interdependencies [66].

**Hypothesis 1.** *The clear nature of the problem: Regarding the formation and planning of the problem, the question of research can be clearly understood in the nature of the problem so that the problem can be set correctly.*

**Hypothesis 2.** *There must be a correlation between questions: Each problem element needs to show its degree of association with other elements. The numbers 0, 1, 2, 3, and 4 are used to represent its association intensity.*

**Hypothesis 3.** *Understanding the essential characteristics of each problem: Make additional explanations for each problem element, which must include agreement and disagreement viewpoints.*

### 3.1. Demetal Causal Model Establishment

This study referred to the calculation process proposed by [67]. The relevant process steps are as follows:

Step 1: Identify criteria and their relationship

Through literature review and expert interviews, six dimensions were identified, for which questionnaires were designed. According to the DEMATEL scale, it is necessary to accurately know the influence degree and direction among criteria. It is suggested that questionnaire distribution must be to influential decision makers or key personnel in the manufacturing department to ensure data accuracy and avoid the subjectivity of a single opinion. Participants were requested to evaluate the impact level and direction based on a pair comparison among the dimensions and to use a positive sign to represent a positive effect and a negative sign for the reverse effect.

Step 2: Establish direct relationship matrix $X$

When the degree of impact has been defined, one can establish a direct relationship matrix. In this study, 34 valid questionnaires were used and labeled as $H_k$ ($k$ = 1, 2, 3, ..., 34). There were six selected dimensions; hence, there were six 6 × 6 matrixes represented as $X_k = x_{ij}$ ($i$ = 1, 2, 3, ..., 6; $j$ = 1, 2, 3, ..., 6; $k$ = 1, 2, 3, ..., 34). The diagonal element of each $X_k$ matrix was 0, that is, $x_{ij} = 0$ for $i = j$.

Step 3: Establish normalized direct relationship matrix $D$

Data was then normalized according to the direct relationship matrix obtained in Step 2, that is, the elements of the whole matrix $X$ were multiplied by $S$, where

$$S = \frac{1}{\underset{1 \le i \le n}{MAX} \sum_{j=1}^{n} X_{ij}} \tag{1}$$

The normalized direct relation matrix could then be obtained, as denoted by $D$:

$$D = X \times S = \frac{X}{\underset{1 \le i \le n}{MAX} \sum_{j=1}^{n} X_{ij}} \tag{2}$$

Step 4: Establish overall impact relationship matrix $T$

The total influence relation matrix $T$ can be calculated by the formula $T = \frac{D}{I-D}$, where $I$ is the unit matrix, and the total influence relation matrix $T$ = *direct relationship matrix D* + *indirect relation matrix ID*. That is,

$$T = D + ID = \sum_{i=0}^{\infty} D^i = D + D^2 + D^3 + \ldots + D^\infty \tag{3}$$

$$D \times T = D^2 + D^3 + \ldots + D^{\infty+} \tag{4}$$

The result of Equation (1) minus Equation (2) is $(I - D) \times \mathrm{D} = D - D^{\infty+1}$, where $D^{\infty+1} \approx 0$:

$$T = \frac{D}{I-D},\ T = [tij]n * n,\ i, j = 1, 2, \ldots\ldots, n \tag{5}$$

Step 5: Causal Map

Each column of the total influence relation matrix ($T$) was added to each row, and the sum of the $D$ values of each column and the sum of the R values of each row were obtained. The value of $D$ indicates that the criterion directly or indirectly affected the magnitude of the impact of other criteria. R represents the degree to which the criterion is affected by other criteria. ($D$ + $R$) and the degree of reason ($D - R$) was then calculated, where $D$ + $R$ represents the intensity of the relationship between the criteria and $D - R$ represents the intensity of the influence or influence of the criterion. The $D + R$ and $D - R$ values of each criterion were plotted on a graph, with $D + R$ as the horizontal axis and $D - R$ as the vertical axis. The threshold value of the influence relation of each criterion (the threshold value is the total influence relation matrix ($T$) of the $n * n$ selected criteria plus the arithmetic average) was used to draw the causal map.

Sorvali and Nieminen [68] pointed out the design benefits of R&D funds, manufacturing competitive advantage, integration of production and marketing system, innovation ability, technical level, production marketing, and branding from the point of view of national competitiveness. In the global competition, enterprises can effectively help brands promote overseas markets through the implementation of design management strategies [69]. To sum up, the application of design innovation is an important development strategy for industrial design integration, promotion, activation of market economy, and promotion of the overall competitiveness of the country.

### *3.2. Data Collection*

In this research, three traditional manufacturing industries in Taiwan were chosen to conduct the survey. The questionnaire was designed according to the principle of DEMATEL and was discussed with industry experts. The questionnaire was pretested and distributed. The three industries were Automobile Component Industry, Machine Tooling Industry, and Hand Tool Industry.

In recent years, the Automobile Component Industry (ACI) has faced a severe test due to increasingly strict sectorial regulation and global market competitiveness [70]. Thus, designing vehicle parts considering safety, performance, and environmental sustainability throughout the entire lifecycle is the major issue for today's automotive industry [71]. For example, while facing increasing oil prices, ACI has developed new high-strength steels in order to reduce the weight of automobiles and reduce fuel consumption. The advantages are to improve the impact resistance of automobiles and to reduce the weight of body parts [72]. As highlighted by one study done in South Africa and Thailand, the automotive industry usually plays a key role in national development in many countries, as it is one of the world's largest manufacturing sectors [73]. Since ACI plays an important role in the development of countries, it is worth analyzing this industry.

The Machine Tooling Industry (MTI) is especially important for the aerospace and automotive industries, although there have been limitations and challenges. For example, chatter in machining is a classic problem that limits productivity and decreases the life of tools and mechanical components. Especially, metal cutting and machine tooling technology has been unable to meet current and future requirements [74]. In the automotive field, all parts have to be machined; thus, the use of machine tools is inevitable. One study showed the development of a five-axis machine that can avoid different settings and fixings and increase productivity and accuracy by reducing errors between different settings [75]. In addition, using the right production equipment can also improve product yield and competitiveness. If solving problems in traditional industries to improve competitiveness is desired, this industry is an area worth exploring.

The Hand Tool Industry (HTI) is regarded as an indispensable part of an economy. This industry is the backbone of industrial development of any country. Hand tools are quite fundamental to producing high-end manufacturing in a wide range of important industries [76]. In addition, many industrial products exhibit complex surface characteristics, such as automobile bodies, turbine blades, and molds. It may be geometrically regular, free form, or spherical. In many cases, manual polishing is the key to greatly shorten the delivery time. Final processing and manual polishing processes account for up to 75% of the processing time [77–80]. Some scholars have proposed ball polishing (with hydrostatic force) technology to complete this type of surface. It features simple operation, low cost, and a high-quality final surface [81]. Using this technology to improve hand tool equipment can improve the production quality and working time of the industry. However, stricter government regulations and the rising cost of raw materials has created challenges for companies trying to increase operational efficiency, reduce operating costs, and improve the quality of the output [82]. Thus, dealing with this challenge motivated us to choose the HTI for this study.

Since innovation involvement for the manufacturing industry is an important agenda, this paper used three traditional manufacturing industries as a case study in developing countries such as Taiwan. We also analyzed six criteria: Design-Driven Innovation ($C_1$), Value Proposition ($C_2$), Integration ($C_3$), Production and Market Resources ($C_4$), Capacity and Knowledge ($C_5$), and Funding and Support ($C_6$). For details, please refer to Table 1. The model was established to comprehend the mutual influence of the key criteria in their relationships. The DEMATEL model is shown in Table 2, where $C_i$ means the key criteria and $C_{ii}$ is the relationship analysis to boost the manufacturing industry's value.

**Table 1.** Six criteria and explanation.

| Criteria | Explanation |
|---|---|
| Design-Driven Innovation ($C_1$) | Design-driven innovation is a key factor in the pursuit of success for all industries and companies. Therefore, the value of the industry as well as the future development is an important indicator to determine whether the industry has the ability to innovate. |
| Value Proposition ($C_2$) | Providing new value to customers, redefining customer needs, and providing new services are the source of competitive advantages and create differentiation. |
| Integration ($C_3$) | Recognizing that consumer interest in innovative products allows businesses to focus on the actual needs of consumers to adapt to innovation through integration. |
| Production and Market Resources ($C_4$) | Innovations focus on the meaning of product realization and business needs to create value for multiple stakeholders. Therefore, industrial innovation needs to assess its own production and market access resources. |
| Capacity and Knowledge ($C_5$) | Industries need knowledge that is reliable and constantly updated and to share knowledge with both internal and external partners to help them innovate. |
| Funding and Support ($C_6$) | In the process of innovation, companies need financial support, such as financing from government subsidies and profit-making revenue. |

**Table 2.** The influence model of six criteria.

| Items | $C_1$ | $C_2$ | $C_3$ | $C_4$ | … | $C_n$ |
|---|---|---|---|---|---|---|
| $C_1$ | | | | | | |
| $C_2$ | | | | | | |
| $C_3$ | | | | | | |
| $C_4$ | | | | | | |
| ⋮ | | | | | | |
| $C_n$ | | | | | | |

## 4. Results

The results include AHP weighting, reliability analysis, validity analysis, and demographic analysis, and the DEMATEL outcomes are demonstrated in this section. The discussions with experts from the Industrial Technology Research Institute involving 40 senior executives in Taiwan confirmed the need of the three industries for innovation and the research results are on the right track.

### *4.1. AHP Weighting*

Using AHP analysis, the weights of three industries were derived, as shown in Table 3. Three pie charts were also created, as shown in Figures 1–3. The outcomes in this section were then adopted in the computation of DEMATEL analysis.

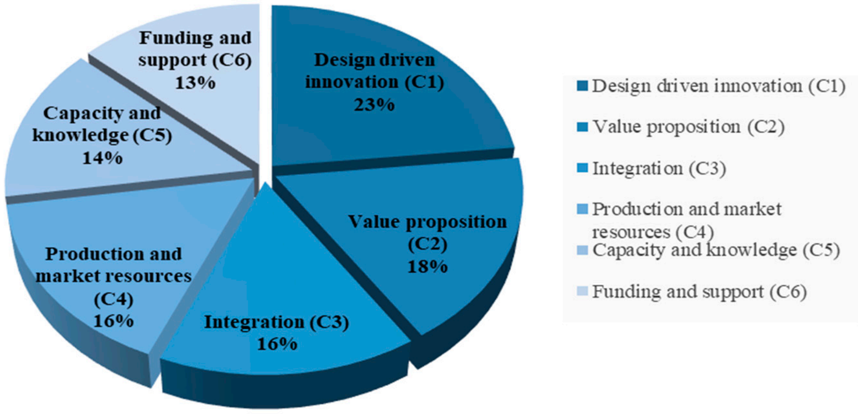


**Figure 1.** Analytic Hierarchy Processing (AHP) weighting in Machine Tooling Industry (MTI).

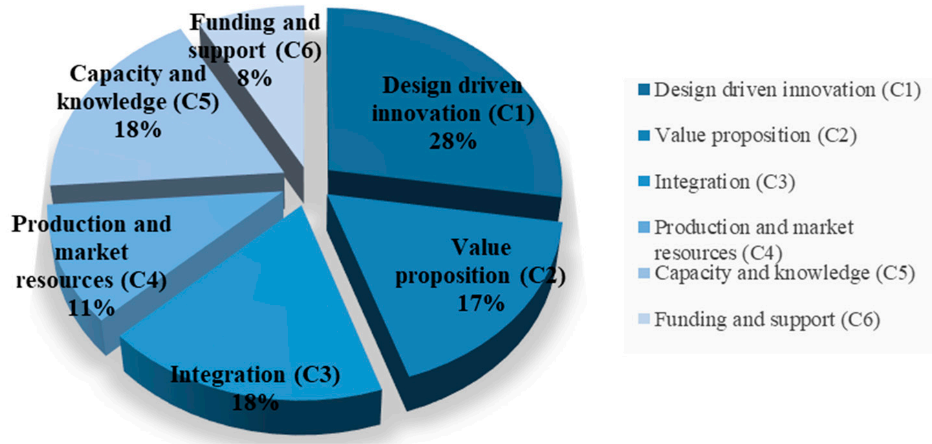


**Figure 2.** AHP weighting in Hand Tool Industry (HTI).

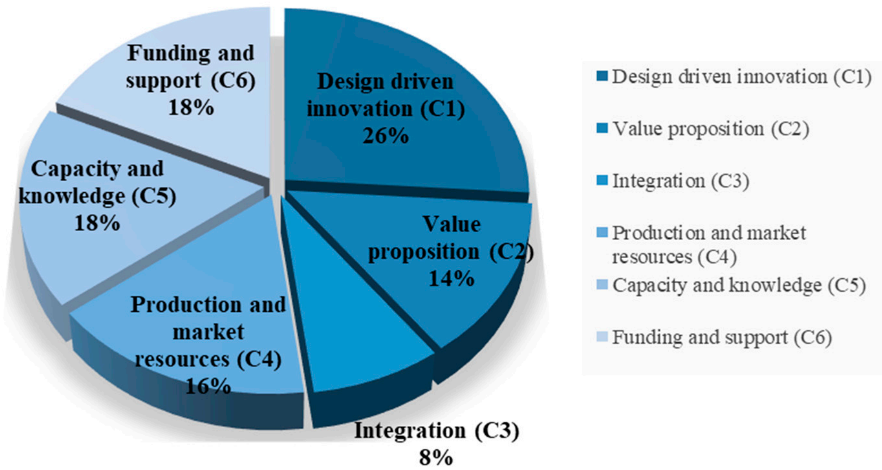


**Figure 3.** AHP weighting in Automobile Component Industry (ACI).

**Table 3.** The criteria weights of three industries.

| Criteria | MTI | HTI | ACI |
|---|---|---|---|
| $C_1$ | 0.233 | 0.275 | 0.261 |
| $C_2$ | 0.175 | 0.174 | 0.138 |
| $C_3$ | 0.156 | 0.181 | 0.081 |
| $C_4$ | 0.162 | 0.109 | 0.165 |
| $C_5$ | 0.142 | 0.182 | 0.175 |
| $C_6$ | 0.132 | 0.080 | 0.180 |

### 4.2. Reliability Analysis

This study provides the reliability analysis for three industries using Cronbach's alpha coefficients to evaluate and test the internal consistency of the questionnaire. The results are shown in Table 4. The alpha values of the six questions are all greater than 0.6, so the reliability is quite high.

**Table 4.** Reliability analysis ($n$ = 34).

| Criteria | Number of Questions | $\alpha$ |
|---|---|---|
| Design-Driven Innovation ($C_1$) | 4 | 0.635 |
| Value Proposition ($C_2$) | 4 | 0.605 |
| Integration ($C_3$) | 7 | 0.717 |
| Production and Market Resources ($C_4$) | 8 | 0.697 |
| Capacity and Knowledge ($C_5$) | 5 | 0.758 |
| Funding and Support ($C_6$) | 4 | 0.730 |

### 4.3. Validity Analysis

According to the literatures and 15 domain experts' opinions, the six criteria were confirmed to cover the research topics. Further, the questionnaire was pretested and the inappropriate parts were amended before distribution. Hence, we are confident that the questionnaire clearly expressed and effectively queried the indicators in terms of content validity.

### 4.4. Demographic Analysis

The interviewees of this research questionnaire included 34 respondents. The demographic information can be seen in Table 5.

**Table 5.** Demographic data.

| Item | Subitem | ACI | MTI | HTI | Total |
|---|---|---|---|---|---|
| Education | Secondary school | 0 | 0 | 0 | 1 |
| | College | 6 | 6 | 3 | 18 |
| | Master's degree | 4 | 5 | 2 | 13 |
| | Ph.D. | 0 | 0 | 1 | 1 |
| | Undisclosed | 0 | 0 | 0 | 1 |
| Company year | Under 5 | 0 | 0 | 2 | 4 |
| | 5–10 | 1 | 3 | 2 | 7 |
| | 10–15 | 1 | 1 | 1 | 4 |
| | 15–20 | 0 | 2 | 0 | 3 |
| | Above 20 | 8 | 5 | 2 | 16 |
| Company departments | Manufacturing | 1 | 0 | 0 | 1 |
| | Marketing sales | 1 | 1 | 2 | 5 |
| | Research and development | 2 | 6 | 4 | 14 |
| | Other | 5 | 4 | 1 | 14 |
| Job title | Vice chairman of the board | 2 | 0 | 0 | 2 |
| | Deputy general manager | 3 | 2 | 1 | 7 |
| | Associate | 3 | 3 | 0 | 6 |
| | Manager | 1 | 3 | 5 | 12 |
| | Other | 1 | 3 | 1 | 7 |
| Nearly three years | 0–5% | 0 | 1 | 1 | 2 |
| | 5–10% | 1 | 2 | 0 | 4 |
| | 10–15% | 1 | 1 | 0 | 2 |
| | 15–20% | 2 | 1 | 3 | 7 |
| | 20–25% | 5 | 3 | 0 | 10 |
| | Above 25% | 1 | 1 | 0 | 2 |
| | Undisclosed | 0 | 0 | 0 | 7 |

## 4.5. DEMATEL Results

### 4.5.1. Automobile Component Industry (ACI)

The causal map for ACI is shown in Table 6 and Figure 4. The results show that $C_1$ affects $C_2$ and $C_6$ and interrelates with $C_3$. $C_6$ affects $C_3$, $C_4$, and $C_5$. $C_3$ affects $C_4$. If ACI industries wish to increase value, it is suggested to consider $C_6$ and $C_3$ first. These two factors are identified as key elements. In the ACI industry, the $C_1$ design-oriented innovation factor dominates with the innovation of technology and materials to facilitate new and multifunctional vehicles. In Taiwan, there is a limited domestic demand market and a lack of economic scale. According to the design-oriented conclusions of this study, it is recommended to design related product components that meet the market demand for lightweight vehicles in the Asia-Pacific region. Thus, the ACI industry can continue to cooperate with design adjustment and innovation in order to create new features so that automakers can continue to innovate.

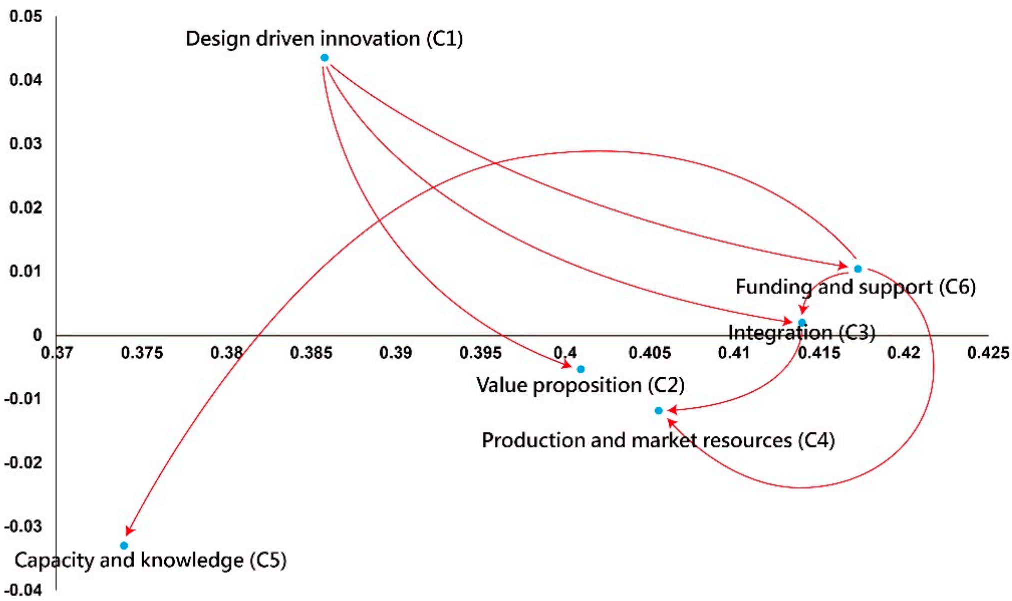


**Figure 4.** Automobile component industry causal map.

**Table 6.** Automobile component industry datasheet.

| Criteria | D + R | D − R |
|---|---|---|
| Design-Driven Innovation ($C_1$) | 0.387 | 0.042 |
| Value Proposition ($C_2$) | 0.401 | −0.008 |
| Integration ($C_3$) | 0.414 | 0.002 |
| Production and Market Resources ($C_4$) | 0.406 | −0.011 |
| Capacity and Knowledge ($C_5$) | 0.374 | −0.034 |
| Funding and Support ($C_6$) | 0.418 | 0.01 |

### 4.5.2. Machine Tooling Industry (MTI)

The results of MTI are shown in Table 7 and Figure 5. The results show that $C_3$ affects $C_1$, $C_2$, $C_4$, and $C_5$. $C_2$ affects $C_1$ and $C_5$. $C_6$ affects $C_5$. Since MTI is unique in terms of systems (light, machine, electricity, communication, and software interface integration), $C_3$ is the most important. Taiwan's machine tooling industry has a long history of export to Europe, the United States, and Northeast Asia due to the lack of large-scale international companies. Machine tooling products have a relatively high unit price. Understanding the needs of international customers and accurately grasping information is extremely important. Based on the conclusion from this study that integrating demand is an important key factor for industries, it is recommended that the Taiwan government assist in integrating resources and international marketing as a top priority.

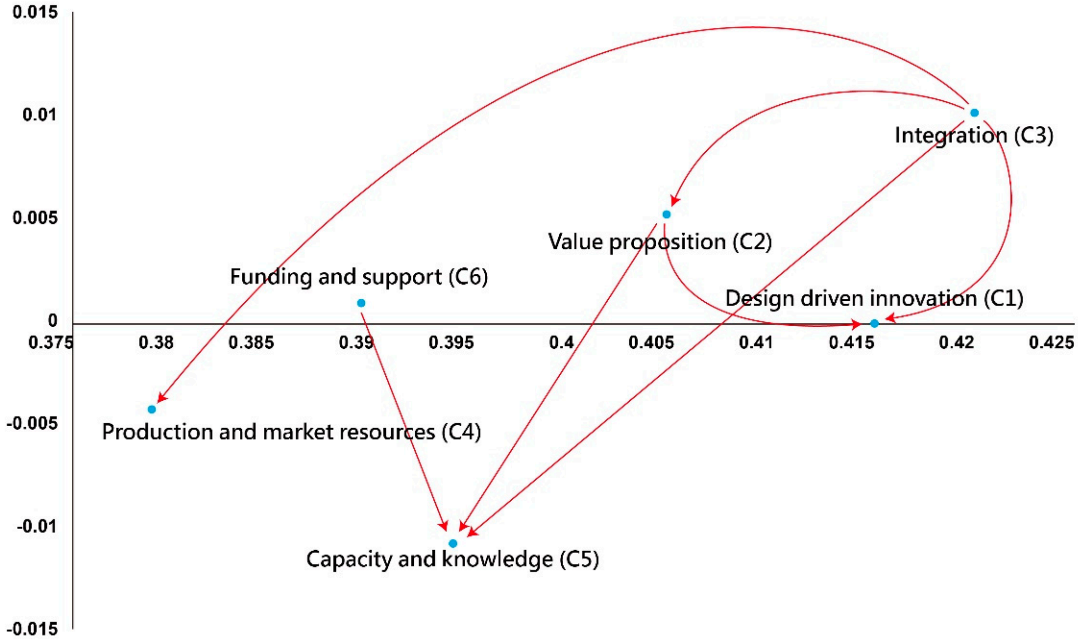


**Figure 5.** Machine tooling industry causal map.

**Table 7.** Machine tooling industry datasheet.

| Criteria | D + R | D − R |
|---|---|---|
| Design-Driven Innovation ($C_1$) | 0.415 | 0.000 |
| Value Proposition ($C_2$) | 0.404 | 0.005 |
| Integration ($C_3$) | 0.420 | 0.010 |
| Production and Market Resources ($C_4$) | 0.379 | −0.004 |
| Capacity and Knowledge ($C_5$) | 0.394 | −0.012 |
| Funding and Support ($C_6$) | 0.389 | 0.002 |

#### 4.5.3. Hand Tool Industry (HTI)

The results of HTI are shown in Table 8 and Figure 6. The results show that $C_6$ affects $C_3$, $C_4$, and $C_5$. $C_1$ and $C_4$ affect each other. $C_5$ affects $C_3$. The HTI industry working capital and logistics support factor $C_6$ has the highest impact, followed by design-oriented innovation. The possible reason for this is that most of its industrial products are simple system operations with great demand in the household market and has huge logistics support and efficient capital operation for its industry. In addition, the hand-tool machine industry is also vulnerable to the global economic climate. Facing the global low inflation rate, the negative impact of the economic activities of advanced countries has threatened exports for Taiwan's hand-tool machine industry. Based on the conclusion that funding is the key factor, it is recommended that the Taiwan government provide financial subsidies to related industries to help adjust the structure of the enterprise and to provide a favorable market for future global competition.

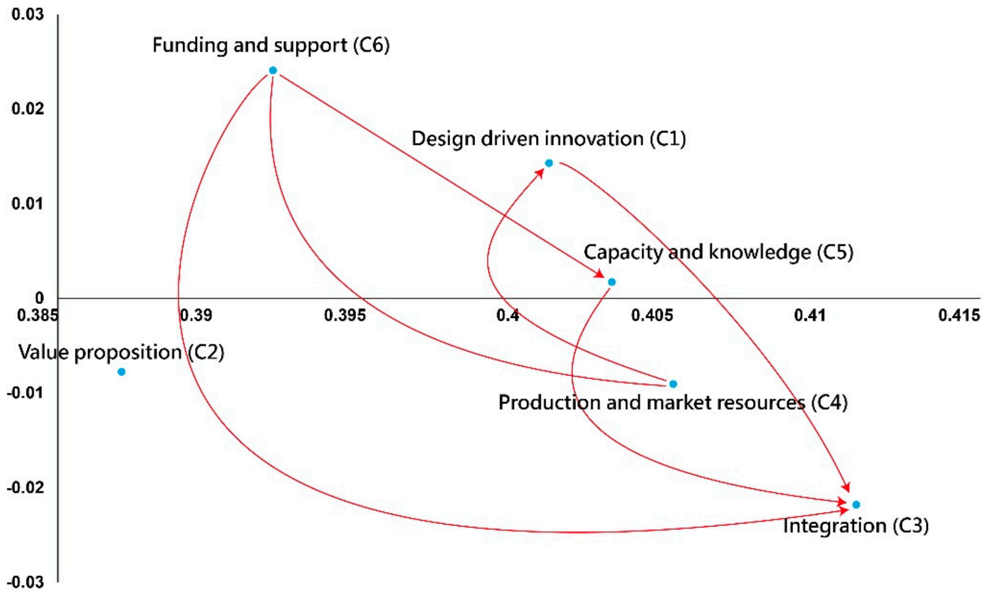


**Figure 6.** Hand tool industry causal map.

**Table 8.** Hand tool industry datasheet.

| Criteria | D + R | D − R |
|---|---|---|
| Design-Driven Innovation ($C_1$) | 0.401 | 0.014 |
| Value Proposition ($C_2$) | 0.387 | −0.008 |
| Integration ($C_3$) | 0.412 | −0.023 |
| Production and Market Resources ($C_4$) | 0.405 | −0.010 |
| Capacity and Knowledge ($C_5$) | 0.403 | 0.003 |
| Funding and Support ($C_6$) | 0.392 | 0.024 |

## 5. Conclusions

Both management and practitioners find the transition to innovation in traditional manufacturing to be critical to adding value. The much shorter product lifecycle and more customization demand has triggered this industry to think out of the box. This mindset has changed dramatically in the digital era particularly. Furthermore, the increasing cost of traditional manufacturing has greatly cut profits. This echoes past research outcomes showing that this is caused by a relatively weak ability to respond to changing market demands and the lack of flexibility to react to economic fluctuations [83]. Thus, one of the key points of this paper is to discuss how innovation can help the traditional manufacturing industry to add value and not fall into the Red Sea market with low price competition. This study firstly identified six key criteria from existing studies on innovation. The criteria included Design-Driven Innovation ($C_1$), Value Proposition ($C_2$), Integration ($C_3$), Production and Market Resources ($C_4$), Capacity and Knowledge ($C_5$), and Funding and Support ($C_6$). Secondly, three traditional manufacturing industries (Automobile Component Industry, Machine Tooling Industry, and Hand Tool Industry) were chosen for data collection for the case study. Thirdly, AHP and DEMATEL were adopted to discover the weights among the six criteria and their causal relationships with these three industries.

In the ACI industry, the $C_1$ design-oriented innovation factor dominated with the innovation of technology and materials to facilitate new and multifunctional vehicles. Thus, the ACI industry can continue to cooperate with design adjustment and innovation in order to create the new features automakers need to continue to innovate. Since MTI is unique in terms of systems (light, machine, electricity, communication, and software interface integration), $C_3$ is the most important. Thus, investing resources and operations is the first priority. The HTI industry working capital and logistics support factor $C_6$ has the highest impact, followed by design-oriented innovation. The possible reason is that most of its industrial products are simple system operations with a great demand in the household market and has huge logistics support and efficient capital operation for its industry.

The data analysis results provide guidance for economic and industry professionals to see if they can manage innovation to effectively move up in the rankings. The data suggest useful criteria that the government and industry can consider to turn the tide or add higher value. These considerations include shifting conventional manufacturing into new and higher value-added markets, suggesting integration of customer interests and higher value-added products, and rethinking resource allocation internally and externally to improve productivity. The above drivers of productivity can be impacted not only by government policies but also by companies through various causal relationships among different criteria.

As with all empirical research, this study has its limitations. The empirical data of this study are from a limited number of domain experts at the senior management level. Although the DEMATEL method can yield good research results from a small sample size, future research might consider employing classical statistical methods with larger sample sizes. The results of such studies could then be compared against those of this study.

Despite scarce resources for traditional manufacturing sectors, the findings from this research show there is a need for sustainable development to consider unique, innovative directions and tactics for success in different international markets. In the past, conventional manufacturing contributed to local economic competitiveness. However, there has now been a shift in focus regarding sustainable development. According to the results of this study, the innovative development in traditional manufacturing is suggested to work in line with global trends through design-driven R&D. The integration of consumers' demands and technological advancements is also encouraged to add value. Doing so can help increase innovativeness in manufacturing companies to thereby gain global competitiveness and enhance the national economy.

According to the research results, we propose that Taiwan's traditional industries should focus on design and innovation, enhance the benefits and international competitiveness of the industrial chain, enterprises, and products, and maintain the ability of Taiwan's traditional industries to continue to operate. Therefore, we believe that traditional manufacturing industries will continue to develop due to innovation.

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