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SUCCESSFUL MANAGEMENT FACTORS FOR LEAN PRODUCT DEVELOPMENT: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

All members of the supply chain, including manufacturers, face new challenges in the post-epidemic era. The latest method for businesses to survive is to efficiently develop new products that meet customer needs while ensuring the flexibility of their supply chain. The widespread applicability of lean thinking appears to afford businesses the opportunity to construct the optimal product development process. Systematic research on the combination of lean and the new product development process is crucial for guiding enterprises to success in Lean Product Development (LPD). However, there is no consensus on the successful management factors (SMFs) for the LPD. In this context, utilizing systematic review techniques, this study analyzed and discussed pertinent research results on LPD in order to investigate the new connotation of relevant factors under the concept of product development. The results indicated that under the classification of the four dimensions "General", "Process", "People", and "Tools/technology", the 10 SMFs, such as "Systematic information management structure" and "Chief engineer", have a broader definition, which also reflects the transition from material flow to information flow in the context of product development. The objective, comprehensive new definition helps scholars understand the multifaceted aspects of SMFs and practitioners make decisive decisions.

1.0 Introduction

Currently, the economies of all nations are still in the recovery phase following the coronavirus outbreak, and the disruption of the global supply chain caused by this shock as well as the sudden

decline in demand for consumer goods have posed new challenges for the development of new products [1]. Innovation through New Product Development (NPD) is undoubtedly an important means for businesses to achieve growth, remain competitive, and survive [2]. However, due to the complexity of new product development projects and the ambiguity of the early stages of the development process, companies have spent a lot of resources but failed to obtain satisfying results. As a result of the tremendous success of lean manufacturing (LM), academics have gradually begun to adapt lean concepts and principles to the product development process in an effort to explore the most effective method for product development. LPD takes customer value as the starting point and explores the synergy between processes, people, tools, and technology to create new profitable value streams [3].

In the earlier research, Khan et al. [4] reviewed the literature in the field of lean PD, provided a reference framework of the enabling factor for lean PD, and described each enabling factor from a technical level. In contrast, more scholars studied LPD from the perspective of the framework [5,6]. However, previous studies rarely discussed and investigated the success factors of LPD from a management perspective. The current research lacks an in-depth analysis and discussion of the principles of lean from the concept of the development process. Therefore, the purpose of this article is to identify, analyze, and explain the management factors driving the success of LPD by reviewing the existing literature on LPD.

In the next section, we introduce the methodology for conducting a literature review, including research questions, criteria for literature retrieval and selection, as well as analysis and integration. This is followed by a descriptive analysis of the reviewed literature. It then presents the study's findings, focusing on the connotation of its SMFs in the context of LPD. Finally, the conclusion, contributions, and limitations of the study are summarized.

2.0 Research Methodology

To obtain a comprehensive understanding of recent literature advancements, we utilized systematic review techniques and followed the 5-steps procedure proposed by Denyer and Tranfield [7]. The first step in the review is to formulate the research questions; the second step is to determine the search conditions and requirements such as databases and search letter strings; the third step is to determine the inclusion and exclusion criteria; the fourth step is data extraction; the fifth step is to report research results. The first four steps are illustrated in this section, and the fifth step is presented in the following section.

Question formulation

The first step of the review is critical as it affects all subsequent processes. The research questions of this study are:
RQ: *"What management factors affect the successful implementation of lean product development, and what are their specific connotations?"*

Locating studies

In order to cover as many documents as possible, the search dates for the documents were set from 2000 to 2022. Web of Science and Scopus were chosen as source databases as they are the two most prominent databases in the globe. To enhance the search's precision and efficacy, the search strings were "Toyota", "Lean", "Product Development", "Product Design", "Product Introduction", and

"Development Process". In addition, the retrieved papers were limited to those published in journals in English.

Study selection and evaluation

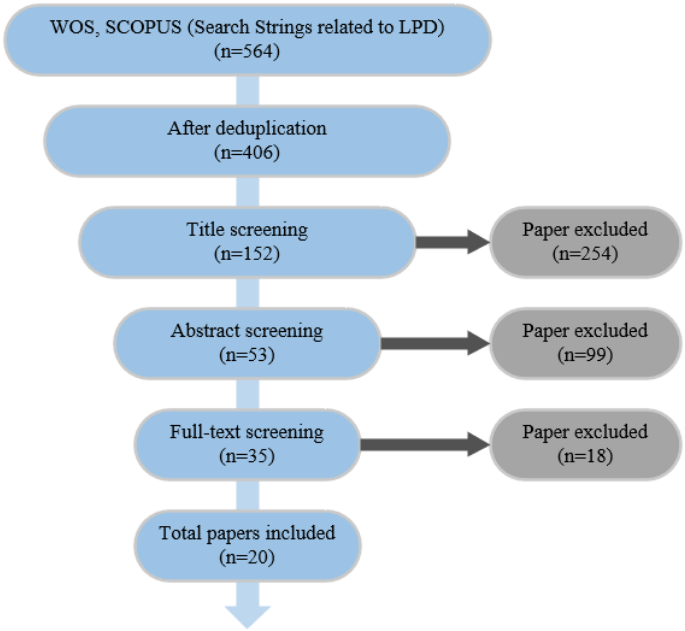

Figure 1. Flow chart of search and screening of LPD literatures.

In the third stage, clear inclusion and exclusion criteria are required. The screening criteria consist primarily of two aspects. The first point is that the article's subject is product design and product development; the second point is that the article analyzes and explains the SMFs of LPD. Only articles that satisfy the two screening criteria listed above will advance to the next phase. Figure 1 depicts the procedure of document retrieval.

Analysis and synthesis

Coding and categorizing the literature enables the identification of commonalities between diverse works of literature and facilitates the summary and discussion of management factors that contribute to effective LPD. Using research findings of Liker and Morgan as a guide, this study divided the most recent SMFs into these four categories: "general", "process", "people", and "tools/technology" [8].

3.0 Descriptive Analysis

Year of publication

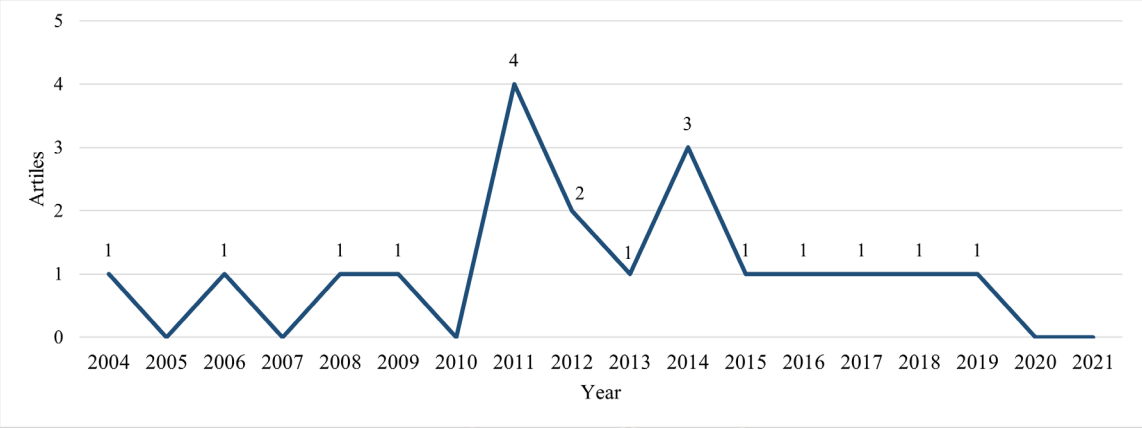

Figure 2. Distribution of the number of publications per year.

Figure 2 describes the growth of annual publications from 2000 to 2022. The first article on SMFs for LPD appeared in 2004. Then, in 2005 and 2007, there were no relevant publications. In each of the years 2006, 2008, and 2009, one article was published. After reaching a trough in 2010, the number of publications in related literature achieved a peak of four in 2011. It is possible to hypothesize that the strong recovery of the real economy following the economic crisis propelled the growth of the field of product development. This also shows that more and more scholars pay attention to the success factors of LPD. In 2012 and 2013, the numbers published were 1 and 2, respectively. After the number of publications reached a sub-peak of 3 in 2014, only one was published each year in the following 5 years. Since 2020, however, no such literature has been published. In other words, in recent years, academicians have focused on the implementation of LPD and the use of related technologies/tools, while ignoring the systematic research on LPD (such as success factors, and conceptual models).

Source of publication

In total, all 20 articles were published by 15 publishers. From this perspective, the research in this field is both extensively dispersed and relatively fragmented. As shown in Table 1, the four most prolific publishers are: “International Journal of Product Development”, “Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture”, “Engineering Management Journal”, and “International Journal of Technology Management”. The average impact factor of these four publishing houses is only 1.747, indicating that the research on LPD success factors has not been favored by high-impact journals and publishing houses. The reasons may include that the methods currently available for this research are relatively traditional and monotonous (primarily based on literature review methodology), that it is difficult to acquire quantitative data and verify the aforementioned factors, etc. Despite this, there are still 4 leading journals with an impact factor higher than 8 that have published relevant research.

Table 1. Distribution of articles by publisher.

Journal	Impact Factor (IF)	Article(s)
International Journal of Product Development	0.156	3
Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture	2.759	2
Engineering Management Journal	2.548	2
International Journal of Technology Management	1.526	2
International Journal of Production Economics	11.251	1
Journal of Cleaner Production	11.072	1
International Journal of Production Research	9.018	1

Journal of Manufacturing Technology Management	8.144	1
International Journal of Computer Integrated Manufacturing	4.42	1
Research Technology Management	2.855	1
Frontiers of Engineering Management	2.7	1
Journal of Engineering Design	2.4	1
International Journal of Mobile Communications	1.522	1
Environmental Engineering and Management Journal	0.858	1
Quality Innovation Prosperity	0.452	1

Author affiliation

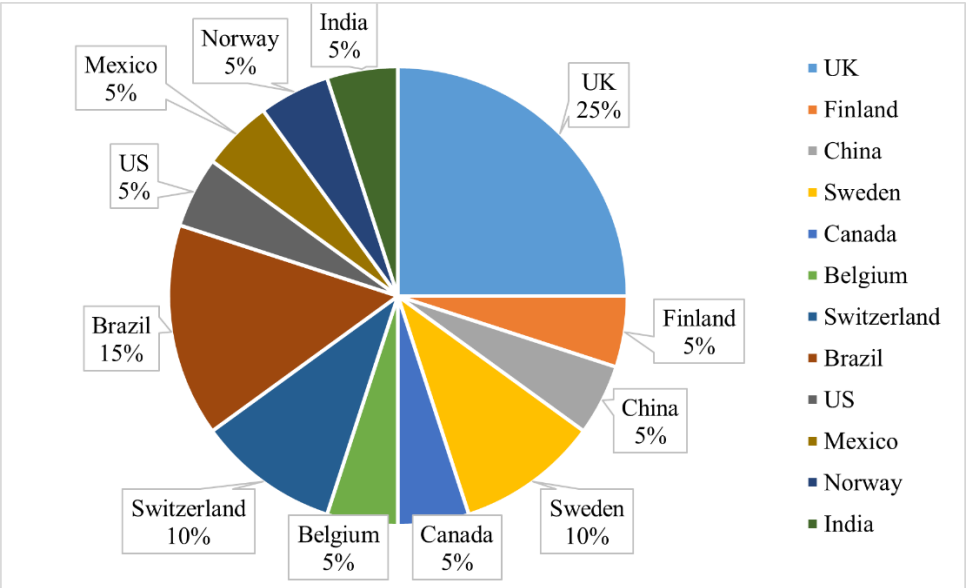

Figure 3. Geographical distribution map of the author's affiliation.

Figure 3 portrays the geographical distribution of author affiliations in detail. European countries top the list, accounting for 60% of the articles we reviewed, with the United Kingdom (5 articles) topping the list, Sweden and Switzerland (2 articles each) tied for second, while Finland, Belgium, and Norway each contributed one. It is not hard to imagine that in recent years, European countries have been committed to the informatization, intelligence, and high-efficiency development of the manufacturing industry, and that research on LPD, which has the potential to bring about significant changes and revolution in the manufacturing industry, has naturally become the focus of scholars. The American Continent ranks second with 6 articles, and it is worth noting that 3 related articles were produced by Brazilian scholars. It appears that, as a result of the relocation of low-end manufacturing from developed to developing countries, emerging economies have become increasingly enthusiastic about LPD research. As for Asia, China, and India, each had an article. Although scholars in developing nations are progressively devoting more attention to LPD research, the gap between developed and developing nations remains enormous.

4.0 Finding

In this study, the content analysis method was utilized to further extract and analyze the data in the literature. During the analysis, a total of 28 SMFs were identified and categorized into the four dimensions previously mentioned. Considering the recognition of different SMFs among scholars and excluding factors that lack widespread support due to personal opinions, this study only selects the top 10 factors (with a frequency greater than or equal to 9 times) as the focus of attention. As

shown in Table 2, the SMFs of LPD are "Systematic information management structure", "Chief engineer", "Selection, use and integration of tools/technologies", "Cross-functional team", "Supplier involvement", "Standardization of PD process", "SBCE process", "Simultaneous engineering", "Establish customer-defined value", and "Learning and training".

Table 2. Successful management factors for LPD.

Classification	Successful Management Factors	Frequency
General	Systematic information management structure	14
People	Chief engineer (CE)	13
Tools/technology	Selection, use and integration of tools/technologies	13
People	Cross-functional team	12
Process	Supplier involvement	12
Process	Standardization of PD process	11
Process	Set-based concurrent engineering (SBCE)	10
Process	Simultaneous engineering	10
General	Establish customer-defined value	9
People	Learning and training	9

General

In LPD, value is derived from stakeholder needs. Establishing customer-defined value means more comprehensively gathering and understanding the requirements of all stakeholders early in the product development process, and incorporating this information into strategic planning and marketing [9]. Consequently, it is essential to precisely translate stakeholder requirements into information flows. It is also worth noting that this factor emphasizes the core position of customers as stakeholders, but it is necessary to weigh the multi-dimensional needs of each stakeholder. On the other hand, the ultimate goal of a systematic information management structure is to ensure the continuous flow of knowledge throughout the organization, in other words, to allow knowledge to be accepted correctly at the right place at the right time. Among them, the core of this structure is a centralized network-based knowledge base, which is not only a crucial medium and platform for promoting the transformation of tacit knowledge into explicit knowledge, but also a significant means of knowledge management and sharing [5]. This database should organize the knowledge and data involved in the product development process clearly and logically, and have functions that can easily provide users with the information they need [4,10].

Moreover, there needs to be a common understanding within the organization, that is, to actively transform implicit knowledge into explicit knowledge. On the one hand, this facilitates the dissemination of knowledge within the organization, while on the other, it can significantly reduce communication barriers and feedback issues [5]. Finally, LPD views failures and problems as a natural part of the development process, further through openness and communication internally as an important source of valuable knowledge [11].

Process

Instead of strictly controlling the entire process and system, the standardization of PD process refers to the standardization of activities with evident periodicity in this process [12]. This practice will drive the creation of design checklists and standards, and the knowledge flow in the enterprise-wide database will reflect in standardization. Successful implementation of standardization can greatly reduce time, risk, and errors, as well as minimize output variability of the process [13].

In LPD, simultaneous engineering and SBCE are complementary. Simultaneous engineering treats the entire development process as a holistic system, integrating organizational stakeholders such as design, manufacturing, quality assurance, and procurement into product development projects at an

early stage. Under the excellent coordination of the organization, designers, engineers, and buyers from various departments discuss product concepts and review design proposals, in order to obtain a draft that meets the needs of stakeholders inside and outside the organization to the greatest extent possible, thereby preventing iterations and changes in later stages [5]. In contrast, the perspective of SBCE is more precise and specific. Using set-based concurrent engineering means considering more possible solutions for each product module in the early stages of product development, and then screening and weighing among a wide range of solutions, thereby reducing project uncertainty and reducing last-minute potential for engineering changes [5,11]. From a management perspective, this approach is essentially the integration of expertise of cross-functional teams and the efficient application of information management structure.

Regarding the supplier involvement factor, Tortorella et al. [3] believed that it is risky to rashly integrate suppliers into the process before it is clearly understood in what form and capacity the supplier participates in the product development process will benefit the project. On the corporate side, it is necessary to not only permit or encourage the participation of guest engineers from suppliers during the early phases, but also to discuss with suppliers how to enhance their products and development process [5]. On the supplier side, they must be responsible for concluding the development of product modules with the assistance of the company, as opposed to ignoring their own advantages and technologies and supplying products completely in accordance with detailed specifications [14]. Rather than “calculating” or “tit for tat”, the relationship between them is one of cooperation and mutual benefit.

People

The chief engineer is the key component to a successful LPD process, and this insight has reached a consensus in the research of many scholars [15,16]. The primary task of the chief engineer is to act as the “voice of the customer”, integrate the collected needs of external stakeholders into the entire development process, and ultimately deliver products that can express the corporate vision and meet the requirements of customers for various functions [17]. As a leader, the chief engineer needs to define and flexibly adjust project milestones to strengthen the commitment to the project [12]; he/she also needs to evaluate alternatives and make final decisions using his superior professional skills and extensive project experience [9]. In addition to serving as an intermediary between engineering design and customer needs, the lead engineer must also transmit the company's vision from the top down and clear the way for internal communication [14].

In LPD, the integration of different functions and technologies mainly relies on cross-functional teams. To ensure that all aspects of the product development project can be reviewed professionally, the company should assign professionals from various departments based on the actual requirements of the project [14]. This cross-functional team ensures efficient internal resource utilization and close communication (knowledge/information sharing) between departments [18].

For any advanced approach or technique, learning and training are indispensable, and the same is true for LPD. Training on lean knowledge is emphasized first, but because the waste that must be identified and eliminated in the PD process differs from that in the manufacturing process, the relevant lean training is resolutely focused on product development [19]. Secondly, direct mentoring of young engineers by specialists in professional technology or seasoned leaders not only passes on the most recent information and best practices, but also reinforces the company's values and culture [9]. To encourage engineers to acquire experience in standard work in various departments and to strengthen communication and assistance within the organization, they are gradually rotated between different functional areas following training. Besides, the specialist career path provides a strong guarantee and support for the company's core technology planning [5].

Tools/technology

Regarding the selection and application of tools/technology, it is necessary to tailor the tools/technology to people and processes based on the requirements of the enterprise and the characteristics of the products it develops [20]. Choosing the appropriate tool/technology to serve the enterprise can improve product development efficiency while enhancing and optimizing the standard process. In addition, the usability of these tools and technology has a substantial impact on their promotion and popularity. Technologists and engineers involved in product development projects have very limited time and are willing to seek to improve products while enhancing their knowledge if the tools and technology are simple to learn and straightforward to apply [9].

Lastly, numerous academics concurred that visual communication is an integral component of LPD and an essential tool for fostering understanding, engagement, and commitment within an organization [17,20].

5.0 Conclusion

Almost all entrepreneurs and academics recognize the significance of new product development to the survival and competitiveness of companies. Although scholars have consistently attempted to incorporate lean thinking into the product development process in recent years, it is still unclear, from the perspective of business managers, which management factors promote the successful application of LPD. Therefore, this study reviews the existing research on LPD and identifies the management factors that contribute to its successful implementation. The study utilized both systematic review techniques and content analysis methods to extract and analyze the literature's content for subsequent research. The results show that in the category of “General”, establishing customer-defined value emphasizes the need for business managers to informatize related requirements in varying degrees according to the importance of stakeholders. Systematic information management structure is a integrated method for knowledge management and sharing based on a centralized network-based knowledge base. In the category of “Process”, it should be emphasized that the standardization of PD process is not a rigid restriction on the product development process or the strict establishment of rules and regulations, but rather a method for increasing PD efficiency by following the flow of knowledge and information. Simultaneous engineering, on the other hand, shares the same goal as SBCE, which is to prevent project iterations or engineering modifications at a later stage. Although they target distinct objects, both seek a solution or design that maximizes stakeholder satisfaction. In a new context, supplier involvement emphasizes the significance of early engagement, utilization of superior technology, and mutually beneficial relationships. After gaining an understanding of the requirements of various stakeholders, it is crucial to accurately incorporate these needs into the entire development process. Therefore, in the category of “people”, the chief engineer functions as the “voice of the customer” to ensure that the products developed always meet the requirements of customers. The cross-functional teams are the primary way to integrate different functions and technologies in development projects. Notably, waste under the LPD concept has a new identification method and connotation, so learning and training encompass not only the dissemination and sharing of new lean knowledge, but also the sharing of expert experience and professional training. In the final category, “Tools/technology”, the selection, use, and integration of tools/technology refer primarily to (i) customizing LPD tools for enterprises and (ii) optimizing tool usability.

From the perspective of theoretical implication, this study first identifies and evaluates the management factors that can facilitate the successful implementation of LPD. In previous studies, the connotation of each factor was vague and fragmented. Therefore, under the premise of integrating

previous research results, the authors conducted in-depth discussions and analyses on each factor to provide a relatively objective and comprehensive definition and connotation. This study can serve as a stepping stone for the completion of LPD research's theoretical development. There are only a handful of successful implementation cases of LPD. From the perspective of managerial implication, this study provides a list of management factors recognized by academics as contributing to the success of LPD, which will assist managers in allocating vital resources and making conclusive decisions when implementing or promoting LPD practices within their organizations.

This research has made contributions from both a theory and a management standpoint, but it also has limitations. On the one hand, this study uses a systematic literature review method, ignoring the views of books, conference papers, gray literature, and other academic resources when searching and collecting literature, which makes the research results somewhat limited. In addition, most of the research is concentrated in Europe. These countries have strong economic and technical conditions to support the application and promotion of LPD, but the same success factors may not be able to promote the development of LPD in developing countries.

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