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Gap analysis of current industrial technology towards the Industry 4.0 scheme: A case study of SMEs in the central region of Thailand

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Abstract

Thailand's government allocates part of its budget to supporting and promoting the international competitiveness of SMEs since SMEs in Thailand account for 42.2% of the GDP. However, the competence in Industry 4.0 technology seems to show only minor improvement. This study aims to extract the problems reported when conducting a project to promote digital technology for transforming SMEs' manufacturing processes. The data were collected from 187 SMEs of all sizes across all sectors in the central region of Thailand during 2018–2019. In summary, Thailand's SMEs are mostly categorized at level 2.0 in industrial technological advancement. The most frequently reported problem was the lacking systematic planning and control of the production process, leading to low-performance efficiency and waste in the process. This problem also caused barriers to the lean automation transformation scheme. Despite the support from the government in technology and investment consultancy, smart technology and techniques for performance improvement and process standardization should be provided to facilitate SMEs' leap towards Industry 4.0 sustainably.

Keywords: Small and medium enterprises, Productivity improvement, Industry 4.0, Smart manufacturing, Lean automation

1. Introduction

Small and medium enterprises (SMEs) are critical for a country's overall economy and play a key role in building the foundation for long-term prosperity. They are also a key mechanism for restoring and strengthening economic progress as well as a strategy for eliminating poverty. SMEs are important to the Thai economy in several respects, including creating jobs and establishing connections with international businesses in the manufacturing and service sectors. SMEs are currently facing the challenge of technological disruption. However, a lack of the resources required for digital transformation is a major barrier to SMEs' survival. Furthermore, SMEs are at a disadvantage in business competition in terms of production efficiency and quality [1-4]. According to the report by the Department of Industrial Promotion, a proper and correct solution to the obstacles that arise in SMEs has not been found. As a result, Thai SMEs cannot compete with the multinational companies that invest in the country [1].

The concept of Industry 4.0 has been promoted to SMEs continuously through a project launched by government agencies. Despite the Thai government's efforts to support SMEs' adoption of Industry 4.0 technologies, there are still gaps that need to be addressed to facilitate their successful implementation of industrial technologies. To understand the current state of industrial technologies to help in developing effective guidelines for the implementation of Industry 4.0, it is important to conduct a gap analysis to identify the current technology level and the problems in SMEs' production system. This information can be used by all partners to understand the challenges and opportunities facing organizations as they work to implement Industry 4.0 technologies and processes.

In this study, the main objective is to summarize the problems and obstacles found in reports on the productivity improvement programmes under the digital transformation scheme implemented by the Department of Industrial Promotion in 2018-2019. SMEs from 22 provinces across the central region of Thailand received consultancy services provided by professional-level engineering consultants for implementing digital technology to improve their process productivity. The review of the technology and techniques of the production process used in companies will be analysed to define the advancement of industrial technology. The problems and obstacles mentioned in the reports are also classified into groups of problems to gain a better understanding of SMEs' limitations and barriers to digital transformation. The results are then summarized to generate a recommendation for SME capability building in Thailand. A review of the past literature on the problems, obstacles, and needs of SMEs in Thailand regarding productivity improvement is presented in Section 2. The research methodology and results are discussed in Sections 3 and 4. Finally, the recommendation for SME capability building is presented in Section 5, followed by the conclusion in Section 6.

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2. Literature review

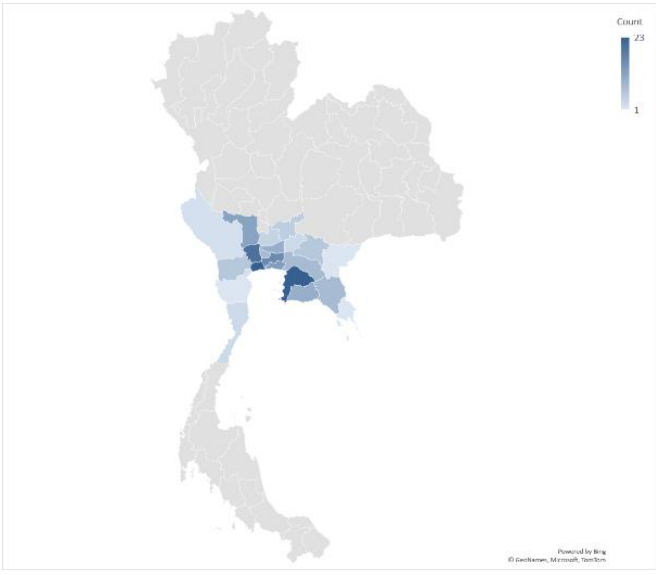
Small and medium enterprises (SMEs) play an important role in driving a country's economy. According to the report by the Office of Small and Medium Enterprises Promotion in 2019 [5], approximately three million companies were registered as SMEs in Thailand, accounting for 99.70% of the total number of registered enterprises in the country. SMEs currently host approximately 14.7 million jobs for Thai people, comprising 78.48% of the total employment. Moreover, SMEs produce a gross domestic product (GDP) of 6.06 trillion baht, accounting for 42.2% of the total GDP of the country. However, most Thai SMEs were reported to have problems in productivity [1]. The problems mainly concern the lack of knowledge and ability in several aspects, including manufacturing processes, modern business administration, marketing, product development, and finances. Moreover, SMEs were reported to be unable to adapt to the rapidly changing world situation, resulting in an inability to compete in the international market [6, 7]. Although the government has launched several policies and projects to assist SMEs, such as training and funding, the problems remain [8].

SMEs in Thailand have adopted the Shindan technique, as promoted by the Department of Industrial Promotion, as a diagnostic tool for the improvement of production efficiency. Although the Shindan technique can help to improve SMEs' operations, it requires in-depth analysis that must be custom made for each company to match its needs and operating conditions [9, 10]. This concept is not new since it is a normal operation found in most successful large companies that are well managed and systematically controlled. On the one hand, many resources are required to implement the concept, such as skilled employees, capital investment, production technology know-how, machines, and tools [11, 12]. SMEs, on the other hand, are often limited in resources, unlike large companies. This results in a lack of development that is necessary for business operations [13]. Although an external consultancy and mentoring programme can help to increase business productivity [14], the template and standard developed for one SME cannot be replicated for other SMEs due to the differences in their operating characteristics [15]. The problems and obstacles facing SMEs have been mentioned frequently in the literature; however, the identification of the type and scale of the problems found in the process and the level of technology used in Thailand's SMEs are still limited. Therefore, the finding from this study could fill the information gap and be incorporated into the strategic planning for the transformation of Thailand's SMEs towards the adoption of smart manufacturing technology.

3. Research methodology

3.1 Data collection

This study aims to assess the current level of technology used and identify the problems found in implementing digital technology in SMEs. As such, we analysed the reports from a process improvement project during 2018-2019 collected from 187 SMEs located in the central region of Thailand. The original reports, as primary data, are the summary reports written by a professional-level engineering consultant hired in a digital technology promotional project for SMEs funded by the Thai government. Each report contains sections including basic information about a company, current techniques and technology used in its production process, problems found in the process, suggestions for improvement, and investment analysis of the improvement plan. As part of the project, the consultants dedicated 42 man-hours to in-depth consultation sessions with SMEs to improve their productivity and promote their use of digital technology. Through these sessions, the consultants were able to provide guidance and support to SMEs as they worked to adopt and implement digital technologies in their operations.



(a)

ProvinceInEnglish	Sector 1	Sector 2	Sector 3	Sector 4	Count
Samut Sakhon	10	11		2	23
Chonburi	9	13	1		23
Nakhon Pathom	8	10	2		20
Bangkok	2	9	5		16
Samut Prakan	2	10	1		13
Suphan Buri	7	5			12
Pathum Thani	2	5	3	2	12
Rayong	3	6		1	10
Chanthaburi	6	1		1	8
Chachoengsao	4	4			8
Nonthaburi	6	2			8
Prachinburi	6				6
Prachinburi	3	3			6
Saraburi	1	3		1	5
Phra Nakhon Si Ayutthaya		2	2		4
Prachuap Khiri Khan	2		1		3
Nakhon Nayok	1		1	1	3
Kanchanaburi	2				2
Samut Songkhram	2				2
Phetchaburi	1				1
Trat	1				1
Sa Kaeo			1		1
Total	78	84	17	8	187

(b)

Figure 1 Demographic of SMEs data in the map of Thailand (a) and the number of SMEs data separated by sectors (b).

The SMEs are from 22 provinces in the central region, namely Nakhon Pathom, Samut Sakhon, Suphan Buri, Saraburi, Samut Songkhram, Bangkok, Pathum Thani, Nonthaburi, Nakhon Nayok, Phra Nakhon Si Ayutthaya, Samut Prakan, Eastern Region, Chanthaburi, Chachoengsao, Chonburi, Trat, Prachinburi, Rayong, Sa Kaeo, Western Region, Kanchanaburi, Prachuap Khiri Khan, Phetchaburi, and Ratchaburi, as shown on the map of Thailand in Figure 1. The sector of SMEs was divided into four groups [16], Sector 1 - agricultural industries and agro- processing industries, Sector 2 - technology and innovation industries, Sector 3 - creative industries and commercial sectors, and Sector 4 - retail and wholesale industries. Moreover, the SME data were classified by business

size based on their number of employees and annual income into three sizes: micro, small, and medium. The criteria used are in accordance with the definition of MSMEs from the Ministerial Regulations on Designation of the Characteristics of SME Promotion Act B.E. 2562 (2019) and Announcement of the Office of SME Promotion Subject Designation of Characteristics of Micro Enterprises [17], as described in Table 1. Table 2 presents the characteristics of the data used in this study, which can be summarized as follows. Sectors 1-4 account for 41.71%, 45.99%, 9.09%, and 3.21% of SMEs, respectively. The number of SMEs by business size is 51.34% for medium, 36.36% for small, and 12.30% for micro companies. This study included data from a diverse range of organizations across all sizes and all industrial sectors, providing a comprehensive view of the adoption of Industry 4.0 technologies.

Table 1 Definition of MSMEs business size

Business Size	**Annual income (million Baht)***	**Number of employment***
Manufacturing Sector		
Micro	0 - 1.80	1 - 5
Small	1.81 - 100	6 - 50
Medium	101 - 500	51 - 200
Trade and Service Sectors		
Micro	0 - 1.80	1 - 5
Small	1.81 - 50	6 - 30
Medium	101 - 300	31 - 100

* In the case that the number of employees fits a type of enterprise but the revenue fits another type, whichever is higher shall be used to determine the type of business.

Table 2 SMEs data separated by business sectors and business size

Business Sector	**Business Size**			
	Micro	**Small**	**Medium**	**Overall**
Sector 1	12	30	36	78
%	6.42%	16.04%	19.25%	41.71%
Sector 2	4	28	54	86
%	2.14%	14.97%	28.88%	45.99%
Sector 3	2	10	5	17
%	1.07%	5.35%	2.67%	9.09%
Sector 4	5	0	1	6
%	2.67%	0.00%	0.53%	3.21%
Grand Total	23	68	96	187
%	12.30%	36.36%	51.34%	100.00%

3.2 Classification criteria of problems and obstacles

In this step, the level of technological advancement and the type of problems were set to classify the problems. Firstly, to measure the technology gap in the production system towards Industry 4.0, the SMEs were grouped into four levels according to the technological advancement of their production technology. The levels of technological advancement depend on the type of machines used, the type of material handling system, and the type of information management system in a production process, as detailed in Table 3. Secondly, since the problems in the production process are diverse, they were then classified based on the overall equipment efficiency theory (OEE) [18]. The OEE is a three-part analysis tool for measuring process performance, consisting of machine availability, process efficiency, and the quality rate of the output from the production process. The theory is widely used to identify the hidden losses of a production process, which is mandatory information for a continuous improvement project in a business process.

The criteria for classifying problems in SMEs based on the OEE concept are divided into three perspectives, specifically the availability of machines (availability problem, AP), product quality (quality problem, QP), and process efficiency (performance efficiency problem, PP). The subgroups of problems for each criterion are defined as AP1-AP5, QP, and PP1-PP7, as explained in Table 4. Consequently, the problems were reviewed based on each criterion mentioned (1) and not mentioned (0) in the reports. Therefore, the maximum possible count of problem types for each case is 13. The observations were recorded in a data table. A summary is presented and discussed in the next sections.

Table 3 Level of Industrial Technology Advancement

Level	**Description**
1.0	Mainly using human labor, no technology, or machines to work
2.0	Some machines are used in the production process.
3.0	Some machines and conveyors are used in the production process but require humans to manage and operate the process information.
4.0	The production is automated with advanced technology such as robots, automated machines, and the use of IoT in information systems.

Table 4 Categories of problems and obstacles

Indicators	Problems and Obstacles
Availability Problems (AP)	
AP1	Machine running rate inconsistent with production goals
AP2	The environment inside the production line is not conducive to long hours of work, for example, employees become fatigued at work and unnecessary movement
AP3	Machine capacity decreases with service life. The cause is the deterioration of the machinery
AP4	There is no management and maintenance plan for machinery
AP5	Machines used in production must stop at intervals
Quality Rate Problems (QP)	
QP	A lot of waste from defective units
Performance Efficiency Problems (PP)	
PP1	Unsuitable manpower on production lines causes bottlenecks in the production process
PP2	Productivity is below the target
PP3	No standard operating time
PP4	Loss in the production process, such as redundant work of employees, resulting in delayed work
PP5	Lack of monitoring and estimating the rate of use of machinery to plan production accordingly
PP6	Employees make mistakes, such as recording the wrong information. quality inspection product count
PP7	Keep incomplete production records. Therefore, the data cannot be used for useful analysis

4. Result and discussion

4.1 Gap analysis of industrial technology advancement

The equipment list and picture of the factories in the reports were reviewed and then matched to the criteria for the level of industrial technological advancement in Table 3 [19]. The data were recorded as a value of technological advancement, specifically 1.0, 2.0, 3.0, and 4.0. The average industrial technology level ($\bar{x}_t$) was calculated based on the weighted average method from the number of SMEs on the same level for each category and the value of the technology level. The value of $\bar{x}_t$ was then rounded up to match the explanation in Table 2. The analysis result of the industrial technological advancement of SMEs is shown in Table 5.

The result reveals that, based on the sector category, the average level of SMEs' technological advancement in the overall sectors is 2.0, the level of technology of sectors 1-3 is 2.0, and sector 4 is at level 1.0. Furthermore, it can be interpreted that most of the SMEs in sectors 1-3 use machines in the production process but they mainly use human labour to handle materials, control machines, and manage information in the process. Meanwhile, in sector 4, the retail and wholesale industries seem to be at level 1.0 of industrial technological advancement, meaning that the industry seems to rely heavily on the human workforce in its operation. Nevertheless, since the data set for sector 4 may not be large enough to confirm the statement confidently, the extension of data observation is recommended. Consequently, according to the business size category, the results show that the overall technology level is 2.0. Micro-sized businesses seem to be at level 1.0, but small- and medium-sized businesses are at level 2.0. In conclusion, for SMEs in the central region of Thailand, the results reveal that the technological advancement is at level 2.0 on average. The recommendation for closing the gap is presented in Section 5. The problems and obstacles were also analysed to obtain insights into the gap found in this part.

Table 5 Summary of the number of SMEs by industrial technology advancement.

Category	Advancement of Technology Level (Count)					Technology Level, $\bar{x}_t$
	Level 1.0	Level 2.0	Level 3.0	Level 4.0	Total	
Business Sector						
Sector 1	32	45	1	0	78	2.0
%	41.03%	57.69%	1.28%	0.00%		
Sector 2	6	74	6	0	86	2.0
%	6.98%	86.05%	6.98%	0.00%		
Sector 3	6	11	0	0	17	2.0
%	35.29%	64.71%	0.00%	0.00%		
Sector 4	6	0	0	0	6	1.0
%	100.00%	0.00%	0.00%	0.00%		
Overall	50	130	7	0	187	2.0
%	26.74%	69.52%	3.74%	0.00%		
Business Size						
Micro	14	9	0	0	23	1.0
%	61%	39%	0%	0%		
Small	22	44	2	0	68	2.0
%	32%	65%	3%	0%		
Medium	14	77	5	0	96	2.0
%	15%	80%	5%	0%		
Overall	50	130	7	0	187	2.0
%	26.74%	69.52%	3.74%	0.00%		

4.2 Analysis of the problems and obstacles faced by SMEs in Thailand

The problems and obstacles in the production process of a sample of 187 SMEs are classified based on the categories in Table 4. The study reveals that, among the problems and obstacles found in SMEs, the most frequent are performance efficiency problems (PPs), followed by quality rate problems (QP) and then availability problems (APs) - regardless of the category of sectors and the business size, as presented in the heat map in Figure 2. In detail, the frequency of problems was ranked as follows. The most frequently found problem seems to be PP5 - lack of monitoring and estimating the rate of use of machinery to plan production accordingly. The reports mentioned that companies have experienced problems involving the lack of an inspection plan, being unable to assess the machine utilization and availability rate, and being unable to plan production effectively.

The second rank is PP4 - loss in the production process, such as redundant work of employees, resulting in delayed work. The third rank is tied between PP3 and QP. PP3 is the lack of standard operating time. The reports also mentioned that the company has not performed the motion and time study properly, which means that it has no information to manage and improve the process. For the QP - a lot of waste from defective units - it was reported that the company lacks a quality control plan. The quality of the product was not recorded and analysed properly, causing problems of too much rework and scrap and not knowing the exact cost of quality.

In summary, it seems that the technology gap cannot be closed only by investing in smart manufacturing technology and that the problem of the lacking systematic production control and improvement should be solved first. This is because the problems and obstacles found in this study mainly pointed to performance efficiency problems, which are technical problems in operation management. The findings from this study are in the same direction as those reported in the previous survey conducted by the Federation of Thai Industries and the National Institute of Development Administration's "Nida Poll" opinion polling centre [20] on SMEs' obstacles to running a business in the economic situation in 2015 based on problems of production efficiency in operations. The results also showed that 44.69% of SME entrepreneurs have problems with production efficiency.

Category	Category of Problems and Obstacles													
	AP1	AP2	AP3	AP4	AP5	PP1	PP2	PP3	PP4	PP5	PP6	PP7	QP	Total*
Business Sector														
Sector 1	15	5	1	19	12	16	22	27	29	40	15	2	26	229
Sector 2	12	5	2	15	16	14	25	25	33	48	18	1	21	235
Sector 3	4	0	1	2	3	5	6	5	9	9	2	0	8	54
Sector 4	1	0	0	0	0	4	2	3	3	0	1	0	1	15
Overall	32	10	4	36	31	39	55	60	74	97	36	3	56	533
Overall, %	**6%**	**2%**	**1%**	**7%**	**6%**	**7%**	**10%**	**11%**	**14%**	**18%**	**7%**	**1%**	**11%**	**100%**
SMEs Type														
Micro	7	1	1	5	6	8	6	12	12	11	2	0	9	80
Small	10	7	2	13	9	14	23	23	29	36	15	0	24	205
Medium	15	2	1	18	16	17	26	25	33	50	19	3	23	248
Overall	32	10	4	36	31	39	55	60	74	97	36	3	56	533
Overall, %	**6%**	**2%**	**1%**	**7%**	**6%**	**7%**	**10%**	**11%**	**14%**	**18%**	**7%**	**1%**	**11%**	**100%**

Figure 2 Summary of problems and obstacles of SMEs in all sectors and sizes.

4.3 Discussion

The results of this study, which analysed the problems and obstacles faced by organizations in the adoption of Industry 4.0 technologies, align with the findings of similar research on the adoption of these technologies. These results suggest that the challenges faced by organizations in implementing Industry 4.0 are consistent across different sectors and contexts.

Several studies have highlighted similar challenges to the findings of this study. In terms of productivity improvement, the development of a basic toolkit can overcome barriers to initial action. It is important to consider the improvement of current operating methods before technology implementation [21]. According to the analysis of the production technology level of Thai SMEs mentioned above, it has been found that inefficiencies in production are often caused by reliance on human labour. Many SMEs in Thailand still rely heavily on manual labour, which can lead to problems with efficiency and productivity. This issue is consistent with research on the challenges faced by the manufacturing industry in China as it adopts Industry 4.0 technologies [22]. According to research, one of the key challenges in the adoption of Industry 4.0 technologies in China's manufacturing sector is a shortage of skilled workers. This issue has been identified as a major barrier to the implementation of smart technologies in this industry. The unit output in China's manufacturing sector is relatively low compared with that in developed countries, which makes it difficult to leverage fully the benefits of Industry 4.0 technologies. Another study has reported barriers to Industry 4.0 technology adoption in Turkish SMEs [23]. The implementation of Industry 4.0 has also not been successful. It is important for SMEs to follow technological developments closely and focus on R&D activities to increase their productivity and international competitiveness.

Research on the development of policies and strategies for the implementation of Industry 4.0 has consistently identified similar issues and trends. The findings suggest that there are certain challenges and considerations that are common across different organizations and industries when it comes to implementing Industry 4.0 technologies and processes. Overall, the process of digital transformation under Industry 4.0 can be very resource intensive and complex, especially for SMEs [24]. These businesses may not have the necessary skills or expertise to implement Industry 4.0 technologies and processes effectively. Therefore, it is important for governments to develop policies and programmes that support the digitalization of SMEs and to ensure that these businesses are aware of these resources and how to access them. In addition, governments should ensure that the necessary infrastructure and support systems are in place to help SMEs navigate the transition to Industry 4.0. More issues concerning the time required to learn and funding are also mentioned in the literature [25].

Additionally, there is still a need for a technology framework that can guide the adoption of Industry 4.0. While some research has already presented such a framework [26], it may not be directly applicable to SMEs in Thailand. This is because there may be a lack of connections between these SMEs and the framework that has been developed. Nevertheless, research has shown that the adoption of Industry 4.0 technologies can help SMEs to create value-added products and services, which can ultimately increase their competitive

advantage and reduce the business risks. Therefore, it is important for policy makers and strategists in Thailand to consider how best to support the adoption of Industry 4.0 technologies by SMEs to help them succeed in the marketplace.

5. Recommendation for SMEs' capability building in Thailand

The Thailand 4.0 model is a 20-year national strategy to develop SMEs and promote their transformation into smart enterprises or startups [27]. With the rapid economic growth, companies' top priority is to make their production system adapt to the changing market to survive. One of the key policies is to strengthen the knowledge of digital technology among SME entrepreneurs to be able to compete effectively. It is believed that the efficiency of the production process, which improves significantly with smart technology, can facilitate SMEs' product development as well as increasing the opportunities to receive investment from abroad [28, 29].

Based on the analysis of the problems and obstacles faced by Thai SMEs in Section 4, the performance problems seem to affect the efficiency of SMEs' production process considerably. Process performance can be improved by laying a robust foundation of lean principles in the operation of an organization. The most important key concept of lean principles is to eliminate waste in the process. This concept is currently acknowledged by SMEs. However, it is not easy to implement the idea in their processes due to the lack of skilled workers to keep the improvement project running continuously. Although the government has provided support for professional engineering consultancy for SMEs, it only lasted for a short period. The consultancy project could help raise awareness and provide an understanding of the productivity improvement programme among SMEs; still, it requires a large sum of investment to keep the project running until the process can reach its lean state. Thus, after the termination of the project, most SMEs may not be able to carry on their improvement project. As such, the plan for the performance improvement project could be stopped or delayed, resulting in wasted time and effort for all parties.

Under the circumstances stated above, smart manufacturing technology should be provided for SMEs to help with the process improvement project. The technology must be easy to use and can provide automated analysis results of the measurement of process performance. For example, smart technology for motion and time study should be provided for SMEs to help measure and analyse the performance of operators in a process. The time study provides time data such as cycle time and standard time, which are normally used as a key performance indicator of a process. To reach the lean state of a process, the time must be measured to analyse and improve the efficiency of motion. Traditionally, the motion and time study must be performed by engineers or technicians and must be carried out repetitively, which may be unaffordable for SMEs. Therefore, providing smart technology for the motion and time study process is recommended for the capacity-building plan to moderate the problems of performance efficiency in SMEs.

After the motion and time in a process have been improved to reach the high-efficiency level, also known as the lean state, the lean automation principle should be introduced into SMEs. The concept of lean automation refers to the optimized process design that enables humans and machines to collaborate, aiming to minimize the cost of production. Much research has attempted to combine lean manufacturing processes and automation [30]. "Lean manufacturing" was developed to improve human-centred production by focusing on maximizing the efficiency of machines and reducing the cost of machinery and acquisition (MUDA), machine waste, and equipment and devising a way to increase the overall utilization rate of the equipment [31]. By adopting lean manufacturing methods and lean automation in the process by using new automated machines instead of human labour, the amount of waste can be reduced, resulting in the improvement of productivity.

The most efficient way to achieve a lean automation system is to verify the idea in a computer simulation model. Simulation software is available in the market; however, the cost of a license and the skills required for developing the model may be unaffordable for SMEs. Therefore, it is also recommended that the government should provide a consultancy service for a feasibility study of advanced technology implementation for SMEs. Moreover, the support for information management system implementation is important to SMEs. Despite the automated processing machines, automated information control and management systems are also mandatory for Industry 4.0. Finally, support for skill upgrading and investment in technology, as widely promoted by the government agencies, would also help to propel SMEs towards the Industry 4.0 scheme.

6. Conclusions

The benefit of new technology, such as smart material handling equipment or automated machines, is well recognized by SMEs, yet investing in the technology is a difficult decision. For SMEs, investment in smart manufacturing technology is unavoidable to close the technology gap. Although several government agencies have launched projects to increase the accessibility to investment funds for SMEs, new machines may create chaos if their implementation is not aligned with the lean automation principle. In addition, lean automation is built upon a solid foundation of the lean production process and the smart selection of digital technology. Therefore, SMEs seem to require a completed lean process before closing the gap of Industry 4.0 with investment in new machines. This is considered a robust foundation for enhancing the competitiveness of Thailand's SMEs.

In summary, the results reveal that the technological level of SMEs in Thailand is 2.0. The problems and obstacles found in the report pointed to the inefficiency of performance due to the lack of systematic planning and management in the production process, leading to problems of performance efficiency and waste in the process. This large gap in technological advancement towards smart manufacturing 4.0 must be closed immediately by providing the right solution from the government. Further studies could extend the gap analysis to include data from other parts of Thailand since similar programmes are reported to be underway nationwide. Moreover, the cluster analysis of the barriers and limitations of SMEs introducing smart manufacturing has the potential to provide a source of information that benefits the strategic planning on smart manufacturing transformation.

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