

# Key Success Factors for Implementing Industry 4.0 of Thailand Manufacturing

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Received: February 4, 2022 / Revised: March 3, 2022 / Accepted: June 17, 2022

**Abstract**—Thailand’s manufacturing is a crucial component to drive the economy. However, most manufacturers in Thailand face obstacles and challenges to reach Industry 4.0 in their production process, which will help improve their productivity and efficiency. This paper aims to identify the key factors for Thailand’s manufacturing firms to implement Industry 4.0. The success factors were identified by literature review and the Delphi method. First, we conducted a semi-structured interview with 2 experts and used the Delphi method to analyze the potential factors. The Analytic Hierarchy Process (AHP) is applied to find the ranking of the top 5 factors. There are 13 experts completing the questionnaire, and they are at the managerial level related to Industry 4.0. Analytic Hierarchy Process (AHP) was applied to find the relative weight of success factors to rank the importance of the success factors and give concrete guidance to implement Industry 4.0. The top 5 factors are leadership vision, support from top management, knowledge of technology by an employee, aligning Industry 4.0 with organization strategy, and the process of digitalization of the industry.

**Index terms**—Industry 4.0, Key Success Factor, Analytic Hierarchy Process

## I. INTRODUCTION

Thailand’s manufacturing is a crucial component of the Thai economy. Thailand manufacturing has 90.1% of the export value of significant products [1]. However, 60% of the development in Thailand’s manufacturing was manual (25%) or a combination of computer numerically controlled and manual (35%), while only 5% of Thailand’s manufacturing is fully

automatic [2]. Regarding Thailand manufacturing’s importance to Thailand’s economic development, identifying and ranking key success factors to help Thailand’s manufacturing reach a higher level is essential.

The current manufacturing age has evolved from mass production to customized production with digitalization in its operation [3]. Industry 4.0 integrates the physical and digital world using Cyber-Physical System (CPS) to create real-time productivity. Industry 4.0 provides real-time data to monitor, which helps improve productivity, performance, and product quality in the production process. Industry 4.0 is a cross-disciplinary concept integrating manufacturing with information technology and the Internet of Things (IoT). Industry 4.0 is characteristic of the automated manufacturing process, with a collaboration between man and machine in the center [4].

However, only a few firms could implement these concepts to bring their factories to Industry 4.0. Thus, we are interested in learning how those successful firms could do it. This paper aims to identify key success factors for Thailand’s manufacturing to implement Industry 4.0. The paper is organized in the following structure. First, the potential success factors are identified from the literature review. The methodology for the Delphi method and AHP are then explained and followed by the results, discussion, and conclusion.

## II. LITERATURE REVIEW

In this section, potential factors were identified from a comprehensive literature review. Articles related to the study of the implementation of Industry 4.0 were reviewed, and 19 factors were identified. The list of these potential success factors is summarized in Table I below.

TABLE I  
POTENTIAL SUCCESS FACTORS FOR THAILAND MANUFACTURING  
IMPLEMENTING INDUSTRY 4.0

Number	Factors Name	Literature Support
1	The expected benefit of technology	[5] [6] [7] [8]
2	Real-time link between physical production and digital factory	[9]
3	Sufficient and capable technological infrastructure	[10]
4	Support from top management	[11]
5	Knowledge of technology by top management	[12]
6	Leadership vision	[13]
7	Align the Industry 4.0 with organization strategy	[14]
8	Degree of automation and the variety of product	[5]
9	Knowledge of technology by an employee	[5] [12] [14]
10	Employee readiness	[15]
11	High-cost investment	[9]
12	The process of digitalization of the industry	[16]
13	Government support	[10]
14	The importance of a company's competitiveness in the market to offer the latest technology	[15]
15	Impact of new technology on logistics and supply chain	[15]
16	Internet and connectivity in the shop floor	[17]
17	Potential Risk	[7]
18	The importance of a company's competitiveness in the market in order to offer the latest technology	[15]
19	Strategy to compromise with employee	[9]

### III. METHODOLOGY

In this research, key success factors for Thailand's manufacturing approach to Industry 4.0 are identified using the AHP method to analyze the potential success factors from literature reviews and expert interviews. A literature review and semi-structured interviews were conducted to identify the potential factors. Delphi method is undertaken to find the potential factors by interviewing experts. Delphi provides more accurate decisions from a structured group of individuals. The expert answer questionnaire rates each possible factor from 1 to 5, ranking from the least to the most important. The factors with a total score higher than 9 will be selected as potential factors.

The Analytic Hierarchy Process (AHP) method was used to analyze the weights for each potential factor for implementing Industry 4.0. Thomas developed the AHP to quantify the weights of decision criteria [18]. Each of the experts utilized their experiences to compare the relative importance of each pair of items using a pairwise comparison questionnaire.

The detailed Analytic Hierarchy Process methodology involves 5 steps, as follows:

#### Step 1: Data collection

The experts who provide the comparison judgment of the pairwise questionnaire must have experience in implementing Industry 4.0. The experts should be a managerial-level industrial company that plans or adapts Industry 4.0 in their organization or an expert in the field of Industry 4.0. A respondent also needs to have job experience of more than 5 years in the field.

A pairwise comparison questionnaire has the format as shown in Fig. 1. The respondents answer the pairwise comparison to select the factors that represent the important degree of each factor to other factors. The respondents would rate by using a scale from 1 to 9, representing the degree of importance. The detailed Thomas scale is shown in Table II [18].

#### Step 2: Construct a pairwise comparison matrix

The pairwise comparison data will be represented in the square matrix  $C^E = [c_{ij}^E]$ , where  $i, j = 1 \dots n$  represents the number of factors and  $E = 1 \dots m$  represents the number of experts. The initial matrix has the principal diagonal containing values of 1 because each factor is as important as itself. Let's suppose that expert 3 decides that factor 1 is strongly preferred over factor 2. In the matrix,  $c_{12}^3$  is rated as 5 and  $1/5$  in  $c_{21}^3$ .

TABLE II  
PAIRWISE COMPARISON SCALE FOR AHP PREFERENCES [18]

Values/Rates	Description
1	Equally importance
2	Equally preferred, but with certain moderate differentiation tendencies
3	Moderately preferred
4	Preferred towards strongly preferred
5	Strongly preferred
6	Strongly preferred towards obviously preferred
7	Obviously preferred
8	Obviously preferred towards extremely preferred
9	Extremely preferred

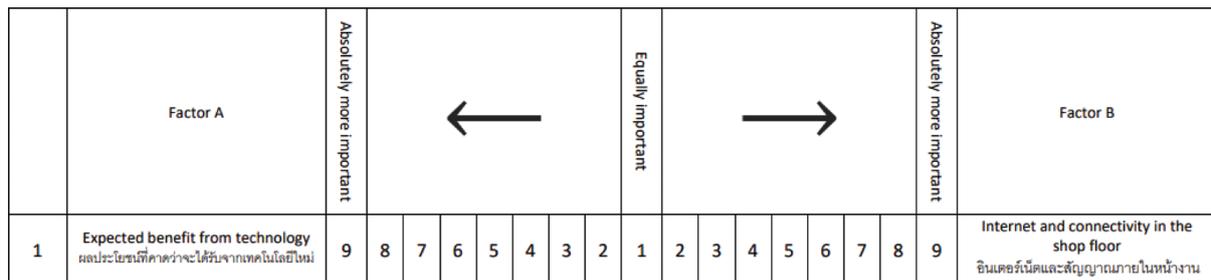


Fig. 1. Example of a Pairwise Comparison of Questionnaires

**Step 3:** Determine the importance coefficients (weights) of the factors for each expert

For the square matrix  $C^E$ , the weights are consistent if  $c_{ik}^E = c_{ij}^E c_{jk}^E$  for all  $i, j$ , and  $k$ . To determine the consistency matrix, find a vector  $W^E$  of order  $n$  such that  $C^E W^E = \lambda^E W^E$ . We call  $W^E$  an eigenvector, and  $\lambda^E$  is an eigenvalue. For a consistent matrix,  $\lambda^E = n$ .

There are many ways to calculate the eigenvector or the importance coefficients (weights) of the factors for each expert. The importance coefficients of the factors  $i$  are calculated based on equation (2), as follows:

$$S_i^E = \sum_{j=1}^n c_{ij}^E \text{ for all } i, \text{ and } E \tag{1}$$

$$\lambda_i^E = \frac{S_i^E}{\sum_{i=1}^n S_i^E} \text{ for all } i, \text{ and } E \tag{2}$$

Note that  $S_i^E$  is the element  $i$  in the score summation  $S_i^E$  and  $\lambda_i^E$  is the element  $i$  in the eigenvector  $\lambda_i^E$ . The following condition must be observed:

$$\sum_{i=1}^n \lambda_i^E, \text{ for all } E \tag{3}$$

**Step 4:** Determine the Consistency Index (CI) and Consistency Ratio (CR) of the matrix

The objective is to determine whether the decision-makers have been consistent in their choices [18]. For example, suppose the decision-makers affirm that the Leadership Vision factor is more important than the Employee Readiness factor. In addition, the Employee Readiness factor is more important than the

Government Support factor. It would be inconsistent to affirm that the Government Support factor is more important than the Leadership Vision factor (if  $A > B$  and  $B > C$  it would be inconsistent that  $A < C$ ).

However, the condition  $c_{ik}^E = c_{ij}^E c_{jk}^E$  does not hold because the human judgment is inconsistent. Thus, we could find  $W^E$  vector that satisfies  $C^E W^E = \lambda_{max}^E W^E$  and  $\lambda_{max}^E \geq n$ . If  $\lambda_{max}^E = n$ , the judgment of expert  $E$  is consistent. The next step is to calculate the  $\lambda_{max}^E$  as follows.

$$R_i^E = \frac{\sum_{j=1}^n \lambda_i^E c_{ij}^E}{\lambda_i^E} \text{ for all } i, \text{ and } E \tag{4}$$

Where  $R_i^E$  represents the estimator for  $\lambda_{max}^E$ . Since there are  $n$  estimates for  $\lambda_{max}^E$ . The mean of the estimators,  $\lambda_{max}^E$  is calculated based on equation (4), as follows:

$$\lambda_{max}^E = \frac{\sum_{i=1}^n R_i^E}{n} \text{ for all } E \tag{5}$$

The difference between  $\lambda_{max}^E$  and  $n$  shows the inconsistency of the judgment. The Consistency Index (CI) for expert  $E$  can be calculated by  $(\lambda_{max}^E - n) / (n - 1)$ . The Consistency Ratio (CR) for expert  $E$  is then calculated by  $CI^E / RI$ , where  $RI$  is the index of consistency for random judgments [18]. If  $CR^E < 0.10$ , then the matrix or the judgment for expert  $E$  is consistent. Otherwise, the expert must re-evaluate the conflicting judgment.

TABLE III  
RANDOM CONSISTENCY INDEX FOR THE CORRESPONDING NUMBER OF FACTORS [18]

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

**Step 5:** Determine the weighted values of comprehensive experts

Once the Consistency Ratio (CR) for all experts is consistent, each factor's weights for all experts are the normalized sum of the eigenvectors.

$$\lambda_i = \frac{\sum_{E=1}^m \lambda_i^E}{m}, \text{ for all } i \quad (6)$$

#### IV. RESULTS AND DISCUSSION

Delphi method is conducted to find the potential factors by interviewing 2 experts. Each expert is selected because there has experience in implementing Industry 4.0 in many organizations and obtained an opportunity to talk with many managerial levels in many organizations. They have high experience in implementation work and understand what organizations need for Industry 4.0 to be implemented. The demographics of the two experts are shown in Table IV.

TABLE IV  
EXPERT DETAIL IN THE DELPHI METHOD

Expert No.	Field of Expert	Position
1	Industrial IoT platform provider	Sales Engineer
2	Industrial IoT platform provider	Solution Engineer

Initially, there are 19 factors identified as potential success factors from the literature. The experts in the specific field were interviewed to discuss and rate these potential factors in the next step. The experts are a sales engineer and a solution engineer in an Industrial IoT platform provider. The experts were selected due to their adeptness in implementing various projects related to Industry 4.0. Both experts also had experience in conversations with the top managerial level in many organizations. Thus, they have a deep understanding of what is important for implementing Industry 4.0 to succeed in the organization.

After the short interview with two experts using the Delphi method, the result is shown in Table V. Some factors had been dropped out because the total score is less than 9. 9 factors out of 19 were selected as the potential success factors to implement Industry 4.0, and they are grouped into 4 categories. In Table VI, there are 9 factors that remained, Expected benefit from technology, Real-time link of physical production and digital factory, support from top management, Leadership vision, Align the Industry 4.0 with organization strategy, knowledge of technology by an employee, Employee readiness, the process to the digitalization of the industry, and Government support.

TABLE V  
EXPERT SCORING FROM THE DELPHI METHOD

Number	Factors Name	Expert 1	Expert 2	Total Score
		Score	Score	
1	The expected benefit of technology	5	5	10
2	Real-time link between physical production and digital factory	5	5	10
3	Sufficient and capable technological infrastructure	4	4	8
4	Support from top management	5	5	10
5	Knowledge of technology by top management	4	4	8
6	Leadership vision	4	5	9
7	Align the Industry 4.0 with organization strategy	4	5	9
8	degree of automation and the variety of product	4	4	8
9	Knowledge of technology by an employee	5	4	9
10	Employee readiness	5	5	10
11	High-cost investment	4	4	8
12	The process of digitalization of the industry	5	5	10
13	Government support	4	5	9

TABLE V  
EXPERT SCORING FROM THE DELPHI METHOD (CON.)

Number	Factors Name	Expert 1	Expert 2	Total Score
		Score	Score	
14	The importance of a company’s competitiveness in the market to offer the latest technology	4	4	8
15	Impact of new technology on logistics and supply chain	2	1	3
16	Internet and connectivity in the shop floor	5	3	8
17	Potential Risk	3	3	6
18	The importance of a company’s competitiveness in the market in order to offer the latest technology	4	4	8
19	Strategy to compromise with employee	4	3	7

TABLE VI  
THE SUCCESS FACTORS FOR THAILAND MANUFACTURING APPROACH INDUSTRY 4.0

No.	Category	Factors
1	Technology	The expected benefit of technology
2		Real-time link between physical production and digital factory
3	Leadership	Support from top management
4		Leadership vision
5	Organization	Align the Industry 4.0 with organization strategy
6		Knowledge of technology by an employee
7		Employee readiness
8		The process of digitalization of the industry
9		Government support

The following steps are the AHP method applied to identify the key success factors to implement Industry 4.0 for Thailand manufacturing.

**Step 1: Data collection**

The detailed descriptions of the potential factors are from the literature review and the Delphi method,

as presented in Table VII. In this step, the pairwise comparison questionnaire is constructed and sent to the target experts to obtain the data. The research target must be an expert in Industry 4.0 technology or managerial level in a manufacturing field planned or used to implement Industry 4.0 in their organization.

TABLE VII  
POTENTIAL FACTORS DESCRIPTION

Factors	Factor’s Name	Descriptions
a	The expected benefit of technology	The expected benefit from technology which will help in improving ROI or performance in the organization
b	Real-time link between physical production and digital factory	The data is obtained from the machine in production in real time.
c	Support from top management	Support from top management in terms of financial and project approval
d	Leadership vision	Leadership has a deep understanding of Industry 4.0 and is ready for a challenge.
e	Align the Industry 4.0 with organization strategy	The project related to Industry 4.0 must be aligned with the organizational strategy
f	Knowledge of technology by an employee	An employee should understand and have some skills related to Industry 4.0
g	Employee readiness	An employee is ready for a change within an organization
h	The process of digitalization of the industry	The process of obtaining the data from physical production to visualization
i	Government support	The government support in terms of policy, law, or BOI

According to the result of the questionnaire, 12 experts (92%) are managerial level in the organization, and 1 expert (8%) is an expert of Industry 4.0 technology, as presented in Table VIII. 8 experts (62%) have planned or using technology related to Industry 4.0, 1 expert (8%) sell the equipment related to Industry 4.0, 3 experts (22%) are solution provider related to Industry 4.0, and 1 expert (8%)

is wanting to study more detail in Industry 4.0, as presented in Fig. 2.

According to Table VIII, all experts have a year experience more than 5 years. 2 experts (16%) have 6-10 years of experience, 4 experts (31%) have 10-15 years of experience, 2 experts (16%) have 15-20 years of experience, and 5 experts (37%) have 20-30 years of experience.

TABLE VIII  
EXPERT POSITION AND YEARS OF EXPERIENCE

Expert	Position	Years of Experience
1	General Manager	15
2	Business Development Manager	10
3	Chief Executive Officer	11
4	Chief Executive Officer	30
5	General Manager	25
6	Chief Executive Officer	26
7	Engineering Manager	10
8	Senior Manufacturing Manager	18
9	Managing Partner	17
10	Chief Executive Officer	6
11	Head of Solution Engineer	8
12	Chief Executive Officer	25
13	Engineering Manager	20

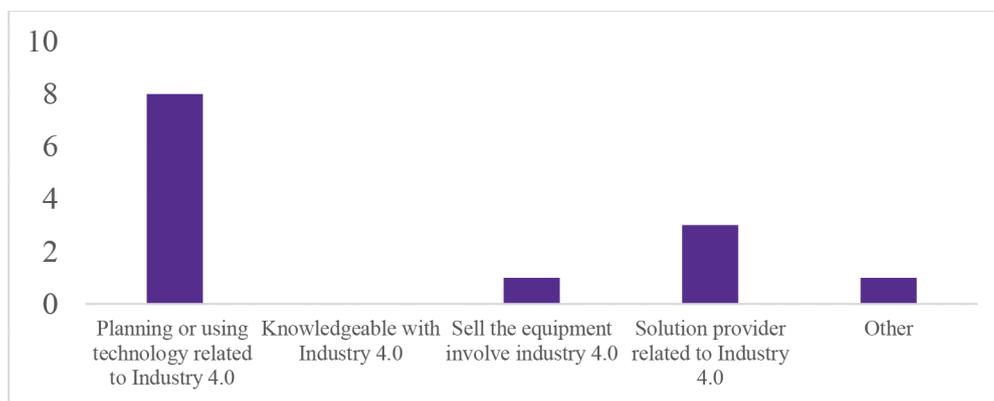


Fig. 2 Experts' knowledge in Industry 4.0

**Step 2:** Construct a pairwise comparison matrix.

In Table IX, the matrix represents the weight comparison between every pair of factors of the first expert. The matrix diagonal value is 1 because comparing

itself would be equally important. To fill in the matrix, if factor a is slightly less important than factor b, which equals 3. Factor b compared to factor a should be inverse, which is 1/3.

TABLE IX  
MATRIX OF COMPARISON WEIGHT BETWEEN EACH  
FACTOR FROM THE FIRST EXPERT

Factor	a	b	c	d	e	f	g	h	i
a	1.00	0.33	0.13	0.33	0.20	0.17	1.00	1.00	0.17
b	3.00	1.00	0.33	1.00	0.33	0.20	0.14	0.20	0.33
c	8.00	3.00	1.00	1.00	5.00	0.14	9.00	9.00	7.00
d	3.00	1.00	1.00	1.00	3.00	0.14	1.00	1.00	5.00
e	5.00	3.00	0.20	0.33	1.00	1.00	0.20	1.00	5.00
f	6.00	5.00	7.00	7.00	1.00	1.00	7.00	7.00	5.00
g	1.00	7.00	0.11	1.00	5.00	0.14	1.00	1.00	5.00
h	1.00	5.00	0.11	1.00	1.00	0.14	1.00	1.00	5.00
i	6.00	3.00	0.14	0.20	0.20	0.20	0.20	0.20	1.00

**Step 3:** Determine the importance coefficients (weights) of the factors for each expert

Equations (1) and (2) are used to calculate the importance coefficients, while equation (3) is also observed, as shown in Table X.

TABLE X  
THE IMPORTANCE COEFFICIENTS (WEIGHTS) OF THE FACTOR FROM THE FIRST EXPERT

Factor	a	b	c	d	e	f	g	h	i	Score Summation (S)	The Importance Coefficients or Eigenvector ( $\lambda$ )
a	1.00	0.33	0.13	0.33	0.20	0.17	1.00	1.00	0.17	4.33	0.024
b	3.00	1.00	0.33	1.00	0.33	0.20	0.14	0.20	0.33	6.54	0.036
c	8.00	3.00	1.00	1.00	5.00	0.14	9.00	9.00	7.00	43.14	0.239
d	3.00	1.00	1.00	1.00	3.00	0.14	1.00	1.00	5.00	16.14	0.089
e	5.00	3.00	0.20	0.33	1.00	1.00	0.20	1.00	5.00	16.73	0.093
f	6.00	5.00	7.00	7.00	1.00	1.00	7.00	7.00	5.00	46.00	0.255
g	1.00	7.00	0.11	1.00	5.00	0.14	1.00	1.00	5.00	21.25	0.118
h	1.00	5.00	0.11	1.00	1.00	0.14	1.00	1.00	5.00	15.25	0.084
i	6.00	3.00	0.14	0.20	0.20	0.20	0.20	0.20	1.00	11.14	0.062
<b>Total</b>	-	-	-	-	-	-	-	-	-	<b>180.54</b>	<b>1.000</b>

**Step 4:** Determine the Consistency Index (CI) and Consistency Ratio (CR) of the matrix

In this step, the program called AHP-OS is used to calculate CR from the matrix [19]. The first round of CR for each expert is represented in Table XI.

TABLE XI  
CONSISTENCY RATIO FOR EACH EXPERT

Expert	Consistency Ratio	
	1 <sup>st</sup> Round	2 <sup>nd</sup> Round
1	0.458	0.092
2	0.205	0.076
3	0.220	0.096
4	0.148	0.070
5	0.214	0.093
6	0.410	0.096
7	0.179	0.094
8	0.126	0.055
9	0.288	0.056
10	0.154	0.080
11	0.073	0.073
12	0.060	0.060
13	0.124	0.052

According to the table, only expert numbers 11 and 12 had CR lower than 0.1 in the first round. Therefore, the other 11 experts were interviewed again to adjust conflict judgments. We interviewed the experts by confirming their opinions on comparing the selected factor with other factors. During the interview, the AHP-OS program is used to check the CR in real time. The interview will continue until the

CR is lower than 0.1. The adjusted CR is shown in the second-round column in Table XI.

**Step 5:** Determine the weighted values of comprehensive experts.

In this step, the compressive weights for each factor are calculated. Equation (6) is used to calculate the comprehensive weight of the factors. The results for both rounds of the interview are shown in Table XII.

TABLE XII  
COMPREHENSIVE WEIGHT OF ALL FACTORS

Factor	Comprehensive Weight	
	1 <sup>st</sup> Round	2 <sup>nd</sup> Round
a	0.0720	0.0625
b	0.0443	0.0479
c	0.1625	0.1625
d	0.1784	0.1868
e	0.1139	0.1147
f	0.1139	0.1172
g	0.1069	0.0983
h	0.1024	0.1067
i	0.1057	0.1033
Summation	1.0000	1.0000

After computing comprehensive weight, the ranking of each factor is obtained, presented in Table XIII, Fig. 3, and Fig. 4.

TABLE XIII  
FACTOR RANKING

Ranking	Factor	
	1 <sup>st</sup> Round	2 <sup>nd</sup> Round
1	Leadership vision	Leadership vision
2	Support from top management	Support from top management
3	Align the Industry 4.0 with organization strategy	Knowledge of technology by an employee
4	Knowledge of technology by an employee	Align the Industry 4.0 with organization strategy
5	Employee readiness	The process of digitalization of the industry

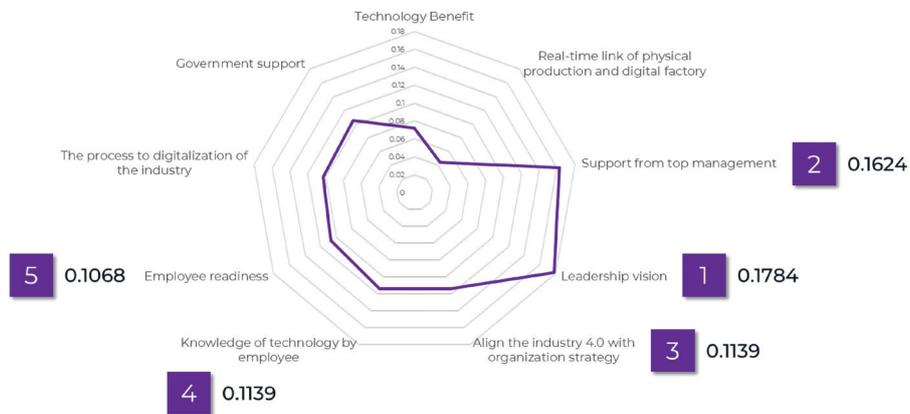


Fig. 3. The comprehensive weight for each factor in the 1<sup>st</sup> Round

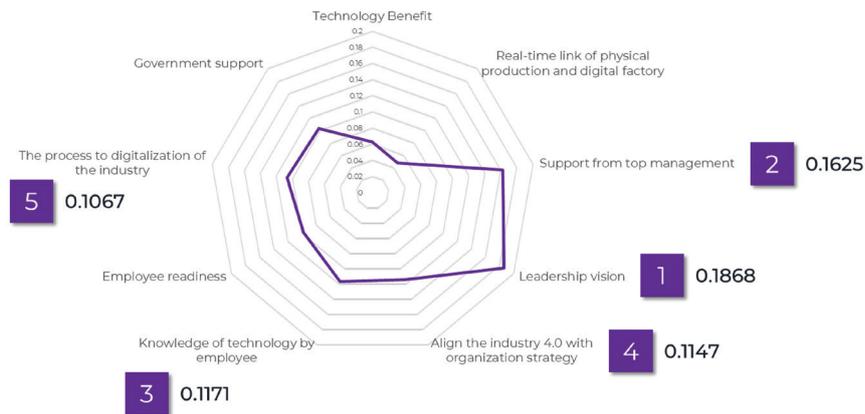


Fig. 4. The comprehensive weight for each factor in the 2<sup>nd</sup> Round

From Table XIII, there is a change of ranking after the experts adjusted their ranking. Rank 3 and 4 factors have been switched placed after the adjustment. Moreover, the Rank 5 factor of the second round is replaced by the new factor, the process of digitalization of the industry. However, Leadership and support from top management do not change after the adjustment. It indicates that these two factors are important in respondents' views. If we look at the comprehensive weight of these two factors, the weights are in the top two highest weights before and after adjustment. Thus, it can indicate that leadership vision and support from top management are the most important factors when implementing Industry 4.0 into the organization.

From Fig. 4, the results indicate that leadership vision (0.1868) is the most critical factor for Thailand's manufacturing to implement Industry 4.0. The top manager must have the vision to challenge new technology and accept the change within an organization. The second factor is support from top management (0.1625), which is needed when starting something new within the organization. The third factor is knowledge of technology by employees (0.1171), which will help the implementation become more accessible and more effective. The fourth factor is aligning Industry 4.0 with organization strategy (0.1147). Aligning the project with the organization's strategy will create a clear implementation objective. The fifth factor is the process of digitalization of the industry (0.1067) which a well-indicated process to digitalize would create a steady work process with a clear information flow. The first step would be to educate the leaders and top managers about Industry 4.0. There are many courses related to Industry 4.0 in Thailand, such as courses from TGI or SIMTEC. Lastly, an employee with skills and knowledge in Industry 4.0 would help the project implementation become easier. The other choice is outsourcing an expert on the solution related to Industry 4.0 to help implement. With help from an expert or skilled

employee, it is possible to create a steady process to digitalize which will lead to the excellent step for implementing Industry 4.0.

## V. CONCLUSION

In this research, the key success factors are identified for Thailand manufacturing firms to implement Industry 4.0. The potential factors were identified using a literature review and semi-structured interviews with 2 top experts using the Delphi method. Then, the Analytic Hierarchy Process (AHP) is applied to find the top 5 factors. There are 13 experts who are managerial level related to Industry 4.0 completed the questionnaire. Analytic Hierarchy Process (AHP) was applied to find the relative weight of important success factors to rank the importance of the success factors and give concrete guidance to implement Industry 4.0.

Based on this research, we recommended that the factors that should be considered when implementing Industry 4.0 for Thailand manufacturing are leadership vision, support from top management, knowledge of technology by an employee, aligning Industry 4.0 with organization strategy, and the process to a digitalization of the industry.

For starters, the top management needs to have knowledge about Industry 4.0. It would be risking to invest their money in the unknown.

## ACKNOWLEDGMENT

This research is fully supported by the Center of Excellence in Logistics and Supply Chain System Engineering and Technology (COE LogEn), Sirindhorn International Institute of Technology (SIIT), Thammasat University. We would like to show our gratitude to all the experts who helped with the questionnaire construction. Without their assistance, we would not have completed a questionnaire for this research. We are truly thankful for their support.

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