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Research Paper

The satisfaction level of SMES with smart factory introduction using cluster analysis

Jeong-Yoon Oh [1] *, Sang-Hyun Choi [1]

[1] *Dept. Management Information Systems, Chungbuk National University, Chungdae-ro 1, Seowon-Gu, Cheongju, Chungbuk 28644, Korea*
**Corresponding author E-mail: Jyoon518@gmail.com*

Abstract

Background/Objectives: It is necessary to confirm whether the introduction of smart factory is moving in the right direction for SMEs applying the basic stage of Smart Factory. We would like to investigate the characteristics of the company according to satisfaction levels of Smart Factory introduction.
Methods/Statistical analysis: We collected the questionnaire of companies applying the basic level of Smart Factory and conducted a cluster analysis on the whole data. Four groups were classified into two groups with low satisfaction level and two groups with high satisfaction level. To investigate the characteristics of each group, we conducted a cluster analysis of each group to identify the difference according to satisfaction.
Findings: The group with low satisfaction was divided into two clusters. One applied MES and the improvement of defect rate is as low as 8%, the other applied ERP and the expectation of quality improvement is high. The groups were divided into three groups. The first one is the group that wants to proceed to next stage regardless of the governmental support without staying at the basic stage. The second one is the group that applied MES and considers governmental support important when progressing with the intermediate 1st stage. And last one is the group that has the highest rate of Equipment linkage, productivity improvement, sales growth and improvement of defect rate.
Improvements/Applications: This paper will help to benchmark companies that are introducing smart factories. However, it would be a better study if we carry out research that increases the number of data and predicts satisfaction.

Keywords: *Use about five key words or phrases in alphabetical order, Separated by Semicolon.*

1. Introduction

Major developed nations have announced new innovation policies to respond to the crisis of manufacturing and pay attention to its importance. Germany announced 'Industry 4.0' in 2012, and it is said that it will build a smart factory through the fusion of manufacturing and ICT. The EU announced 'Factories of the Future' in 2013 to make the manufacturing process more flexible and networked. The United States announced 'Remaking America' in 2009 to promote cutting-edge manufacturing technology innovation and revitalization of industrial robots. In 2016, Japan announced the realization of the Fourth Industrial Revolution in the Industrial Recovery Plan [1].
Korea also announced 'Manufacturing Innovation 3.0' at the Ministry of Commerce, Industry and Energy. To cope with the ongoing manufacturing crisis, the government has formed a 'Smart Factory Promotion Team' to support the smartization of factories. As of the end of September 2016, 2,611 smart factories were built and significant results were achieved [2]. And they announced that the public-private partnership planned to support smart factories of more than 2,200 SMEs by investing 101.8 billion won within 2017 [3].
Since the 'Manufacturing Innovation 3.0', the establishment of smart factory has been accelerated by the government's support, and it is attracting the attention of SMEs dreaming of innovation in manufacturing. In addition, researches on smart factory promotion strategies and considerations for establishing SMEs are being conducted. At this point, it is necessary to confirm whether the Smart Factory is moving in the right direction.
In this study, we surveyed SMEs applying the basic level of Smart Factory to identify the status and features of Smart Factory adopters. In addition, I would like to find out the difference between the satisfaction level and the satisfaction level.

2. Materials and methods

2.1. Smart factory

Smart Factory means an intelligent factory that enhances quality, cost reduction, and productivity by combining information and communication technology (ICT) in all necessary processes of producing products.
The ultimate goal of Smart Factory is to realize a manufacturing company to achieve productivity improvement and production cost reduction response to rapidly changing external environment and customer demand by intelligentizing, flexible, optimizing and streamlining production system and actively [4].
There are vertical integration based on production facilities and horizontal integration based on value chain in Smart Factory [5].
Smart Factories are classified into four stages according to level and field, and they are divided into basic stage, intermediate 1st stage, intermediate 2nd stage and advanced stage according to the

degree and capability of IT industry. Table 1 shows the level of construction of smart factories provided by KOSF (Korea Smart Factory Foundation) [6].

Table 1: Level of Construction of Smart Factory [6].

Stage	Automation	Plant operation	Business
Advanced stage	IoT-type automation combined with control automation and digital identification	Intelligent production with self-diagnosis and control capability using CPS, IoT, Big data	Real-time customized service through value chain linkage
Intermediate 2 stage	Automation of facility control	Real-time decision making and facility direct control	Real-time decision-making and control by actively responding to market and customer needs
Intermediate 1 stage	Real-time data collection from the facility	Performance-oriented factory operation analysis	Real-time information exchange based on information management and factory operation
Basic stage	Level of basic logistics information collection through barcode and RFID	Performance management focusing on process logistics	Quality history management through lot-tracking

Companies that do not use ICT conducting the process monitoring manually and manage it with paper documents. These companies will enter the basic stage of Smart Factory through ICT application. At the basic stage of smart factory, basic process information is collected through barcode, and production management is carried out based on collected data. In the intermediate 1st stage, the sensors automatically collect the real-time data and establish the optimal production environment. In the intermediate 2nd stage, the facility control can be automated to control the process in real time, and real-time management is performed based on the accumulated data and analysis technology. In the advanced stage, a real-time dialogue between modules is established and the business is carried out by automating the self-diagnosis and control.

2.2. Big data in manufacturing

As the Smart Factory is promoted as a new innovation policy of the manufacturing industry, the data of various fields arising from the equipments are analyzed in connection with the big data technology. This trend can be confirmed by manufacturers' interest in big data. A study by Forbes found that 47% of manufacturing companies said Big Data affected company performance7. As shown in Figure 1, in the SCM World survey, Big Data analysis was selected as the factor that would have the greatest impact on changing the operation and management of future manufacturing environments [8].

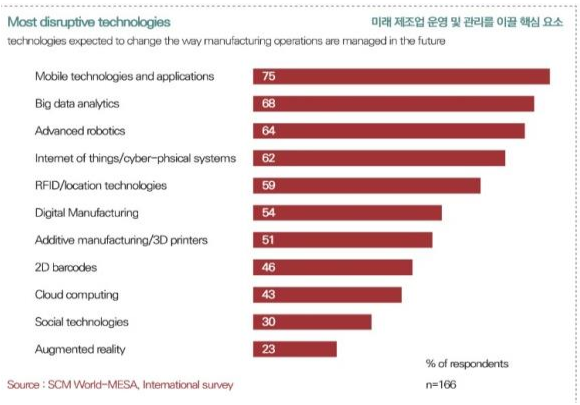

Fig. 1: Key Factors Driving Future Manufacturing Operations and Management [8].

As shown in Figure 2, in particular, real-time analysis of big data technologies is expected to have the greatest impact. Real-time factory performance analysis (57%) and real-time re-planning (42%) were the top respondents [8].

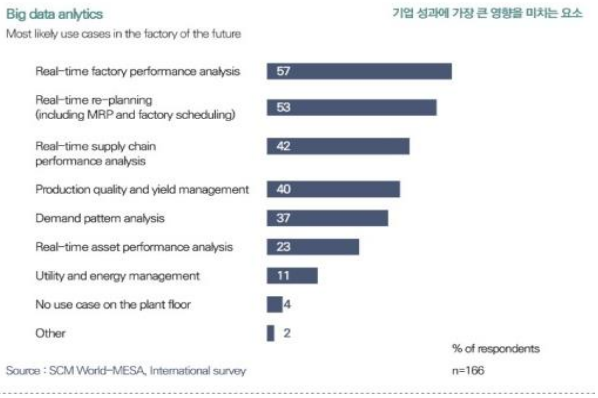

Fig. 2: Factors That Have the Biggest Impact on Company Performance [8].

2.3. Cluster analysis

The cluster analysis is a collection of similar records that measure the distance between records, and then group the records closer together[9]. In general, there are two types of clustering algorithms, and there are several implementation algorithms according to each methodology[10].

There are two methods of hierarchical methods. One is an agglomerative analysis in which n records are regarded as one cluster and each cluster having similar characteristics is combined. The other is a divisive analysis in which the entire record is regarded as a cluster and then the data with different characteristics is separated[9].

The non-hierarchical method is a method of clustering without specifying the number of clusters, and it is necessary to provide the number of clusters after anticipating to be divided into several clusters in advance. The most commonly used method for non-hierarchical methods is k-means analysis. In this method, the number of clusters is determined, and the distance from each record to the center of k predefined clusters is determined and allocated to the closest cluster[9].

3. Analysis

3.1. Basic analysis

This study was conducted to survey the companies that will introduce or introduce smart factories, and it was set up to apply the Smart Factories above the basic level. The questionnaire was prepared based on expert opinions of KOSF. The questionnaire was answered by face - to - face interviews with KOSF experts. A total

of 140 questionnaires were retrieved. Of these, 11 companies were excluded from the survey to analyze the firms applying the Smart Factory basic level or higher. Of the remaining 129 cases, 125 were used for the analysis except 4 cases with poor response status. The total number of variables is 25. Table 2 shows the variables used in this study.

Table 2: Variables Used in the Analysis

Variable	Survey contents
Business type	What is your business type?
Location	Where is your business location?
Sales	How much is your sales last year?
Employees	What is the approximate number of your employees?
Intermediate 1 stage biggest difficulty	What is the biggest difficulty for a company when implementing the Smart Factory the intermediate 1 stage (all facilities)?
Difficult level after 3 years	Do you think it will be the most difficult for you to enter the Smart Factory during the next three years?
System	What system did you first introduce when building your Smart Factory?
Intermediate 1 stage Promotion	Will your company perform upgrading from the basic stage (some facilities) to the intermediate 1 stage (connecting all facilities) during the Smart Factory promotion?
Satisfaction	How satisfied are you with applying the basic step smart factory applied to your company?
Intermediate 1 stage Requirements	What do you need most when you go to Intermediate 1 stage after applying the basic stage?
Director	Do you have directors and operators who are dedicated to managing Smart Factory related operations?
Connection of measuring equipment	How much of your production measurement equipment does you have in direct connection with the server?
Connection of production facilities	How much of your production facility does your company have direct connections with the server?
Appropriate level (within 5 years)	When considering your business environment, what level are you planning to target after five years of Smart Factory?
Stay at the basic stage	If you want to stay longer at the basics stage, why?
No government second support	What is the most realistic plan if the government does not second support it?
Company History	How long have you been established?
Motivation	What was the biggest motivation for implementing the Smart Factory?
Productivity Improvement	How do you think the application of the current Smart Factory system will improve productivity?
Application period	How long have you been applying SmartFactory to your production site?
Increase in sales	How do you think the application of SmartFactory at the current level will affect the sales growth of products?
Promotion of advanced stage	When do you think you can achieve Smart Factory final level of improvement (unattended automation)?
Investment	What level of investment do you think each year?
Improved defect rate	Do you think applying smart factory system at current level is effective in improving defect rate?
Propulsion speed	Do you think that your Smart Factory promotion is fast compared to domestic competitors?

First, to analyze the characteristics of collected survey data, cluster analysis was performed using Simple Kmeans in Weka3.6. Cluster analysis was performed on 125 data, and 25 variables were used.

As the number of clusters was changed from 2 to 6, it was difficult to find distinct clusters. Among the four clusters, some significant features were derived. As shown in Table 3, four groups were classified into two groups with low satisfaction level and two groups with high satisfaction level.

Table 3: Cluster Analysis of Whole Data

Cluster0(N=47)	Cluster1(N=22)	Cluster2(N=31)	Cluster3(N=25)
Appropriate level (within 5 years): Intermediate 1 stage	Appropriate level (within 5 years): Advanced stage	Promotion of advanced stage:Less than10 years	Improved defect rate: Less than20%
Increase in sales:Less than5% satisfaction:3.21	Increase in sales: Less than10% satisfaction:3.72	Increase in sales: Less than5% satisfaction:3.41	Increase in sales:Less than10% satisfaction:3.64

The number of companies with 1, 2, and 5 satisfaction were few, and the number of companies with 3 and 4 satisfaction were high. Therefore, the difference in satisfaction between groups with low satisfaction and high satisfaction group is not significant. However, the difference in the results of cluster analysis was obvious when the two groups were divided by the average satisfaction. Based on the average satisfaction level of 3.4, the cluster with low satisfaction is Cluster0 and Cluster2, and the cluster with high satisfaction is Cluster1 and Cluster3.

Cluster0 thinks it is appropriate to equip the intermediate 1 stage within 5 years, and the sales growth rate after the Smart Factory is less than 5%.

Cluster2 has a sales growth rate of less than 5% after introducing Smart Factory, and plans to push Smart Factory advanced stage within 10 years.

Cluster1 thinks it is appropriate to have an advanced stage facility within 5 years, and it is a group whose sales growth rate is less than 10% after introduction of smart factory.

Cluster3 is a group with sales growth rate of less than 10% and defect rate improvement of less than 20% after introduction of Smart Factory.

Comparing Cluster0 and Cluster2, which are low satisfaction groups, and Cluster1 and Cluster3, which are highly satisfied groups, the group with low satisfaction has lower sales growth rate and defective rate improvement than the group with high satisfaction.

Based on these results, this paper classified the satisfaction level 3 as low because the average of satisfaction was 3.4 points. The results of this study are as follows. I would like to analyze the cluster analysis between the companies with 4-5 satisfaction and the satisfaction 1-3 and find out the difference between the high satisfaction level and the low satisfaction level.

3.2. Depth analysis

3.2.1. Characteristic

As shown in Table4, when we look at the general characteristics of responding companies, companies with high satisfaction are mostly in Chungcheong and Gyeonggi provinces. In the business sector, 58% of other industries, 14% of electronic components and 8% of surface treatment are in order. More than 20 to less than 100 employees account for more than half of the employees. Sales are less than 5 billion and more than 40 billion are 23%.

Companies with low satisfaction are mostly located in Gyeongsang Province and Gyeonggi Province. Other industries account for 52%, while casting and molds account for 10%. Employees are more than 20 to 100 people, more than half of them are satisfied, and more than 40 billion are 25%.

Table 4: Basic Characteristics of Companies with High Satisfaction and Low Satisfaction

		High satisfaction (N=65)		Low satisfaction (N=60)	
		N	%	N	%
Area	Seoul	0	0%	2	3%
	Gyeonggi	13	20%	12	20%
	Incheon	3	5%	2	3%
	Chungcheong	14	22%	9	15%
	Daejeon	1	2%	1	2%
	Kyungsang	11	17%	15	25%
	Daegu	11	17%	5	8%
	Busan	8	12%	10	17%
	Jeonra	1	2%	1	2%
	Gwangju	3	5%	3	5%
Sectors	Electronic parts	9	14%	5	8%
	casting	2	3%	6	10%
	Plated	4	6%	3	5%
	mold	4	6%	6	10%
	food	2	3%	4	7%
	Surface treatment	5	8%	1	2%
	Heat treatment	1	2%	4	7%
	Etc	38	58%	31	52%
Employees	Less than 20	6	9%	9	15%
	Less than 50	26	40%	18	30%
	Less than 100	16	25%	14	23%
	Less than 200	7	11%	9	15%
	More than 20	10	15%	10	17%
Sales	Less than 5 billion	15	23%	8	13%
	Less than 10 billion	14	22%	14	23%
	Less than 20billion	9	14%	13	22%
	Less than 40 billion	12	18%	10	17%
	More than 40 billion	15	23%	15	25%

3.2.2. Cluster analysis

According to satisfaction, 1-3 were classified as low satisfaction group and 4-5 were classified as high satisfaction group. As a result, 61 low satisfaction group and 68 high satisfaction group were classified. After classification, cluster analysis on high satisfaction and low satisfaction groups was performed using Simple K means in Weka3.6, a data mining tool. The variables used were 24 variables excluding 'satisfaction'.

1) Low satisfaction group

As shown in Table 5, as a result of the cluster analysis on the low satisfaction group, it was divided into two groups: 26 for Cluster0, and 35 for Cluster1. The characteristics of each cluster are as follows.

Table 5: Cluster Analysis of Low Satisfaction Group

Low satisfaction group	
cluster0(N=26)	cluster1(N=35)
system : MES	system : ERP
Improved defect rate: Low defect rate improvement (Average 8%)	motivation : improve quality

① Cluster 0

Cluster 0 applied MES and the defect rate improvement is an average of 8%. This cluster was expected to produce optimal production activity by introducing MES, a production management system, but it did not show much improvement in the defect rate, which shows that satisfaction with introduction of smart factory is low.

② Cluster 1

Cluster 1 adopts ERP and has a high expectations of quality improvement. The ERP system does not directly improve quality because it is a system that improves the business processes by integrating processes related to management activities such as production, logistics, finance, accounting, sales / purchasing, and inventory in the enterprise. Although the Smart Factory was promoted with expectation of quality improvement, it can be regarded as a cluster with low satisfaction because the ERP system can not achieve the quality improvement.

2) High satisfaction group

As shown in Table 6, as a result of the cluster analysis of the high satisfaction group, it was classified into three groups: cluster 0, cluster 1, and cluster 2. Cluster 0 was the group with the lowest improvement in productivity, sales growth and defect rate (productivity improvement: 12%, sales increase: 7%, defect rate improvement: 10%). cluster2 was the group with the highest productivity improvement, sales growth and defect rate improvement (productivity improvement: 26%, sales increase: 18%, defect rate improvement: 22%). The productivity improvement, the increase in sales, and the defect rate improvement of cluster0 were found to be the lowest among the cluster of companies with high satisfaction, but higher than those of two groups with low satisfaction. The characteristics of the cluster with high satisfaction are as follows.

Table 6: Cluster Analysis of High Satisfaction Group

High satisfaction group		
cluster0 (N=11)	cluster1(N=25)	cluster2 (N=32)
stay at the basic stage : Do not want to stay at basic stage	system: MES	Connection of measuring equipment: High Equipment connection ratio (Average 37%)
No government second support: Regardless of Support	intermediate 1 stage Requirements: Government support	Productivity Improvement: High Productivity Improvement (Average26%)
	stay at the basic stage: investment cost	Increase in sales: High Improve sales (Average 18%)
		Improved defect rate: Low defect rate improvement (Average 22%)

① Cluster 0

Cluster 0 does not want to stay at the basic stage, and it is a group that will pursue regardless of the impossibility of second supporting of the government. This cluster can be regarded as a cluster with a high level of willingness to pursue, since it wants to proceed to the intermediate 1st stage consistently in the two items.

② Cluster 1

Cluster 1 applied MES and considers governmental support important when progressing with the intermediate 1st stage. They think the reason for staying at the basic stage is the investment cost. This cluster has been successful in improving productivity, increasing sales and improving defect rate by adopting MES. This group would like to move on to the intermediate 1 stage, but due to the investment cost, it is currently at the basic stage. This cluster seems to be expected to be promoted through the government support.

③ Cluster 2

In cluster 2, the equipment connection ratio is as high as 37%, and productivity, sales increase, and defect rate improvement are the highest. This group has the highest rate of equipment connection, so it is highly satisfied with productivity improvement, sales increase, and defect rate improvement.

4. Conclusion

In this study, we conducted a questionnaire survey on SMEs in the basic stage with the introduction of Smart Factory. Then, we analyzed the current status and characteristics of SMEs, and found that there is a difference between enterprises with high satisfaction level and those with low satisfaction level. We conducted a cluster analysis of all companies to see what characteristics they have. As a result, two of the four clusters were lower than the average satisfaction (3.4), and the two clusters were higher than the average satisfaction. In the low satisfaction cluster, the improvement rate

of the sales growth rate and the defective rate is lower than that of the high satisfaction group, and it can be confirmed that the goal to reach within a relatively short period is low.

After confirming these differences, cluster analysis was conducted to identify the individual characteristics of the groups with high satisfaction and low satisfaction.

The group with low satisfaction was divided into two clusters. One applied MES and the defect rate improvement was as low as 8%, the other applied ERP and the expectation for quality improvement is high. The groups with high satisfaction were divided into three groups. A group that does not want to stay at the basic level but wants to promote without governmental second support, MES is applied and the government support is most important in the intermediate 1 stage promotion, and the investment cost is the reason to stay at the basic stage. Finally, the equipment connection ratio is the highest at 37%, with the highest rates of productivity improvement, sales growth, and defect rate improvement.

In this study, we conducted a cluster analysis of SMEs that have established the basic stage of Smart Factory, and confirmed the difference between companies with low satisfaction level and those with high satisfaction level. This can be used as a reference for companies that are planning to introduce smart factories. It can be used for satisfaction evaluation which is one of the evaluation factors of smart factory. It is meaningful that it presents characteristics according to satisfaction based on actual company data.

There are some limitations to this study. First, the number of data is very small, 125, which can be overfitted to produce inaccurate results. In addition, it is also necessary to estimate the satisfaction as well as to confirm the simple characteristics. In order to supplement this, it is necessary to increase the number of data and to derive a general result. It is also necessary to study ways to improve the satisfaction through predictive analysis.

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