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Factors that Drive the Adoption of Smart Factory Solutions by SMEs

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Abstract

This paper aims to analyse the factors influencing the implementation of smart factories and their performance after implementation, using the grounded theory analysis method based on interview data.

The research subjects were 21 companies that were selected by the Smart Manufacturing Innovation Promotion Group under the SME Technology Information Promotion Agency in 2020-2021 as the best case smart factory implementation companies, and introduced the intermediate stage 1 or above. A total of 87 concepts were generated as a result of the analysis. We were able to classify them into 16 detailed categories, and finally derived six broad categories. These six categories are “motivation for adoption”, “adoption context”, “adoption level”, “technology adoption”, “usage effect” and “management effect”. As a result of the overall structure analysis, it was found that the adoption level of smart factory is determined by the adoption motivation, the IT technology experience affects the adoption level, the adoption level determines the usage and usage satisfaction, internal and external training affects the usage and usage satisfaction, and the performance or results obtained by the usage and usage are reduced defect rate, improved delivery rate and improved productivity.

This study was able to derive detailed variables of environmental factors and technical characteristics that affect the adoption of smart factories, and explore the effects on the usage effects and management effects according to the level of adoption. Through this study, it is possible to suggest the direction of adoption according to the characteristics of SMEs that want to adopt smart factories.

Keywords : Environmental Factors, Technological Characteristics, Smart Factory, Management Effect, Utilization Effects, Grounded Theory

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1. Introduction

Smart factories have emerged as an important topic after the Fourth Industrial Revolution, and many companies are realizing the need to introduce smart factories [Yoo et al. 2023].

While large companies are adopting smart factories and leading the way in terms of time and technology, there are various constraints for SMEs to take the lead in adopting smart factories [Yim, 2020].

It has been observed that various environmental factors influence the adoption of smart factories by SMEs. However, the extent to which environmental factors influence the adoption of smart factories by SMEs is not well understood, so this study aims to identify the extent to which environmental factors influence the adoption of smart factories by SMEs.

It is assumed that the technical characteristics of an organisation will affect its adoption of smart factories. However, it is not known to what extent the technical characteristics affect the adoption of smart factories by SMEs, so this study aims to provide guidelines for companies' smart factory adoption strategies by identifying the relationship between technical characteristics and smart factory adoption [Lee, 2019].

2. Research Background

2.1 Definition of Smart Factory

Based on the definitions of previous researchers, this study defines.

"A smart factory is a factory that integrates the entire process of product planning, design, and production with ICT technologies such as the Internet of Things, artificial intelligence, and big data to increase productivity, reduce energy, and create a human-centred work environment."

2.2 Deploying Smart Factories for SMEs

According to government disclosures, starting with the diffusion of 277 small and medium enterprises in 2014, a total of 5,003 enterprises have been supported as of December 2017, with the goal of supporting the diffusion and diffusion of a total of 30,000 enterprises by 2025 [Ministry of SMEs and Startups, 2022].

The level of manufacturing innovation capability of enterprises is classified according to the degree of ICT technology use and smart

<Table 1> Smart Factory Adoption Levels

Step	Category	Field automation	Factory Operations	Enterprise Resource Planning
1	ICT not applied	handwork	handwork	handwork
2	basics	Automated performance aggregation	Process logistics management (POP)	Individual operation of management function-oriented functions
3	Medium1	Automatic aggregation of facility data	real time Decision	Integration between features
4	Medium2	Facility control automation	real time factory control	Integration of factory operation
5	Advancement	IoT/IoS	Diagnosis and operation based on IoT/IoS (modular) big data	
		CPS based on IoT/IoS		

factory capability, and the five essential requirements of smart factories are (1) digitisation of 4M+1E, (2) integration, (3) intelligence, (4) engineering knowledge creation, and (5) connection with smart systems [Ko, 2021].

2.3 Review of Existing Smart Factory Research

In an analysis of previous studies on smart factories, Gil [2019] conducted an empirical analysis of the impact of technical factors (uncertainty, relative advantage, fit, and intangibility), organisational factors (entrepreneurship, firm size, financial readiness, and absorptive capacity), and environmental factors (government support, business environment, and consulting support) on the intention to adopt smart factories.

In a study of the relationship between the individual factors that determine the adoption of smart factories and the intention to adopt, Park [2020] found that technological factors (experts, technology readiness) affect the intention to adopt smart factories, higher technology readiness has a positive effect on the adoption of smart factories, and better availability of experts has a positive effect on the adoption of smart factories.

Kim [2021] conducted a hypothesis test on the impact of independent variables on adoption intention in relation to smart factory adoption and found that effort expectation and social influence were not significant on adoption intention, while financial factors, performance expectation, facilitating conditions, government support expectation, CEO willingness and ICT utilisation capability had a positive impact on adoption intention.

3. Case Studies and Grounded Theory

3.1 Qualitative Case Study

Qualitative research is a research method that uses a subjective and interpretive approach [Ko, 2009]. The aim of the research is to understand the phenomenon as it occurs and the researcher needs to understand the phenomenon in context as a whole [Park, 2021].

Within qualitative research, the case study is an appropriate form of research when one wishes to examine how a phenomenon changes over time through intensive and holistic description and analysis of a single event, phenomenon or social unit [Merrim, 1998]. A qualitative case study is a useful research design for understanding and interpreting the uniqueness and complexity of a case as it unfolds within a critical context [Park, 2021].

In addition, because qualitative case studies can give meaning to everyday events and lead to a deeper understanding of complex phenomena [Ko, 2009], they are often used to place single or multiple cases in context and to explore bounded systems or the development of a particular case over time through diverse and rich data collection [Creswell, 1998].

3.2 Grounded Theory

Grounded theory, as defined by Strauss and Corbin [1990], is an iterative process of inductive and deductive induction from the phenomenon under study that exists in the field, allowing for the discovery, development, and tentative validation of a theory through the systematic collection and analysis of data appropriate to the phenomenon in question.

Therefore, research that applies grounded theory becomes an important resource for explaining the various changes that occur in contemporary society, aiming for a spiral of research that derives the mechanism of the process by reconstructing the phenomenon [Lee and Kim, 2011].

In addition, the inductive approach of validation, which involves hypothesis generation, comparison and inference through iterations of induction and deduction in the process of theory integration, and the selection of the assumptions that best explain the phenomenon, creatively confirms the relevance of categories and organises connections [Strauss and Corbin, 1990].

This approach to grounded theory is suitable for developing theories and models by empirically validating phenomena in the real world and identifying related phenomena [Fawcett, 1989]. Among the different positions of grounded theory, this study adopts the position of Strauss and Corbin [1990].

4. Methods

4.1 Study Design

This study followed the grounded theory research procedures of open coding, axial coding, and selective coding as suggested by Strauss and Corbin [1998].

In the open coding process, each interview was broken down into smaller units, such as phrases, sentences, and paragraphs, to identify their meaning and extract concepts that fit the meaning. The interviews were combined into one large file, and similar concepts were grouped together to compare and categorise the results of the analysis of each interview.

Categories are concepts that represent phenomena, and these categories are further divided into subcategories that clarify and refine the categories.

Axial coding is the process of linking categories to subcategories. It is called axial because it takes place around the axis of a coded category, linking categories at the level of attributes and dimensions.

The paradigm proposed by Strauss and Corbin [1998] was used to clarify the relationships between the categories by dividing them into central phenomena and situations (causal, contextual, and mediating conditions), and action and interaction strategies and outcomes.

We used a paradigm model to link categories, explore the contextual relationships of key phenomena, and identify the properties and dimensions of individual categories to provide a basis for developing a theory of entities.

Selective coding is the process of integrating and refining the theory. Using the relationships, attributes, and dimensions of the categories identified in the axial coding, the hypothesised relationships underlying the theory of entities are presented and typified.

By analysing the process of how the circumstances surrounding a central phenomenon can interact and influence its outcome over time, we clarify the story and present a levelled model of the situation that can serve as a direct basis for a theory of entities.

After the researcher's primary analysis was completed, the analysis team checked for consensus to ensure the validity of the categories.

4.2 Collecting Data

One of the best implementation cases selected by the Smart Manufacturing Innovation Promotion Group under the SME Technology Information Promotion Agency. The analysis is based on interviews with selected companies in 2020-2021.

Interviewees include senior decision-makers who have implemented and operationalised a Smart Factory, and 3-4 employees from each company involved in the project.

Excluding top decision makers, 2-3 respondents are middle managers, senior level, such as deputy general manager, general manager and general manager, and 1-2 respondents are workers, junior level, such as deputy, employee and foreman.

Interview questions include: what prompted you to adopt Smart Factory, how you overcame difficulties, the impact of the implementation, what you liked and didn't like about the implementation, problems you had before the implementation, what has changed since the implementation, and what you are satisfied with.

5. Analysis

5.1 Open Coding and Categorization

5.1.1 Open Coding Results

Open coding is the process of generating concepts from data, then grouping them into similar concepts, then into subcategories of more abstract concepts, and then into more logical and abstract conceptual categories.

Based on the interview data, the researcher conducted open coding by constantly asking questions and comparing and analysing the data.

I used a combination of deductive and inductive thinking as described by Strauss and Corbin [1990].

While watching interviews about the adoption of smart factories, I first hypothesised in my head what factors would have an impact, collected and categorised concepts that fit this logic, and used a deductive method to check the appropriateness of the categorisation.

I also used an inductive method to group similar concepts into categories, discovering logic as I went along and refining the wording of each category to fit it.

Open coding resulted in a total of 87 concepts.

I was able to group them into 16 subcategories.

I ended up with six broad categories.

These six categories are 'Motivation for introduction', 'introduction context', 'introduction level', 'Skill Acceptance', ' Utilization effect' and 'effectiveness of management.'

<Table 2> The Result of an Integrated Analysis of Concepts

Large categories	Subcategories	Concepts
Motivation for introduction	external pressure	Requests and proposals from partner companies, level of demand from customers, latecomers from China, competition with global companies
	government support	The government's smart factory support project, the support of the Creative Economy Innovation Center, and the support of the Smart Manufacturing Innovation Promotion Team
	Industry Trends	Introduction of smart factory system, introduction of ERP system, introduction of MES system, system establishment failure
	production environment	Occurrence of human errors, labor-intensive and dangerous production sites, labor-intensive work, retirement of senior employees, short delivery times
	Product Specifications	Multi-species production, various customer companies, mass production
	technical characteristics	Line production, repeatability, standardization, difficulty in quality control, production sites that require precise data, and outdated facilities

〈Table 2〉 The Result Of An Integrated Analysis Of Concepts(Continued)

Large Categories	Subcategories	Concepts
Introduction Context	It Technology Experience	Mes System Use Experience, Automation System Use Experience, It Technology Introduction Failure Experience, Pop System Introduction Experience
Introduction Level	System Introduction	Establishment Of System Integration Operation, Fast Decision-Making Based On Accurate Data, Development Of Artificial Intelligence Program, Establishment Of Voice Recognition Function, Establishment Of System Based On Big Data, Power Measurement System, Introduction Of Mes System And Cloud Service
	Facility Introduction	Establishment Of A High-Level Quality Control Site, Introduction Of Electronic Measuring Equipment By Introduction Of Pop System, Process Automation By Introduction Of Articulated Robot For Functional Inspection, Smartization Of Logistics System, Attachment Of Sensor Suitable For Product Characteristics, Input Of Production Information With Touch Screen
Skill Acceptance	Inside Itself Education	Erosion Of The Agitation That Jobs May Be Reduced, New System Education For The Elderly, Education For Foreign Workers, Role-Sharing Education According To Job Relocation, Sharing Of Common Values With Employees, Establishment Of In-House Colleges And In-House Training Programs
	External Support Education	Supplier Technology Review And Advice, Supplier-Supported Design Advice, Supplier Certification Maintenance Support, Supplier Idea Sharing, Supplier Business Solution Solution Program, External Expert Consulting, External Expert Diagnosing And Presenting Customized Factory Directions, Participating In Government Agency Education And Training Institute Training, Supporting Consultant Matching Free Training, Conducting Training And Consultation For Invited Smart Meister Employees
Utilization Effect	Usage	Automatic Calculation And Aggregation Of Performance And Production Status, Real-Time Data Check, Computerization Of The Entire Manufacturing Process, Accurate Data Extraction, Accuracy Of Manufacturing Product Information, Accurate Inventory Management
	Satisfaction With Use	Work Fatigue Improvement, Problem Solving Speed Improvement, Efficient Work Progress, Simple Repetitive Work Improvement, Manual Work Improvement, On-Site Quick Response Possible, Job Satisfaction Improvement By Reassignment Of Employees From Simple Repetitive Work To High Value-Added Work
Management Effect	Reduced Defect Rate	Reduction Of Design Defect Rate, Product Defect Rate, Occurrence Of 1 Defect Out Of 1 Million, Reduction Of Mold Defect Due To Number Of Strokes Management, Prevention Of Operator Mistake Due To System Construction Such As Barcode System, Reduction Of Process Defect Rate
	Improvement In Delivery Rate	Improvement Of Delivery Compliance Rate, Reduction Of Delivery Time
	Growth Of Production	Productivity Improvement Due To Reduction Of Machine Setting Time, Productivity Improvement, Facility Operation Rate Improvement, Production Efficiency Increase, And Reduction Of Man-Hours

5.2 Securing Category Validity

5.2.1 Analytics Team Consensus Work

〈Table 3〉 Interview Analysis Team Information

category	job
Coder 1	Worked at a manufacturing company in Seoul
Coder 2	Worked at an architectural consulting firm in Seoul
Coder 3	Worked at a manufacturing company in Gyeongnam

〈Table 4〉 How to Ensure Category Validity

formula	source
$Validity(reliability) = \frac{Number\ of\ consensus}{total\ target\ count}$	Miles and Huberman (1994)

5.2.2 Result of Validity Analysis by Category

Out of a total of 336 episodes, 282 episodes were agreed by the independent coders, giving a result of 0.839. Specifically, category 16

<Table 5> Result of validity analysis by category

	category1 (external pressure)	category2 (government support)	Category3 (Industry Trends)	category4 (production environment)
episode	16	23	9	36
match count	14	19	8	29
number of discrepancies	2	4	1	7
result	0.875	0.826	0.888	0.805
	category5 (Product Specifications)	category6 (technical characteristics)	category7 (IT technology experience)	category8 (system introduction)
episode	6	10	18	42
match count	5	8	15	35
number of discrepancies	1	2	3	7
result	0.8333	0.8	0.8333	0.8333
	category9 (Facility Introduction)	category10 (inside itself education)	category11 (external support education)	category12 (usage)
episode	30	27	13	24
match count	26	22	11	20
number of discrepancies	4	5	2	4
result	0.866	0.814	0.846	0.8333
	category13 (Satisfaction with use)	category14 (Reduced defect rate)	category15 (Improvement in delivery rate)	category16 (growth of production)
episode	27	21	7	27
match count	22	18	6	24
number of discrepancies	5	3	1	3
result	0.814	0.857	0.857	0.888
	total			
episode	336			
match count	282			
number of discrepancies	54			
result	0.839			

(productivity improvement) had the highest score, with 24 out of 27 episodes agreed, giving a score of 0.888, and category 6 (technical features) had 8 out of 10 episodes agreed, giving a score of 0.8.

This is the lowest result, but it's over 0.8, so it's valid.

5.3 Episode Classification Results by Category

<Table 6> Episode Classification Results

Large categories	Subcategories	number of sentences	total
Motivation for	external pressure	16	100
	government support	23	

Large categories	Subcategories	number of sentences	total
introduction	Industry Trends	9	
	production environment	36	
	Product Specifications	6	
	technical characteristics	10	
introduction context	IT technology experience	18	18
introduction level	system introduction	42	72
	Facility Introduction	30	
Skill Acceptance	inside itself education	27	40
	external support education	13	
Utilization effect	usage	24	51
	Satisfaction with use	27	
management effect	Reduced defect rate	21	55
	Improvement in delivery rate	7	
	growth of production	27	

5.4 Axis Coding

In order to derive a paradigmatic model of the environmental factors and technological characteristics that influenced the adoption of smart factories, the categories extracted by open coding were recoded.

Axial coding is the process of reassembling the findings from open coding to create a more systematic explanation of the phenomenon.

It identifies the attributes of categories and links them into subcategories along their dimensions, using paradigmatic models to show how categories are related [Strauss and Corbin, 1998].

5.4.1 Causal condition

A causal condition is the cause of a central phenomenon and is "an event or occurrence that leads to the occurrence or development of a phenomenon" [Strauss and Cobb, 1990].

5.4.2 External Pressure

Many of the drivers of smart factory adoption have been external pressures. Increasing customer demands, customer equirements and suggestions, competition from global companies and China's laggard status.

> "In addition, customers are becoming more demanding globally and our data collection rates are being linked to order opportunities. This has led to aggressive adoption for sustainable growth." (Vice President, Company N)
>
> "Hyundai actually suggested it first. Hyundai's suppliers were adopting MES as a whole, so we followed suit and adopted it to improve our overall production management capabilities." (Company C, CEO)

5.4.3 Government Support

The fact that various government departments supported the implementation of Smart Factories and continued to support the implementation of the next steps, not just once, was a motivation for the implementation of Smart Factories.

> "We have improved some of our manufacturing processes through this third round of support, but I think we still have a long way to go." (Company L, Director of Standard Division 1)
>
> "At that time, the Gwangju Centre for Creative Economy and Innovation provided us with 20 million won, so we decided to pursue MES." (M, CEO, Company M)

5.4.4 Industry Trends

The introduction and operation of new systems in the industry, such as those of competitors or suppliers, was cited by companies as one of the motivations for implementing the system. The mere fact that competitors or suppliers failed to introduce the system, or tried to introduce it but failed, was cited as a motivation to introduce the Smart Factory.

> "Hyundai actually suggested it first. Hyundai's suppliers were adopting MES as a whole, so we followed suit and adopted it to improve our overall production management capabilities." (Company C, CEO)

5.4.5 Production Environment

The presence of human error, labour-intensive production sites, or dangerous or labour-intensive tasks are motivating factors for adoption, and as senior employees approach retirement, companies are more likely to adopt these smart factory systems.

> "Initially, we were able to manage the manual method with people because the production volume was not large. However, as the size of the factory grew and sales increased, the existing manual production method became a factor that reduced productivity because it took a long time and caused errors." (Company T, CEO)
>
> "As a 30-year-old foundry, we have a lot of long-serving employees. I think there is a reason for this. Long-term employees who work in the production part have their own know-how, and even if the system is not supported, there is no difficulty in production based on the know-how of the technicians. However, if these people leave or change jobs, there will be a gap in the company." (Company C, CEO)

5.4.6 Product Specifications

Companies that produce large volumes, a wide range of products and a variety of customers are more likely to want to adopt an intelligent factory system.

> "We make 100 parts per minute and 6,000 parts per hour, and we operate in multi-product, high-volume production. Sometimes we lose a lot of money per hour when equipment or production efficiency goes down. Also, if we don't manage a lot of products by batch, we can't track production, and the range of products that have to be scrapped when defects occur is very large." (Company C, CEO)
>
> "When you're dealing with a lot of items, it's really hard to get all the workers to do it correctly. We're producing a fairly large number of products at a low cost to the consumer, so of course we're all looking for systems that can collect data". (Company G, CEO)

5.4.7 Technical Characteristics

Companies with line production or repetitive and structured production technologies cited the smart factory system as a motivation for implementing the system, while companies with difficult quality control or ageing equipment cited it as a reason for implementing the system. In addition, manufacturing sites that require accurate data also cited this as a reason for adopting smart factory systems.

> "Previously, workers would run very sim-

> ple repetitive tasks through the conveyor belt every time." (Company U, CEO)
>
> "When almost all the records from quotation to delivery are written manually, human error cannot be excluded, which inevitably affects quality. We decided to use it for accurate quality control." (Company L, CEO)

5.4.8 Contextual Condition

They are the "specific characteristics inherent in the central phenomenon" that influence the relationship between the causal conditions and the central phenomenon, and are the "specific conditions that lead to the choice of an action/interaction strategy" [Strauss and Corbin, 1990].

5.4.9 IT Technology Experience

Experience of using an MES or automation system appears to be a prerequisite for system adoption, and experience of failing to adopt IT technology is also cited as influencing the level of system adoption.

> "Even before the introduction of the Smart Factory, we started with the digitization of the site. As we developed the line with the link to MES, PLM, SCM, etc. in mind, we were concerned about the scope and processing method of the linked information." (Company Q, Team Leader)

5.4.10 Central Phenomenon

A central phenomenon is "a central life event, process, or occurrence that is related to a set of actions, interactions, or causes a response. angle, event, or incident" [Strauss and Corbin, 1990.

5.4.11 System Introduction

Building systems that enable integrated operations, making quick decisions based on accurate data, building voice recognition capabilities, and building systems based on big data will determine the level and scale of system adoption.

> "With the introduction of the PLM system, we were able to convert 3D to 2D in 2-3 hours instead of 3-4 days. This is a significant improvement. This is the result of three years of continuous consultation with the programme developer after the failure of the MES in 2017." (Company M, CEO)

5.4.12 Facility Introduction

The scale and level of equipment in a smart factory will be determined by establishing a high-level quality control site, introducing robots for quality inspection or articulated robots for functional inspection, automating processes, smartening logistics systems and attaching sensors to product characteristics.

> "The introduction of collaborative robots and the replacement of complex work elements by robotic arms is one of the biggest changes we have seen with smartisation. By transferring tasks that were previously performed by workers standing for long periods of time to robots, we have not only reduced the workload for workers, but also increased productivity and safety. In the end, smart factories benefit everyone in many ways." (Company R, CEO)

5.4.13 Intervening Condition

It is the 'structural conditions that influence the action/interaction strategies in relation to the central phenomenon. structural conditions that facilitate or hinder the performance of those strategies in a particular context [Strauss and Corbin, 1990].

5.4.14 Inside Itself Education

The introduction of the Smart Factory was met with both resistance and active participation from internal employees. The company continued to provide education and explanation to allay fears of job loss, trained senior and overseas workers on the new system, and promoted interactive strategies through various methods of internal self-education for the implementation and operation of the Smart Factory system.

> "It took a lot of trial and error to get used to the new environment, but we didn't stop there. We investigated the causes of every error that occurred and took corrective measures such as system modifications and user training." (Company S, Production Manager 1)

5.4.15 External Support Education

When implementing smart factories, we conduct various training activities not only through our own training but also through external institutions and companies. We are striving to increase the use of the Smart Factory system through various external training activities, including technical reviews and advice from suppliers, training to improve practical performance and develop leaders supported by the government, and know-how transfer through support for linking innovation activities tailored to the site using experts in each industry.

> "In the process of promoting smart factories, we were very concerned about how to actively involve employees. We held workshops at the company and sent them to the Kyungnam Education and Training Institute. We encouraged employees to participate by giving them high marks for completing the content." (J, Director, Company J)
>
> "We also invite smart meisters to provide relevant training and advice to our employees to improve their understanding of smart factories." (Company P, Managing Director)

5.4.16 Action/Interaction

> "Actions taken in response to a central phenomenon; strategies designed to adapt, manage, perform, or respond to the central phenomenon in a perceived concrete situation" [Strauss & Corbin, 1990].

5.4.17 Usage

It can be said to be an action taken in response to the central phenomenon by applying the system adoption part and the facility adoption part of the smart factory system to the automatic calculation and aggregation of performance and production status, as well as real-time data verification, computerisation of the entire manufacturing process, and accurate data extraction.

> "It is very convenient that the production status and the previous day's performance are automatically calculated and the profit and loss can be checked immediately. As a manager, I feel it is easier to manage than before. As long as the programme is installed, all employees can share the same sales and production status." (Company A, General Manager).

5.4.18 Satisfaction with Use

Depending on the level of adoption of the smart factory, it is possible to improve work fatigue, speed up problem resolution, efficient work progress, improvement of simple repetitive work, improvement of manual work, rapid on-site response, accurate inventory management, etc.

> "I used to write a lot of diaries a day and it took me 20-30 minutes to write each one. I felt burdened because I had to create a basic database for the workers. Now I can check the data just by looking at the ERP, so I think my work is 5 times faster." (Company B, Manager)
>
> "I think the biggest change is that even if there is a problem, we can solve it quickly through immediate feedback. In short, it has made it possible to work more efficiently and reduce work fatigue." (Company N, Quality Manager)

5.4.19 Consequences

It is 'the result or outcome of action and interaction and the moderated manifestation of the central phenomenon' [Strauss & Corbin, 1990].

5.4.20 Reduced Defect Rate

As the smart factory systems and equipment were implemented and used, the defect rate fell, and the defect rate fell in a number of ways, including a reduction in design defects, a reduction in product defects, only one defect in a million, and a reduction in process defects.

> "As a result, we have achieved positive results such as a 6% increase in productivity and an 11% decrease in defect rate after implementing the smart factory." (Company T, CEO)
>
> "In fact, since the implementation of the smart factory, the product defect rate has decreased from 0.8% in 2016 to 0.3% in 2019." (Company L, CEO)

5.4.21 Improvement in Delivery Rate

As the satisfaction of the employees implementing and using the smart factory increased, the delivery rate improved, the delivery standard yield increased and the delivery time decreased.

> "With better resource management, we have more confidence in our inventory. It's easier to produce and ship to customers at the right time, and our on-time delivery rate has increased from 88% to 98%." (Company U, CEO)
>
> "It used to take more than an hour to find the required threads before preparing for work, and more than a day to check for quantity or defects during the product shipping process. Now that the data is checked in real time, the work order process is reduced and the delivery time is shortened as the product is shipped immediately after production is completed. Looking at the actual performance indicators, the manufacturing lead time is reduced by 40%, the number of man-hours is reduced by 16%, and the delivery time is improved by 20%." (Company O, Business Management Department)

5.4.22 Growth of Production

The use of Smart Factory has led to productivity improvements in several areas, including reduced machine set-up time, increased productivity, improved equipment utilisation, increased production efficiency and increased productivity due to reduced labour.

> “The most tangible results are cost savings and productivity improvements. By redeploying the labour used for simple repetitive tasks to other production departments, we achieved cost savings of about 100 million won. We also achieved productivity improvements of 14.2% in the PCB inspection process and 20.2% in the voice inspection process. In the labelling automation process, productivity increased by 11.1% by reducing the number of workers by one.” (Company F, Research Manager)
>
> “The ability to automatically extract product design specifications from purchasing specifications has increased production efficiency by 25% and reduced production costs by 56%.” (Company E, CEO)

5.5 Selective Coding

Selective coding is the final stage of coding in which core categories are derived and theory is integrated and refined [Strauss and Corbin, 1990]. First, core categories are derived by linking categories and subcategories to form an outline of the narrative through which the participating companies can be observed, and then by explaining the content abstractly and conceptually. This process can be described as theory generation [Seol, 2016].

5.5.1 Core Category

A core category is a central phenomenon that unifies all categories.

After analysing the overall structure with the axial coding results, we found that

> “The motivation for adoption determines the level of adoption; experience with IT technology affects the level of adoption; the level of adoption determines usage and satisfaction; internal and external training affects usage and satisfaction; and the outcomes or results of usage and satisfaction are reduced defects, improved delivery rates, and increased productivity.”

5.5.2 Story Line

Storyline is a technique for theory synthesis and is the process of describing what the researcher knows about the study through instinctive senses gained through immersion in the data. It is a systematic description of the relationships between core categories and other categories. In other words, it is a process of conceptualisation through narrative description of how other categories relate to the core category. This narrative process should be followed by conceptualisation in the next step [Strauss and Corbin, 1990, 1998].

The companies in the study showed different types of motivations for adopting smart factories, including external pressure, government support, industry trends, production environment, product characteristics and technical characteristics. This means that motivation can be divided into environmental factors and technical characteristics, and adoption motivation can be considered as a causal condition. The level of adoption of smart factory is determined by the “IT technology experience” of existing enterprises, and the level of adoption can be divided into “equipment adoption” and “system adoption”.

Internal self-training and 'external support training' influence 'facility adoption' and 'system adoption' and promote 'usage' and 'usage satisfaction'. Usage and usage satisfaction are shaped by the central phenomenon in a perceived specific situation. Depending on 'usage' and 'usage satisfaction', 'defect rate reduction', 'delivery rate improvement' and 'productivity improvement' are the results.

6. Conclusion

6.1 Summary and Meaning of Study Results

In this study, interviews with smart factory best practices from the Smart Manufacturing Innovation Promotion Group were analysed using grounded theory in qualitative research. External pressure, government support, industry trends, production environment, product characteristics and technical characteristics emerged as the main factors motivating the adoption of smart factories.

The factors can be broadly divided into environmental factors, such as external pressure, government support and industry trends, and technical characteristics of the firm, such as production environment, product characteristics and production technical characteristics. Companies' experience with IT technology influences the level of adoption. The areas of adoption are divided into system adoption and equipment adoption, with smart factory adopters adopting both areas.

Depending on the level of adoption, companies have increased their usage and satisfaction after implementing smart factories, and internal and external training has an impact on promoting this usage and satisfaction. Management effects are shown in terms of usage and satisfaction, and defect rate reduction, delivery rate improvement and productivity improvement are shown as effects of smart factory implementation.

We were able to derive detailed factors of environmental factors and technical characteristics that affect the adoption of smart factories, and we found that these factors also affect the level of adoption. We found that the level of adoption affects the usage effect and the management effect, and the usage effect affects the level of usage and satisfaction, and the management effect affects the reduction of error rate, the improvement of delivery rate, and the improvement of productivity. In addition, we found that IT technology experience affects the level of adoption, and internal self-training and external support training affect the utilisation effect.

6.2 Implications of the Study

In this study, the environmental factors and technical characteristics that influence the adoption of smart factories were identified by analysing interview data. By synthesising external pressures, government support, industry trends and the production environment, product characteristics and production technology characteristics derived from the environmental factors and technical characteristics, we can provide guidelines for SMEs wishing to adopt smart factories in a new way.

In addition, it is possible to provide an appropriate level of introduction for enterprises with appropriate environmental factors and technical characteristics, allowing them to introduce smart factories in stages, identify their IT technology experience in advance to infer whether they will be able to introduce them successfully, and anticipate the effectiveness of their use through internal self-training and external support training. Based on these guidelines, government support for the deployment of smart factories can be further segmented and used as a basis for government policies to provide intensive support according to environmental factors and technical characteristics.

This study has examined the environmental factors and technical characteristics that influence adoption, and in the future it may be possible to investigate whether it is possible to skip stages of adoption, rather than sequentially increasing the level of adoption according to the level of IT technology experience.

In addition, at the introduction level, it is necessary to check how much the use, application and utilisation time is shortened depending on the level of internal self-education and external support education in the introduction of equipment and systems. In the case of the excellent construction companies, although they were selected as excellent construction cases in 20 or 21, it can be seen that the introduction starts from 18 and takes at least 2 to 3 years. It's important to look at how quickly it's implemented and how seamlessly the company is able to use the facilities and systems. If it is introduced quickly and settles in, the timing of the next stage of adoption will also be faster, and not only will domestic manufacturing SMEs become smarter, but the level of adoption will increase sequentially, increasing the likelihood of progression.

In addition, follow-up studies are needed to determine whether there are other factors besides the usage and satisfaction factors that have been identified as usage effects of smart factories, and if additional usage effects are identified, this could serve as a motivation for new companies to adopt smart factories.

In addition, based on the management effects of reducing defect rate, improving delivery rate and increasing productivity, empirical studies can be conducted on enterprises that have implemented and operated smart factories to determine which factors have the greatest effect, and the factors with the greatest effect will be used as the basis for further government policy support for new implementations and enterprises with low effectiveness, and the factors with poor management effects will be used as the basis for government support policies or the introduction of smart factory systems and equipment to maximize the effectiveness of the factors.

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