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A Study on Smart Factory Efficiency of Small and Medium-sized Enterprises Based on Electricity and Electronics

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Abstract. It is important to manage the analysis and utilization of various information and data generated in real-time to enhance the efficiency of the smart factory of electric and electronic-based small and medium-sized enterprises. The core task of a Smart factory is to establish an integrated data hub to process storage, management, and analysis in real-time, and to manage cluster processes, energy, environment, and safety in an integrated manner. Smart factory efficiency is important to improve reliability through accurate analysis and collection of production data by real-time monitoring of production site management for SMEs. In particular, as various advanced equipment related to artificial intelligence is included in the configuration of the Smart factory, the efficiency of data collection and utilization produced at the manufacturing site is gradually increasing. In this paper, we analyze the enterprise application cases of SCM, MES, and CPS, which are smart factory technologies applied to the manufacturing sites of SMEs based on electricity and electronics. By analyzing the platform technology competitiveness, which is the key to the introduction of the smart factory, it is intended to enhance the efficiency of applying and operating the smart factory for SMEs.

Keywords: Smart factory, data hub, real-time, SMEs, artificial intelligence, platform technology

1. Introduction

Smart Factory refers to an intelligent factory that improves quality, customer satisfaction, and productivity by combining automation solutions in the production process such as manufacturing and distribution and applying information communication technology to it. It is a next-generation factory that collects process data in real-time by integrating factory processes such as machinery with artificial intelligence, big data, and the internet of things, and then analyzes this data to control it automatically (Johannes Z et al., 2021; Mantravadi S et al., 2021). If the existing automated factory is a continuous process for conveyor belts, the smart factory performs self-diagnosis remote control for each module and actively finds the optimal process module. In other words, the smart factory uses digitalization to create an evolved factory that custom-produces product requested by customers in the shortest amount of time and at the lowest possible cost, which distinguishes it from existing uniform factory automation. If a smart factory is applied to each company, the status of the manufacturing industry will be strengthened further, and the entire process from production to service will be integrated, resulting in job creation and the attraction of high-quality labor (Lee et al., (2018)). As a result, in a smart factory, it is possible to analyze a large amount of data collected and systematize the factory operating system based on this data to solve problems at the production site, as well as identify the cause of the failure or poor quality. In addition, by accumulating each technology in the factory and systematizing it, the corresponding technologies can also be easily utilized (Osterrieder et al., 2019; Won et al., 2020). Smart factory is like the core of the 4th industrial revolution in which ICT is fused with manufacturing, and if technology is dependent on foreign countries, secrets in the production process are highly likely to be leaked to the outside. Therefore, according to the value creation, the government is encouraging the spread. Smart factory is organized from level 1 to level 5 as shown in Table 1 according to the competency of information and communication technology and the degree of technology utilization, and each stage is composed of a level that is the maturity index of the Smart factory (Soares et al., 2021).

Table 1: Reference model of smart factory

Level Definition	Standard	Properties (Main Tool)	Condition (Build Level)
Level 5	Autonomous Operation	Customized (AI, AR/VR, CPS etc.)	Autonomous progress from monitoring to control and optimization
Level 4	Optimization	Optimized (Sensor, Controller, Optimized Tool)	Proactive response possible through process operation simulation
Level 3	Control	Analyzed (Sensor+Analyzed Tool)	Controllable by analyzing the collected information
Level 2	Monitoring	Measured (Sensor)	Real-time monitoring of production information

Level 1	Inspection	Identified (Bar Code, RFID)	Partial standardization and Data management

The reason for defining the level in 5 stages of the Smart Factory reference model is that it is difficult for SMEs or mid-sized companies to make large-scale investments on their own to build a smart factory compared to large enterprises. Hence, a development strategy that evolves in stages and enters the sophistication stage based on the company's capabilities and capacity is required. Each level can be implemented in various forms according to the characteristics of the company, and smartization can be promoted step by step considering the situation the company faces(Chun et al., 2021; Lee et al., 2020). Many SMEs are building the basic stages (Level 1, Level 2) because they can easily enter at a relatively low cost. Looking at the above 5 steps, the basic step uses basic ICT to collect production information in the factory as bar codes and radio frequencies. It is the level of establishing an information system at the minimum cost by identifying the production process for each product production unit and creating product history management. Level 3 is a level that aims for automation by automatically operating facility information and sharing reliable information with the parent company. Quality analysis is possible with real-time data collection, allowing for the establishment of an efficient production plan and decision-making. Level 4 optimizes production by achieving a controlled factory and enabling real-time decision-making. Level 5 is a fully intelligent factory, a service factory that realizes business in cyberspace to produce and deliver in real-time according to customer needs (Hussain et al., 2021; Arden et al., 2021). When the smart factory is applied to the electrical and electronic component assembly process, the aggregated analysis of production information is systematized at the basic level. As work productivity increases and transaction information is provided in real-time, ties with customers can be strengthened. At the intermediate level, automation of production performance counting is realized to improve production concentration and work efficiency. In addition, by providing engineering data, order receipts are increased by improving customer trust (Rok 2021; Park et al., 2020). This paper is a study on the efficiency of SME Smart Factory based on electricity and electronics. This is an analysis of corporate application cases such as SCM, MES, and CPS, which are smart factory technologies applied to manufacturing sites. It is also intended to improve the efficiency of applying and operating the smart factory to SMEs by analyzing the platform technology competitiveness, which is critical to the introduction of the smart factory.

2. Analysis of Related Technologies and Applied Companies

2.1. SCM, MES and CPS

In SCM (Supply Chain Management), one can easily check the real-time workflow with a PC or mobile device by attaching bar codes and QR codes to work orders created by computer input and handwritten records. By connecting to the company program from the outside with a Tablet PC and Smart Phone, the delivery schedule can be checked immediately, improving customer reliability. If it is difficult to produce customized according to the design drawings provided by the customer and it is impossible to make it ahead of time, the delivery schedule, as well as the quality, must be met. In this case, if SCM is used, it is possible to monitor the entire process in real-time, from product receipt to final shipment, using a PC and a mobile device. In addition, it is possible to check the real-time status of the intermediate key stage immediately. Therefore, workers can check the tasks to be done according to the schedule, and customers can receive products on time, which increases efficiency (Adnan et al., 2016). GPN, a small and medium-sized company, an electrical and electronic PCB company, saw a 10% increase in sales with the introduction of SCM, and the system accuracy reached 80-90%. In addition, job creation occurred as the number of orders increased due to improved reliability.

MES (Manufacturing Execution System) is a field system that can integrate and analyze data in real-time by applying standardization of the production operation process through PI (Process Innovation). Fig. 1 represents the MES system. It makes it possible to check and monitor the production status in real-time. Therefore, it is a field system that helps workers and managers make quick decisions and play a key role in the establishment of a smart factory. MES collects and analyzes on-site information in real-time using barcodes for raw material warehousing and outgoing, enabling product tracking and quick decision-making. By managing the incoming and outgoing raw materials with barcode labels, it is possible to track when a defect occurs. Therefore, productivity is improved by monitoring the production status in real-time.

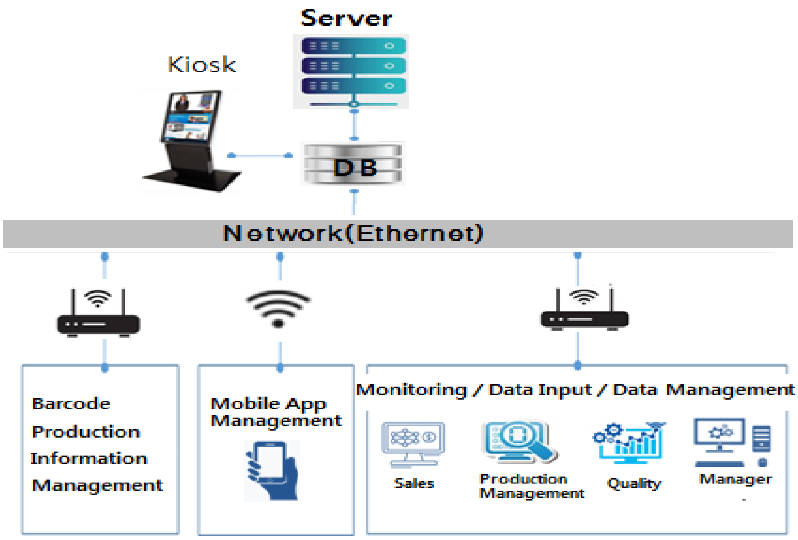

Fig. 1: MES system

In Fig 1, the barcode production information management connected to the server outputs the production barcode and traces the production history through production time tracking. The PCs connected to sales, production management, quality, and manager use Windows 7 or later and Alegro 1.0 as software. By sharing production information, various customer requirements are reflected in the production site in real-time, improving product quality and improving delivery compliance. In addition, when external customers visit the company, they can directly check the facility operation rate, defect rate, process progress, etc. Barcode production information management connected to the server prints production barcodes and traces production history through production time tracking (Mantravadi et al., 2022; Lee et al., 2021). Ashin, a small and medium-sized company, an electric vehicle parts maker, increased facility operation by 10% and reduced process defects by 70% with the introduction of MES. Inventory costs have also been reduced by 30%, and order shipments have decreased from an average of 14 days to 6 days.

CPS (Cyber Physical System) is an intelligent system that integrates a cyber-system and physical systems such as processes, facilities, and people into a network. With the advancement of communication technology that connects data, such as the cloud, simulation that can accurately simulate a factory is now possible. By applying IoT sensors, it is possible to collect data from manufacturing sites, analyze and make predictions with big data, and implement learning through AI. Fig. 2 is the configuration diagram of CPS smart factory.

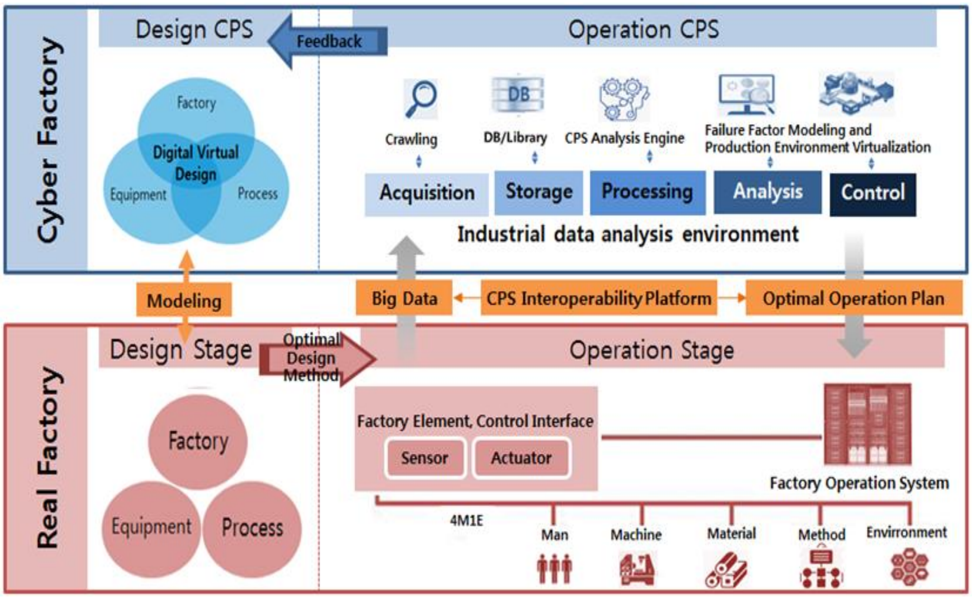

Fig. 2 CPS smart factory diagram

If CPS is applied to the manufacturing system, the limitations of the existing production informatization such as vertical network and limited information exchange can be overcome. Furthermore, various production information, such as 4M (Man, Material, Method, Machine), can be set flexibly, allowing for efficient management and operation. Through CPS, it is possible to understand the operating status in advance of actual operation by performing virtual operation on cyber. The ability to control the real world can be added to support human decision-making. It is possible to prevent dangerous situations by identifying abnormalities or responding immediately in the event of an accident. In addition, if the manufacturing process is virtually designed in cyberspace, the off-line production line is changed to a common mode, enabling customized mass production. High-quality products can be produced by converting product quality and facility operation status data into big data and analyzing it to continuously manage product quality. CPS technology in smart factory can be divided into product CPS and production CPS according to the application target. Product CPS creates new products and services by exchanging information through the network. For this, the convergence of sensors, actuators, and control technologies, the computing technologies that support them, and the communication technologies that connect them are essential. The production CPS is an integrated system of cyber and real worlds based on digital models of products, production facilities, and factories. In other words, it builds a digital model of the cyber world through virtualization of products, processes, facilities, and factories in the real world. After that, changes in the actual field, such as equipment failure, are recognized with various sensors and synchronized to the cyber world in real-time. In particular, based on data, it builds and utilizes a digital model of the cyber world that is synchronized and aligned with the actual manufacturing site, that is, a DT (Digital Twin) (Taioun 2019; Napoleone et al., 2020; Chen et al., 2020). Through this, it can be said that it is the core technology of smart factory to achieve design and operation optimization autonomously and actively. Korens, a small and medium-sized company, an automobile engine parts company, saw an 8% increase in sales and a 95% decrease in process defects due to the introduction of CPS. Moreover, productivity increased by 13%, and confidence increased, which boosted exports.

2.2. Applied company analysis

Every year, for the selection of the best smart factory companies, excellent companies are recommended based on on-site inspections at regional techno parks (19 regions nationwide). Among the companies recommended by the Manufacturing Innovation Promotion Team, they are selected in consideration of the policy direction, region, and performance of the smart factory. In this paper, the applied company analysis was based on the criteria for each system used by the companies that were successfully operating among the companies selected as best practices for the last 4 years (2017-2020). Osung, Ashin, GPN and Korens were selected as four small and medium-sized electrical and electronic parts companies as shown in Table 2.

Table 2: Excellent selected company

Company	Osung	Ashin	GPN	Korens

Smart Factory System	Inspection Automation	MES	SCM	CPS
Promotion Period	2019	2019 - 2020	2018 - 2019	2017 - 2018
Year of Establishment	1983	2008	2002	1990
Main Product	Consumer Electronics & IT Devices	Automotive Parts	PCB	EGR Cooler, Module, Pipe
Level	Level 3	Level 2	Level 3	Level 5
Building Cost (about $)	167,000	158,000	92,000	317,000

Just a few years ago, Osung was about to relocate its factories overseas. The reason is that it was difficult to reduce manufacturing costs in the domestic manufacturing environment where the offensive of low-priced Chinese products continued and labor costs continued to rise. However, in 2015, through the ‘Smart Factory Construction Support Project’, it was possible to solve this problem by establishing the PCB soldering automation process used for wireless products. In 2019, through the automation of the PCB process and voice inspection, the automation rate of the entire process reached 50%. The product manufacturing history management system was newly established to significantly lower the defect rate. In addition, as workers who were put in before automation was put into production processes in new industrial fields, production cost savings were shown. Due to the simple, repetitive process performed by hand, the work fatigue of the workers was high and the production efficiency was greatly reduced. After the application of smart factory, worker fatigue was reduced and work efficiency improved by automation of the introduction of joint robots. In particular, in the case of the soldering process, product quality uniformity was secured due to automation. The possibility of defective products was high due to difficulties in quality control while the inspection equipment was carried out manually. However, if there were defective products, the robot automatically separated and discharged them. When designing foolproof products, defective products are blocked by design management to prevent possible errors in advance. By linking the data on product manufacturing history management with the computerized system, it was possible to trace the manufacturing history, thereby increasing product reliability.

Ashin was manually organizing and analyzing various production items. In order to build a Smart Factory, MES was introduced by applying process standardization through PI (Process Innovation) for each task. We built a system that enables route tracking by managing the incoming and outgoing raw materials with barcode labels. As a result, it was possible to monitor the production status in real-time and improve productivity. Through MES, various customer requirements are immediately reflected in the production site, improving product quality and improving delivery compliance. In addition, when external customers visit the company, they can check the current plant's facility operation rate, defect rate, and process progress through the kiosk from the factory entrance, greatly enhancing customer trust. After the worker grasped the production status, etc., the facility utilization rate was analyzed through excel work. However, after the Smart Factory was applied, barcodes were attached to the entire process from warehousing of raw materials to shipment of products. Therefore, comprehensive management was performed and data was automatically shared in real-time. While performing sales, purchasing, production, delivery, and quality control, the work process was not standardized. However, with the introduction of MES, standardization of each task was prepared, and the number of tasks with low added value was reduced, resulting in increased productivity. When trying to understand the production status, the current production facility utilization rate and defect rate are checked through documents, so the time for writing the documents is inevitably a thing of the past. It was difficult to know the exact situation, but the reliability was increased as the production information was delivered in real-time and directly confirmed through the kiosks installed throughout the factory.

Since the size and shape of the PCB produced in GPN are different, the process is not constant and it is impossible to make it in advance because it is custom-made according to the drawing provided by the customer. Therefore, it is necessary to meet the delivery schedule exactly as well as the quality. So, from receipt to final shipment, we introduced SCM that can be checked in real-time with monitors, PC’s or Personal Computer and mobiles in the office. So, if you log in to the company program from anywhere, you can check the progress of 13 products and 100 procedures. Workers can check the tasks to be done according to the schedule, and customers can receive the product at the desired time, which improves satisfaction. Since the process status was directly grasped in the form of handwritten documents, it was difficult to immediately check the real-time process status. There were many difficulties for workers as they were weak in quality, logistics, and delivery management. After applying smart factory, barcodes and QR codes were attached to the work order so that they could be identified in environments such as PC and mobile. The defect rate was reduced and effective sales were possible by checking the real-time process and the delivery date and progress could be checked by logging in to the online system.

As the first step, Korens built an ICT system including automated robots and barcodes throughout the production line. By including IoT and big data technologies in the already built automation facilities, various process data were systematized to increase the efficiency of the facilities. The Cyber Physical System introduced here is a digital twin system that is applied to the field after realizing optimization by virtual operation in cyber. And equipped with the technology to self-diagnose and control equipment based on big data. By combining IoT technology and QR code, it systematically informatizes environmental factors such as temperature and humidity by using big data on manufacturing and quality histories that occur in each process. With this process, it was possible to produce products by changing the process line immediately according to the customer's request with an automated facility in the form of collaboration where workers and robots work together.

3. Platform Technology Competitiveness

The key to the introduction of Smart Factory is the competitiveness of platform technology. It is a service that enables convenient access to various and extensive information regardless of location since platform technology creates and opens an information system environment. In addition, it plays a role as a medium to deliver various information and data collected from sensors and devices in the smart factory to the top-level application used for analysis. Platform technologies in the technical components of the Smart factory are classified into big data analysis, CPS, modeling/simulation, process control through monitoring, and cloud computing. The analysis of the platform construction of the four electric and electronic SMEs mentioned above is as follows.

Osung is promoting factory digitalization, starting with the automation of PCB soldering, and the automation ratio of the entire process has reached 50% with automation of the production process and inspection. It is difficult to check the manufacturing history of individual products because the data that manages the manufacturing histories is not linked to the computerized program. Furthermore, if the product identification number is used repeatedly, there is no way to check it, making tracking impossible if a defect occurs. By establishing a product manufacturing history management system, data is automatically saved in the final inspection process, making it possible to track and manage product history. It is also possible to check whether the unique number is duplicated, preventing double mixing, reducing the defect rate, and increasing product reliability. In addition, MES, ERP, AI, QR code, and Fool Proof systems were configured and real-time information was shared to manage the entire factory status in an integrated way.

Ashin's production is in progress with the process being centered around equipment that precision-cuts parts for electric vehicles. By building MES, it is possible to monitor work order and process flow information. Data is accurately collected by scanning barcodes for information input and utilizing IIoT devices. In addition, by integrating ERP, MES, and QMS system functions, the optimal platform suitable for the production process is being operated. Big data is generated in real-time using IIoT and smart sensors for automatic processing equipment, inspection automation equipment, and robot equipment so that it can be aggregated, analyzed, and monitored.

GPN has developed and used a smart app to understand the flow of the entire production process by introducing SCM. It was linked with the ERP system within the company to enable overall management with QR code and smartphone. By attaching a QR code to the work order created by computer input and manual record, you can easily check the real-time workflow on pc and mobile. After this system is established, workers can immediately check the production status from the outside using tablet, PC, and smartphone. In addition, the reliability was improved by knowing the exact delivery schedule.

Korens is a global star company with the world's largest market share in the gasoline automobile sector for EGR coolers developed with its own technology. In terms of technology, it has excellent development capabilities that differentiate it from other companies. We are developing and operating various smart factory systems such as ERP, PLM, and MES on our own. With the promotion of facility automation and advancement, an ICT system including automated robots and barcodes was established throughout the production line. By combining IoT and big data technology, facility efficiency is being promoted. Therefore, a system for operating a smart factory that systematically manages and analyzes various manufacturing data to achieve quality innovation has been completed.

4. Conclusion

When Smart Factory is applied to electric and electronic SMEs, work efficiency is increased through production automation. Quality competitiveness is secured through data analysis, and business operation is optimized through real-time monitoring. In applying the intelligent system that integrates the cyber system and the physical system of processes, facilities, and workers, it is necessary to apply a solution suitable for each SME. With the development of computer technology as well as communication technology that links data such as the cloud, factories can be precisely simulated. By applying IoT sensor, data from manufacturing sites can be collected, analyzed, and predicted with big data, and self-learning through AI has become possible. By equipping automated robots specialized for each process, quality control for each process can be realized, and high-quality products can be stably produced through collaboration between workers and robots. It is possible to manage the production site while managing product flow, progress, defect count, expected delivery date, and overall communication of employees in real-time. Therefore, a prompt decision-making support system was secured through the integrated management of production factors. The downside is that continuous education of new subscribers is important, and work is paralyzed when the server is stopped. In addition, as a precaution against external hacking, Kaspersky software is currently used, and due to the fact that regular backups are made using document backups and external hard drives, direct external attacks can take a hit. The purpose of this study is to present the efficiency of Smart Factory platform installation and operation to electric and electronic-based SMEs that want to introduce a smart factory.

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