

System Integration and Functional Priorities to Maximize Profit and Loss for Smart Factory

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Abstract. Smart factories have already become a key theme in the manufacturing industry. Advanced IT technology, industrial engineering, and management know-how will be combined to improve all areas of manufacturing. Improving productivity is the most important goal for a factory. However, this is only part of the overall goal of corporate management. Corporate management pursues a greater goal of optimizing all of the company's resources to reduce losses, increase profits and achieve sustainable growth. All companies should achieve smart factories to prevent unnecessary waste of time and resources and maximize profits by increasing productivity. This paper deals with the integration effect of the major fundamental system, including the Manufacturing Execution System that operates production, and the method of measuring it. When integrating core systems to maximize successful inventory management and revenue, a method of assessing them is required. Here it would be appropriate to have an evaluation method in which scores are given and calculated differently depending on the results and functional priorities obtained by the system. This approach will help solve the problem of which systems each company will use and integrate when introducing smart factories.

Keywords: Smart factory · Manufacturing Execution System · Enterprise Resource Planning · System integration

1 Introduction

Smart factory is already being distributed as a global trend. The combination of cutting-edge IT technology, industrial engineering, and know-how in management has resulted in the improvement of the productivity of manufacturing companies. It is expected that Smart Factory will be able to efficiently and profitably produce customized small lot products since the setting for vertical integration as it means collecting data from factories and realizing manufacturing sites with high flexibility and reconfiguration [1]. The introduction of smart factories has already enabled companies to utilize accurate market information on consumers' tastes and demands and to fine-tune the purchase of raw materials and components needed for manufacturing. It is also operating all of the resources required for manufacturing rationally, reducing waste and reducing manufacturing lead time while increasing factory utilization. As a result, the ratio of compliance

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with customer delivery has also increased, greatly improving customer satisfaction and enjoying the effects of smart factories.

Although the manufacturing sector has set productivity gains as its most important goal, this is only part of its overall management. Corporate management must achieve a greater goal: how to optimize all the company's resources to reduce losses and increase profits, and how to achieve sustainable planning and implementation. Therefore, this paper deals with the establishment and operation of the Advanced Planning System (APS) [2] which is a system in which inventory management and production are planned from a profit-and-loss perspective so that all companies seeking to improve productivity through the achievement of smart factories can achieve another big management goal. In addition, Enterprise Resource Planning (ERP) [3] and Manufacturing Execution System (MES) [4] operate as basic systems, but many companies do not yet use a variety of systems, such as Supply Chain Management (SCM) [5], Product Lifecycle Management (PLM) [6] and Quality Management System (QMS) [7]. This paper would like to emphasize that when operating with ERP, MES, SCM and PLM, achieving the upgrading of plant operations at the enterprise level can bring about productivity maximization and loss minimization.

This paper consists of: Sect. 2 reviewed the production and operation factors of profit and loss perspective studied in the past as related tasks, and dealt with the non-production factors that should be added additionally. In addition, in terms of system operational efficiency to achieve that goal, proposals were added for the integration of ERP and MES currently being used by businesses. Section 3 numerically illustrates the conditions under which gains and losses are achieved under the assumption that all major systems are integrated and all of its core functions are used, and Sect. 4 compares the figures that can be achieved only by systems that are substantially insufficient compared to performing all four core systems integration and various functions. It is an effort to quantify reality on the premise that it can vary depending on industry, manpower and corporate financial conditions. The following study concludes that the conditions and results analysis of Artificial Intelligence (AI) based APS deployment will be faithfully performed, and that a review of the conditions and expected system environment for system integration of smart factories is proposed.

2 Related Work

The problem that manufacturers always worry about is the management of production and inventory. Inventory management is based on the premise that adequate quantities of safe stock must be secured in line with the sales schedule. Excessive inventory is also one of the major reasons for reducing profit margins and must be carefully managed. Products with large price variations or long production lead times depending on the operating level of the safe inventory often face a crisis of existence, as well as the benefits of the enterprise, depending on the success or failure of that operation. This is especially true for companies that involve huge Fabrication (FAB) facility [8] investments, such as the Dynamic Random Access Memory (DRAM) manufacturers. However, for industries like Fast-Moving Consumer Goods (FMCG) [9] that have a fast turnover and relatively low price fluctuation, the amount of safe stock holdings should be small and its impact on profit or loss is not so great [10] Fig. 1.

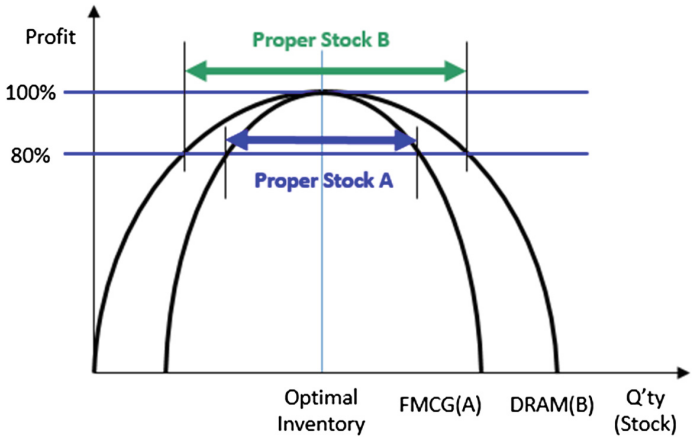

Fig. 1. Optimal inventory range

2.1 Inventory Management

In general, the inventory control curve is as follows and the operating level of the safe inventory is described as different for different types of products.

Determining output is the core of production management and manages all conditions for its implementation in the MES. The MES must meet the conditions of ISA-95 [11] and ensure that the production status is in real time how accurately it is planned beyond the basic requirements and executed in accordance with the work instructions without any abnormalities. And we need to accumulate and analyze that data to review how efficiently it was done and whether there was no abnormalities. It is the APS that is responsible for the key functions of this production management and it is a key function of the MES to build smart factories, which is a basic requirement for improving productivity. In past papers, the logic and additional considerations for the establishment of accurate production plans, including inventory operations, are as follows.

- Raw Material Supply Situation [Price and Period]
- Sales Price Fluctuation
- Cost and Average Sales Price
- Customer Service Experience
- New Product Development Period
- New Product Sample Supply and Qualification Progress
- Facility Operation Rate
- Capital Expenditures (CAPAX) and Operational Expense (OPEX)

2.2 Integration of ERP and MES

The direct impact on production plans is current inventory and sales plans and availability of available raw materials and production facilities. In addition, however, external factors that determine the implementation of the production plan are described in 2.1, in which

business management only needs to consider these external environments first, then develop a sophisticated planned production plan and then implement the plan faithfully. If a faithfully executed plan is wrong, the effect of the outcome on the firm in the long term is critical and can affect the existence of the entity Fig. 2.

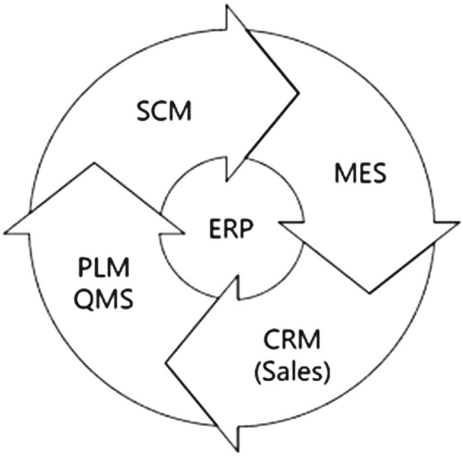

Fig. 2. System integration for smart factories

The direct element of the production plan is well-run within the MES. That is, materials required and retained, facility capacity, and basic information for operation. Other factors for production include inventory holding and demand for finished products, the schedule and type of products desired by the customer and most importantly, sales price information. Because companies must consider both profit margins and customer satisfaction, a simulated production plan must be established, both of the customer priorities determined by the sales department and the profit-to-market ratio calculated by the management. Large companies have nothing to worry about as they establish mid- and long-term production plans and repeat implementation and analysis through consultation of important departments such as sales and production and management. The problem, however, is that small and medium-sized enterprises that have failed to introduce smart factories or are currently under consideration do not precisely make comprehensive judgments on production by these external environments, as they have very small staff and their roles in sales, production and management.

Large companies are using ERP packages supplied by large companies such as SAP and Oracle well. In addition, SCM, PLM and MES are developing very well and working together smoothly. However, the problem again this time is small and medium-sized enterprises. Small businesses can hardly afford to introduce large packages for each sector. Given the small-scale operating workforce or simple processes, the fact that it is too many, complex and heavy a system is a major stumbling block for representatives of small and medium-sized enterprises to decide on investment in such smart factory systems.

Therefore, it is essential to have an integrated system of scale in order to build a smart factory that fits the reality. Thus, in recent years, frequently chosen MESs by small and medium enterprises include some of the ERP and SCM functions, which in fact demonstrate the need to establish and implement production plans, such as resources available and external environmental factors based on MES-specific capabilities. And there are attempts to emphasize the aspects of integration and call it the integrated Factory Information System (FIS) [12].

2.3 System-Specific Function

The process of making one finished product is a long journey from product planning and development, design, sampling, standard certification, mass production testing, marketing and sales activities to purchasing, import inspection, production planning, manufacturing, shipping and supply, inventory and quality control. In addition, smooth information sharing and detailed processes at each stage can reduce the waste of time and money generated by stopping at a particular stage or creating the wrong product Fig. 3.

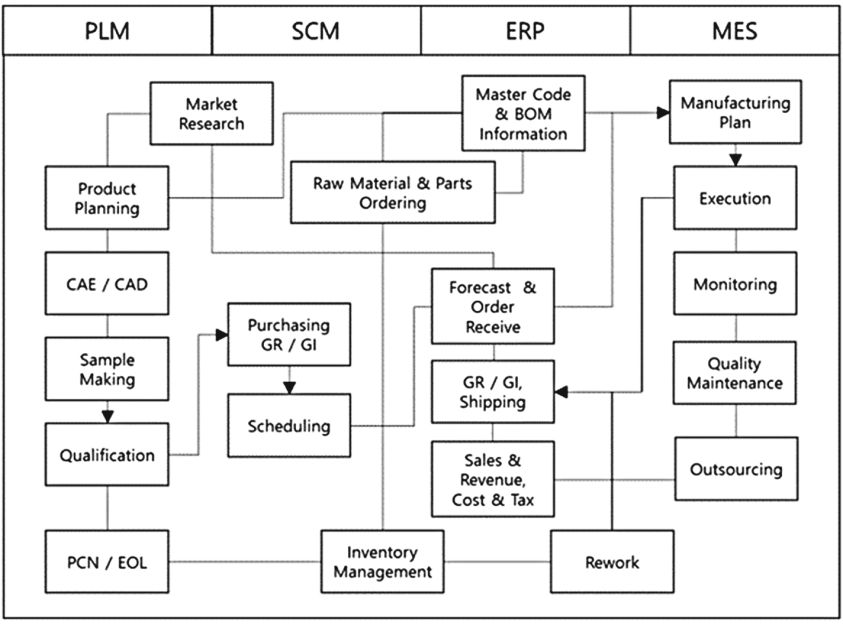

Fig. 3. Function diagrams

The purpose of standardization of each process, the establishment of an essential information sharing system at that stage, and the collection and storage of data are all aimed at improving productivity by managing factors that affect profit or loss As such, planning a single product and neglecting any of the cycles from manufacturing to sales has a significant impact on quality and is difficult to manage without integrating each process. Currently, small and medium-sized enterprises are not able to collect their

respective data and are not equipped with such manpower and systems, and are experiencing numerous trial and error, overloading and inconvenience, and feeling the limits of productivity improvement. Therefore, listing all of these functions and defining each association will give you a clearer relationship and priority. The figure below represents the full function of the entire process, from planning to shipping, and market research, including simple manufacturing activities. From this we can see that all functions are connected and very few function independently. Of course, modules related to personnel management and training, and the use of expenses, such as overseas travel, among ERP functions do not seem to be able to establish direct links to manufacturing activities. Ultimately, however, we have to get a Forecast or Order to increase its hit rate, so we can only link it to the gross profit ratio, but we will skip it here.

3 Functional Priorities

Each of the system-specific functions discussed above will be able to establish a more accurate production plan from a profit-rate perspective, provided that all companies can use it. This is a step that is proposed as a model that can be implemented and applied at a corporate site and is not yet subject to practical verification. However, if there is any accumulated data in the system, it is quite a meaningful approach to actually calculate the difference in weight and then extract the priority of the production plan.

Table 1 shows the lists the items used as important system factors in a semiconductor production company and scores them in a meaningful order. The sum of each system is arranged so that the sum of values listed in order of importance within the system is 1 as well. Although there will be other items to be added by industry, we have first made efforts to add as much as possible what can be selected as an important factor in general manufactured goods manufacturing companies. Each of these data may exist, but if the data were difficult to collect or manage, the factors were all rated at 0.01 level, which did not mean much. However, all of the management items above 0.05 are important data management, and efforts to obtain each data must be made to take into account the priorities of the scores.

Table 2 is evaluated based on the priority and weight of the very basic core system in the smart factory. It is arranged randomly so that the total is all 1. All four key systems are designed to define companies that hold and operate with one point, or 100 percent gain or loss achievement, or to clearly show a reduction in other large and small gains and losses. The assessment is based on a detailed analysis and comparison of the results simulated in the next Section. The above model used the functions of the system-building model obtained through on-site surveys at the factory over about six months and the weights derived from numerous meetings with the company's management and working-level staff. Although the same application cannot be applied to all industries, commercialization can be considered because it reflects the opinions of a total of 20 executives and practitioners. This model used the functions of the system-building model obtained through on-site surveys at the factory over about six months and the weights derived from numerous meetings with the company's management and working-level staff. Although the same application cannot be applied to all industries, commercialization can be considered because it reflects the opinions of a total of 20 executives and practitioners.

Table 1. Scores of each system function

ERP ($w1$)	Profit Margin	0.250
	Raw Material	0.200
	Order	0.150
	Forecast	0.150
	Customer Priority	0.100
	Sales Price	0.050
	Production Cost	0.030
	Goods Receive	0.025
	Goods Issue	0.020
	Shipping	0.010
	Tax	0.005
	BOM	0.003
	HR Cost	0.002
	Master Code	0.002
	Part Number	0.002
	Others	0.001
	0.40	**1.000**

MES ($w2$)	Manufacturing Plan	0.300
	Execution	0.300
	Quality Maintenance	0.100
	Yield Performance	0.100
	Facility Matenance	0.050
	Monitoring	0.050
	KPI Management	0.050
	Outsourcing	0.030
	Others	0.020
	0.50	**1.000**

PLM ($w3$)	Product Planning	0.300
	Qualification	0.150
	PCN	0.100
	Sample Making	0.100
	Market Reasearch	0.100
	CAE / CAD	0.100
	EOL	0.100
	Others	0.050
	0.03	**1.000**

SCM ($w4$)	Purchase Price	0.300
	Forecast Accuracy	0.200
	On Time Delivery	0.150
	Scheduling	0.100
	Goods Receive	0.100
	Goods Issue	0.100
	Others	0.050
	0.07	**1.000**

4 Comparison of System Integration and Partial Operation

Of the configurations of smart factory basic systems presented in the previous Section, the priorities of each industry may differ from those presented. However, the general manufactured goods are presented here, and the graph presented in Sect. 1 compares the relatively short production lead time of the FMCG with the relatively short inventory turnover rate of the FMCG and the long production lead time of the semiconductor. First of all, if all four basic systems, including large companies, are in place and detailed menus of items are organized and managed by system, it will be very easy to maintain the peak in response to long production lead times or changes in the internal and external environment. This can be assumed to be one point, or 100%, and the formula is as follows.

$$\mathcal{W}1*\sum \text{ERP (n)}+\mathcal{W}2*\sum \text{MES (n)}+\mathcal{W}3*\sum \text{PLM (n)}+\mathcal{W}4*\sum \text{SCM (n)} \quad (1)$$

Table 2. Examples of scores for small and medium enterprises

ERP ($w1$)	Profit Margin	0.250
	Raw Material	0.200
	Order	0.150
	Forecast	
	Customer Priority	
	Sales Price	0.050
	Production Cost	0.030
	Goods Receive	
	Goods Issue	
	Shipping	
	Tax	
	BOM	
	HR Cost	
	Master Code	
	Part Number	
	Others	
	0.40	**0.680**

MES ($w2$)	Manufacturing Plan	0.300
	Execution	0.300
	Quality Maintenance	0.100
	Yield Performance	
	Facility Matenance	
	Monitoring	
	KPI Management	
	Outsourcing	
	Others	
	0.50	**0.700**

PLM ($w3$)	Product Planning	0.300
	Qualification	0.150
	PCN	
	Sample Making	
	Market Reasearch	
	CAE / CAD	
	EOL	
	Others	
	0.03	**0.450**

SCM ($w4$)	Purchase Price	0.300
	Forecast Accuracy	
	On Time Delivery	
	Scheduling	0.100
	Goods Receive	
	Goods Issue	
	Others	
	0.07	**0.400**

The scores for each item in the Table 2 are calculated as follows.

$$0.40 * 1.0 + 0.50 * 1.0 + 0.03 * 1.0 + 0.07 * 1.0 = 1 \tag{2}$$

However, most small and medium-sized enterprises or basic plants without smart factories do not have all the above four systems. That is, either MES or ERP will be selected and used. Thus, the table below can be filled with scores and calculations based on the random assumption of this situation.

$$0.40 * 0.680 + 0.50 * 0.700 + 0.03 * 0.450 + 0.07 * 0.400 = 0.664 \tag{3}$$

Comparing (2) and (3) may be an intuitive explanation that while all conditions are met, they can be optimized for 100% profit or loss, it is difficult to reach 100% profit or loss if the system is not equipped at all or only some functions are used.

This shows that if the production process, such as semiconductors, is complex and the production lead time is long, it is imperative to utilize many systems to increase productivity and maximize profits through organic information sharing between processes.

Products with fast inventory turnover, such as the FMCG, need not be as complex as semiconductors because even if the amount of safety inventory they have is small, it affects profit or loss.

5 Conclusion

Existing APS is a high-tech planning system that focuses only on production parts themselves and establishes production plans based on priority of delivery dates considering inventory. Of course, this is because production, including the limitations of accumulated data volumes, is divided into unique tasks for the production department, and there are many difficulties in planning beyond the production elements.

But the introduction of smart factory now, as mentioned earlier, should not only be an area of manufacturing itself, but also a plan that includes a variety of factors beyond manufacturing as demand and its attributes, price and delivery, and the need for multi-species small production or mass customization increase. Each company will have a different system and different menu configurations that it considers important for each industry it produces. In addition, the KPIs (Key Performance Index) [13] that are managed intensively may vary. However, ultimately, the nature of the manufacturing industry, which processes and assembles raw materials and materials to produce finished products, remains unchanged in that purchasing and inventory management are the biggest factors that determine gains and losses, and the importance of SCM linking sales to purchases cannot be overemphasized. The reality is that ERP and MES are considered the most important component systems. APS is a key feature of MES that needs to be organically connected to the SCM, which also comprises SCM and MES as a single system, depending on the enterprise. What it seeks to achieve through system integration is to establish a more efficient production plan and ensure appropriate inventory operation standards. And it is a meaningful study that more objective and systematic evaluation criteria have been presented to achieve the goal of integration.

Next, more advanced system configurations than conventional APS can be assisted by machine learning using AI, and the importance order for angles is re-determined by organizing the above system functional elements and multiplying weights. Of course, each company will have to decide and implement whether to re-calibrate after the final judgment or to a level that can automatically control production based on AI's judgment.

References

1. Wang, S., et al.: Implementing smart factory of industrie 4.0: an outlook. Int. J. Distrib. Sensor Networks **12**(1), 3159805 (2016)
2. Meyr, H., Wagner, M., Rohde, J.: Structure of advanced planning systems. In: Supply Chain Management and Advanced Planning, pp. 99–106. Springer, Berlin, Heidelberg (2015). https://doi.org/10.1007/978-3-642-55309-7_5
3. Rashid, M.A., Riaz, Z., Turan, E., Haskilic, V., Sunje, A., Khan, N.: Smart factory: E-business perspective of enhanced ERP in aircraft manufacturing industry. In: 2012 Proceedings of PICMET 2012: Technology Management for Emerging Technologies, pp. 3262–3275. IEEE, July 2012

4. Zhong, R.Y., et al.: RFID-enabled real-time manufacturing execution system for mass-customization production. Robot. Comput.-Integr. Manuf. **29**(2), 283–292 (2013)
5. Liboni, L.B., Cezarino, L.O., Jabbour, C.J.C., Oliveira, B.G., Stefanelli, N.O.: Smart industry and the pathways to HRM 4.0: implications for SCM. Supply Chain Manage. Int. J. **24**(1), 124–146 (2019)
6. Stark, J.: Product Lifecycle Management, vol. 1, pp. 1–29. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-24436-5_1
7. Lech, M.M., et al.: Quality management system with human-machine interface for industrial automation. U.S. Patent No. 6,539,271, 25 Mar 2003
8. Schulze, B.D.: System and method for automated monitoring and assessment of fabrication facility. U.S. Patent No. 6,671,570. 30 Dec 2003
9. Kerry, J., Butler, P. (eds.): Smart Packaging Technologies for Fast Moving Consumer Goods. John Wiley & Sons, New York (2008)
10. Kho, J.S., Jeong, J.: On reflecting optimal inventory of profit and loss perspective for production planning. Procedia Comput. Sci. **155**, 722–727 (2019)
11. Unver, H.O.: An ISA-95-based manufacturing intelligence system in support of lean initiatives. Int. J. Adv. Manuf. Technol. **65**(5–8), 853–866 (2013)
12. Hao, Y., et al.: Designing of cloud-based virtual factory information system. In: Advances in Sustainable and Competitive Manufacturing Systems, pp. 415–426. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-319-00557-7_34
13. Ge, Z.: Distributed predictive modeling framework for prediction and diagnosis of key performance index in plant-wide processes. J. Process Control **65**, 107–117 (2018)