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Research paper



A study on the optimal line integrated design analysis system

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Abstract

Background/Objectives: This paper is a study on a system that standardizes processes based on smart virtual production technology strategy for manufacturing line design and development, and integrates new or existing resources and systems into one consistent and structured framework.
Methods/Statistical analysis: In this paper, we standardize the process based on the digital virtual production technology strategy for manufacturing line design and development. A system that integrates new or existing resources and systems into a single, unified framework. Through this system, various events participating in the development of the manufacturing line can receive standardized work progress and communication in one consistent system. In addition, we standardized and library the scattered data to minimize the loss of data management.
Findings: Users across a wide range of areas can quickly and easily perform line development from line planning to design, setup and optimization based on standardized processes and an intuitive user experience. By providing analysis results in conjunction with heterogeneous analysis engines, you can perform solution-independent business processes. The effectiveness of the proposed system was verified by applying the proposed system to the actual new and expansion manufacturing line and redesign line in the company and performing line development work.
Improvements/Applications: Through this study, it is expected that the actual field data of MES (Manufacturing Execution System) and the information of planning system such as ERP (Enterprise Resource Planning) can be linked to the integrated decision support system of engineering solution.

Keywords: *Standardized Process; Smart Virtual Production Technology Strategy; Data Management; Intuitive User Experience; MES; ERP.*

1. Introduction

Digital production models an integrated computer model by rigorously modeling the physical and logical components and behavior of the production system. It utilizes various information technologies such as three-dimensional computer aided design (CAD), internet, and database to perform reliable preliminary verification and efficient decision making of various errors that may occur throughout production. This is a technology to realize rapid and efficient product development and production15.
Specifically, manufacturing companies can verify the plan of production line layout, process, logistics, work (human, robot, etc.) in a virtual environment in advance and predict the result of various alternatives through simulation. It is possible to establish an optimal process through the complementary process. This will help to shorten lead times by providing the right products and services that consumers want in the fastest time, at the lowest cost, in the process of making the product.18
There are a wide range of effects that companies can achieve by applying simulations to production lines. First, the economic impact can be assessed by anticipating and analyzing the impact of new process additions and deletions. Second, by identifying the characteristics and capabilities of the existing process, alternative measures can be derived based on sudden increase in demand or decrease in raw materials. Third, we can find the strategy and tactical control variables of complex processes and operate them in real time. In addition, the efficiency of the system can be improved by solving the problem of scheduling11.
There are a variety of commercially available solutions for this purpose, but they are mainly focused on optimization for individual segments. In the development of the manufacturing line, the integrated optimization of the whole is difficult to realize in reality due to the standardization of work and data for the entire company and the integration of various engineering solutions scattered within the company5.The manufacturing line design and development work of the manufacturing company is complicated, difficult, and has a long lead time due to the complex combination of various stakeholders, engineering process, data, and engineering tools. In other words, it is a field that can be expected to have a great effect when it is improved and optimized. To successfully introduce digital production technology and utilize simulation, standardize business processes and data from the data collection phase to all stages of the analysis, from the results of the analysis to the creation of documents for decision-making. There is a need for a structured method that minimizes user intervention through interoperability with related existing systems2.
In this paper, we propose a methodology and system to support collaborative decision making through systematically integrating and automating simulations throughout the engineering process in manufacturing line development. In order to solve the above problems, the proposed system should provide an intuitive and easy user environment that can be easily used by anyone, automate the generation and analysis of the simulation model, and provide the

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results to support decision making, and it should be possible to minimize the repetition work through reuse of data.

2. Concept of the system

This system is an integrated simultaneous design system for analyzing existing line operation. It standardizes and libraries data scattered in various places in various forms within the enterprise. It has been proposed that a single user environment can enable collaborative decision making by using business people in design and evaluation tasks. Figure 1 shows the core concept of the system.

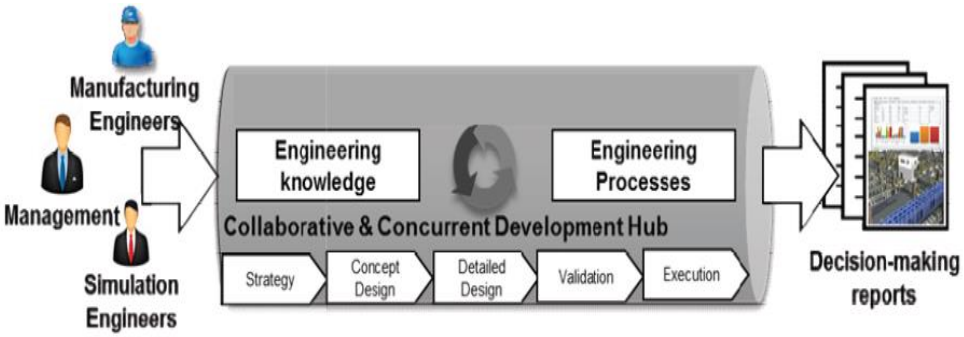


Fig. 1: Concept of the System.

This system allows the various engineers and management departments related to the production line development to access the concurrently and make decisions through collaboration. It serves as a hub that standardizes and provides engineering knowledge and processes. To do this, we construct a system that integrates various types of engineering solutions from various vendors. Provide loose coupling using Web services technology. A loose connection is a flexible, expandable open structure. It also improves both the productivity of the engineer and the productivity of the production system by sharing and reusing the engineering knowledge from the initial strategy establishment to the final line development, setup and execution by organizing the engineering process and knowledge into the system.

2.1. Framework

Figure 2 shows the framework for the system. The system consists of two main components, in detail, four main components. The server and client structure are largely composed of a service layer that provides business services and a middleware layer that performs user, project management, and data storage / management. Clients send and receive data, including the entire layout and P3R (Product, Process, Resource, Plant) through a data model defined in the server schema information and, simulation information. The client performs design in an intuitive modeling environment that utilizes layout drawings through Advanced Factory Designer (AFD), which designs the layout, and the relevant reference information is automatically input through the database and standardized Excel forms, if necessary. The designed AFD model is created as a model capable of logistics analysis through verification of design errors and in - house design criteria through Smart Supporters, a rule base design validation tool.

The completed model is stored in the middleware at the request of the user, and is automatically mapped by the service adapter of the simulation service according to the analysis requested by the user. The results are scored based on internal logic and feed back to the user. At this time, the user does not need knowledge about the use of the individual solution, and even the novice can perform the procedure according to the guide of the system.

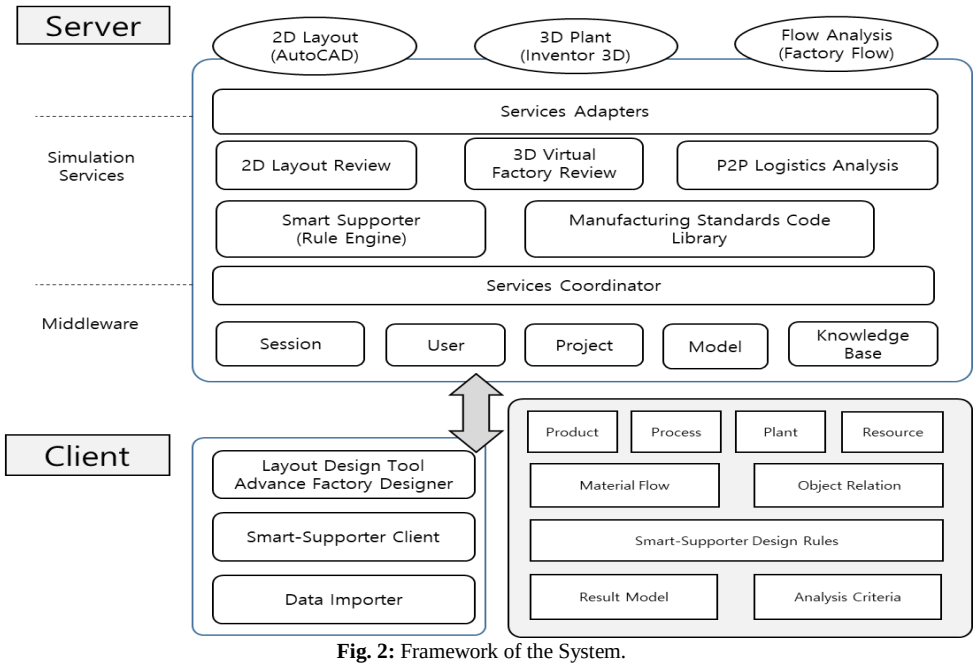


Fig. 2: Framework of the System.

2.1.1. SOA (Service Oriented Architecture)

A service-oriented architecture is an effective approach to building business processes by combining reusable services. It is a technology that increases interoperability and reusability based on platform independence, language independence, and standards compliance through loose connectivity. The system provides an open environment for the change of commercial solution connected with the service through loose connection or addition of the service providing new function by organizing and combining individual functional components based on SOA, providing a single business service [Figure 3].

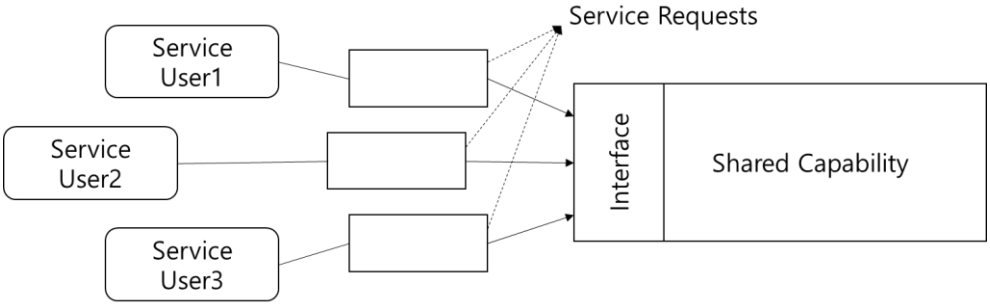


Fig. 3: Service Model.

2.1.2. Schema

The Schema consists largely of a layout / simulation model (SIM-MODEL) including P3R information and product flow information, a result model (RESULT-MODEL), and a smart supporter rule base (DESIGN-RULE). The simulation model consists of a configuration that expresses flow information and other information expressing product routing including P3R information in detail. The result model contains information on various analysis results including the scoring model, which includes scoring logic, logistics flow results, and product results.

Figure 4 shows the detailed structure of the plant schema. In the case of factory information, it represents the physical structure of the factory. It contains the ID and location information of the resource in related Resource related information based on the internal factory number and floor information, so that the 3D CAD file registered in the module library. It is possible to automatically generate the whole three-dimensional factory by combining. In addition to physical information, it contains logical information such as the flow point of the logistics point such as the gate of the process, and is used to perform logistics analysis automatically in combination with logistics flow information.

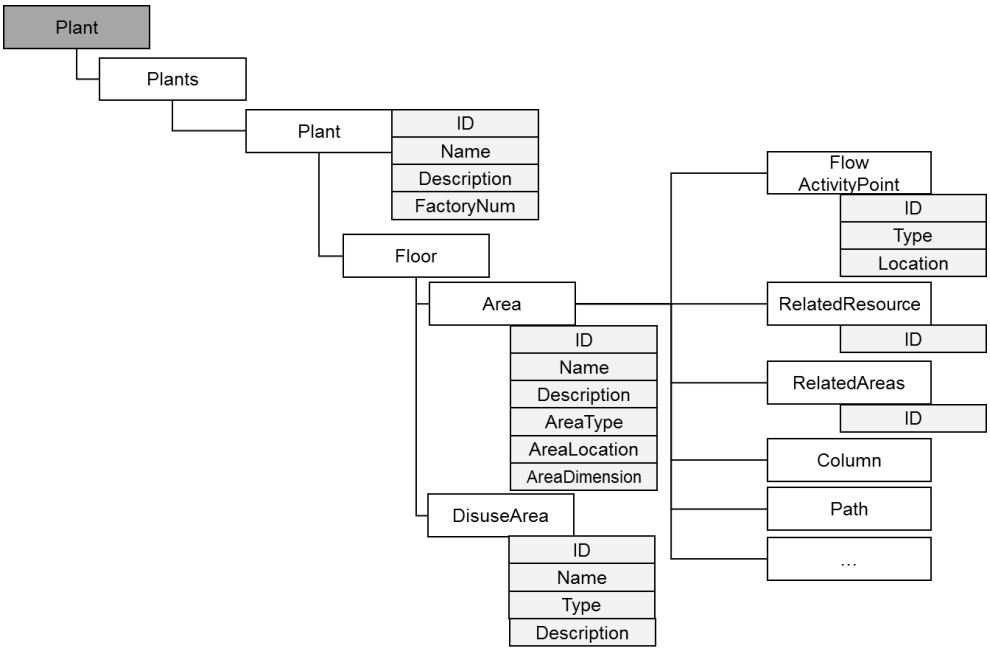


Fig. 4: Structure of the Plant Schema.

2.2. Functions

2.2.1. Integrated management of manufacturing facilities and modules

The facility model and the property information created in 3D CAD are entered as Excel data and registered by the facility and module library registration function. The CAD physical file transferred to the server automatically extracts meta information such as image and size, stores it in the database, and the manufacturing module library is configured and provided as a graphical environment. The user can search the library through the metadata and easily identify the facilities and modules through the automatically generated module image and apply them to the line design.

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2.2.2. Layout design

AFD (Advanced Factory Designer), which features a drawing environment like PowerPoint, is a key component of this system. The layout of actual factories is managed by a separate drawing library and can be used as background of AFD modeling screen if necessary. It provides an intuitive way to perform layout design by searching and verifying the module library through meta information and 3D images (Top, Birdview) and placing it on the actual layout drawing. Processes and lines that combine facilities and module libraries can also be registered as user library templates and reused to increase productivity.
The smart supporters (client) installed on the client verifies the constraints, errors, and data consistency in the layout model through the rule engine through the rule data downloaded from the knowledge base database through design error verification function. Then, it provides errors and warning notices to the user to prevent mistakes and improve the design quality.

2.2.3. Automated virtual factory reviews

The completed AFD layout model is automatically generated as a 3D model for 3D virtual factory review at the user's request. The server extracts the P3R information and the relationship information of the layout model without any separate operation. The CAD file of the facility / module library is read from the physical repository and automatically created as a 3D CAD model. The 3D virtual factory evaluation tool downloaded to the client is used to verify and evaluate the space usage through the 3D visualized layout model.

2.2.4. P2P (process to process) logistics analysis

In general, logistics analysis requires extensive data collection, which takes a long time to collect and analyze. However, this system can download the information from the production information system such as MES, and refine the data through the data importer easily designed for fast input. The system layout model, the input representative process, and the work process routing information are automatically mapped through the reference information database. Therefore, it is possible to perform the logistics analysis simply by filling the standardized input form. When a logistics analysis service is requested, a logistics analysis model is automatically created in the simulation service based on the model and the inputted reference information, and the result is calculated as a scoring model after the analysis, and the result is feed back to the user as a decision report. The analytical service is an automated process that excludes user intervention and can apply a formalized and standardized logistics simulation analysis process, as well as a scoring model for analysis of results and a basis for objective decision making.

2.2.5. Rule-based fool proof of design

With Smart Supporters, a rule-based design error verification tool, users with poor layout / line design knowledge can perform high quality designs. Figure 5 shows the design validation rule flow of Smart Supporters. In order to verify the rule base design, it is necessary to extract the knowledge and experience of the line design engineering from the line design specialist, the business rules and rules existing in the company, and build it into the database. This information is managed through a rule manager as a kind of knowledge-based, and it verifies based on the defined IF-THEN rules the relationships among the objects in the layout design model, the constraints and the consistency of the input data. If it matches a rule, it modifies the design through information of the output or control command, or induces the user to correct the error of the input data.

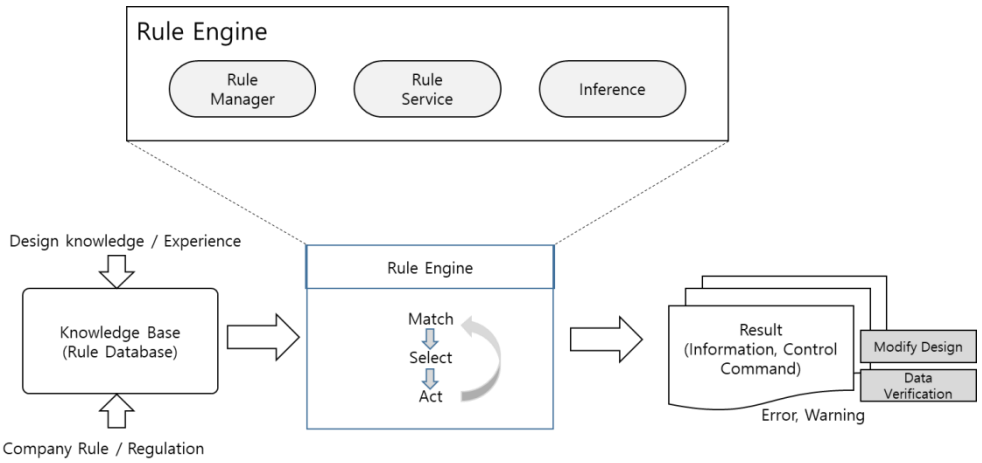


Fig. 5: Smart Supporters Line Design Verification Rule Processing Flow.

Table 1: Smart Supporter Rule Classification

Rule Classification	Explanation	Example
Object Relationship Rules	A rule classification definition that defines the property relationship constraint between manufacturing module object, factory object, and model object.	The lift object must be in the closest passage on the same floor.
Input Data Verification Rule	Rule classification definition that verifies the consistency, suitability, and validity of input data when inputting standard information	The work process name of the work process information should have a representative process mapping.
Analysis Execution Rules	Define rules for errors that occur during analysis run	One factory must have one input gate. There must be one Output gate in a factory.
Company Regulations Rules	Classification of rules defined in company regulations	The area of the restroom should be within 10% of the floor area.

The rule engine basically defines the following four rule classes, the contents of which are summarized in Table 1.

3. Results and discussion

This system was applied to new / expansion manufacturing line and existing line redesign. The system proposed in Chapter 2 was

used in actual line design work. Through interviews with the line design specialists in charge, we performed a full comparison of the existing work methods and the improvement of the tasks when using the proposed system in layout design. The results are summarized in Table 2. It showed about 30 ~ 90%labor input factor saving effect on individual task performance.

Table 2: Business Improvement Result

	Items	Manufacturing Line Design Conventional method	Manufacturing Line Design Utilizing the proposed system
Layout Design	Method	Using AutoCAD Low recyclability	High recyclability
	User	Line design specialist	Everyone
	Labor	100%	30% or less

3.1. Application of layout design

3.1.1. A factory

The purpose of this study was to design a standardized production line that optimizes the product flow, product movement distance, and product handling method.It is the optimum line design for standardization of 4 manufacturing kits (Return, Transport, Work, Storage) for job-shop flow line composition, in-process / inter-logistics optimization, and application.

First, there were delayed transportation time, unnecessary transfer and touch due to inter - layer logistics movement, and relatively long logistics distance. Second, the ratio of manufacturing, reconditioning, inventory, unit, and idle area did not meet the criteria. Third, the standardization rate of 4 manufacturing kits was relatively low. Fourth, there were very many touches of product transfer and manufacturing 4 kits.

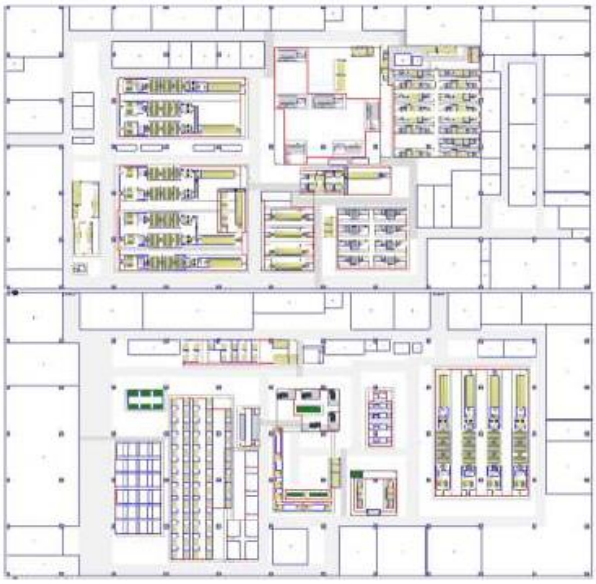


Fig. 6: Comparison of Layout Design of Factory A (Above Is Existing, Below Is New Design).

By applying the design to the layout, the labor input factor has been reduced by 40% compared to the existing one, and the library of the facilities / 4 kits has been increased and the recyclability has been increased accordingly. As a result of the application effect, the carrying distance was reduced by 44.7% from 39,755 m/month to 21,972 m/month.The transport load was reduced by 18.8% from the previous 3.57% to 2.90%.The transfer work had a 41.3% reduction from the previous 126 times to 74 times. The product touch had a saving of 40.9% from the previous 22 times to 13 times. The capacity increase was 0.2 man/month, from 12.8 man/month to 13 man/month. In terms of area efficiency, there was a saving of 492.5 square meters with 4,347.1 square meters using the existing 4,839.6 square meters. This resulted in a 45% increase in productivity [Figure 6].

4. Conclusion

The rapid development of IT technology in recent years has brought unprecedented changes in global markets and business environments. Beyond time and space constraints, multinational digital enterprises are emerging that target consumers around the world, and we are making great efforts to realize agile production systems that meet the needs of global consumers. Although many global leaders are investing in PLM-based digital production, integrating the entire process and designing and implementing simulation-based technologies in the manufacturing line design and development process has many difficulties and limitations.

First, high introduction cost and settlement cost act as barriers to entry. Second, it takes much time and cost to train specialist personnel due to the difficulty of simulation package itself after introduction. Third, due to limitations of commercial simulation package Model reuse is difficult, and concurrent engineering collaboration is difficult. Because of these factors, the application of existing simulations was carried out as a one-time or occasional project, which did not contribute to constant and continuous productivity enhancement. On the other hand, through the proposed system in this paper, it is easy to design the layout of the field logistics manager and layout designer who have no experience in the simulation, and to perform space and logistics analysis on a regular basis, by doing so, it is possible to reduce the lead time of decision making and to improve productivity continuously by improving space and logistics flow.

Quantitatively, it saved more than 60% of the time and cost savings in the steps of data acquisition, analysis, and simulation model, which are the most time consuming and error-prone stages. In the overall business stage, less than 25% to 90% or more.

Qualitatively, the communication development is improved by sharing and collaborating with the layout model through the AFD of the system, which is the same user environment of the line development business, and the result of analysis based on the formalized scoring model- Based on a common understanding of the decision-making has become possible.

This paper is focused on spatial analysis and logistics analysis. In the future, we will standardize complex operating logic and apply it to the system to develop inter-process load balancing, process capability calculation, predictable process and line simulation functions. Also, by automating data collection using standardized data templates through interface with existing legacy system, current automation level can be improved.

Therefore, it is expected that this system will be extended to the integrated decision support system of engineering solution by linking actual field data of MES (Manufacturing Execution System) and planning system information such as ERP (Enterprise Resource Planning).

Acknowledgment

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