Chapter 42
Research on Automatic Layout Planning and Performance Analysis System of Production Line Based on Simulation

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Abstract The automatic layout planning and performance analysis of production system is important and key technology to manufacturing enterprise to response market demand. The factors of system configuration, production mode, WIP, and buffer configuration are considered in this paper to solve the lack of the automatic layout planning and performance analysis system with operation factors of production line. Based on the performance analysis of existing configuration, the layout configuration is stated in detail, the suffer allocation principle is studied by simulation, the dynamic mathematical model of system configuration and WIP is presented. The design integration frame of multi-product and variable batch product line automatic layout and performance is presented based on these proposed models and key technologies. The software system is developed and the effectiveness is verified; this platform has high practical reference and application value to the automatic layout planning and performance analysis of enterprise production line.

Keywords Production line · Automatic layout planning · Dynamic performance analysis · Simulation

42.1 Introduction

Along with the competition in the market, manufacturers need a modern production system to respond to market demand for customized, the required of production lines and systems for modern manufacturing are becoming increasingly reflect the adjust of intelligent dynamic, the superior of system configuration, adapt to the varieties to variable volume and the agile response characteristics, so the research on production line layout planning cannot be divorced from the goal of the factors

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Logistics Engineering Institution, CMES (ed.),
Proceedings of China Modern Logistics Engineering,
Lecture Notes in Electrical Engineering 286, DOI 10.1007/978-3-662-44674-4_42

of production, it should be research on multi-factor index, such as integrated production mode, the system configuration, buffer configuration, dynamically adjustable and the amount of product and so on. Analysis of existing domestic and foreign literatures, Solimanpur and other scholars study the impact of different layout on manufacturing system [1, 2]. Renzhong Jiang proposed hybrid array structure and Holon structure, the establishment of a mathematical programing model based on matroids [3, 4]. Zhong and other scholars studied the impact principle of a different layout structure and performance of manufacturing system and provided the thinking framework for performance analysis method.

Design of normal layout of manufacturing systems often used the corresponding algorithm to solve the optimal or suboptimal solutions of the model under constraints of the portfolio objectives; goals used in the layout design include the cost targets, the utilization target, logistics objectives, the convenience target, and so on; in this area, domestic and foreign scholars conducted in-depth study, the optimization method summed up in operations research methods, nonlinear programing methods, genetic algorithms, simulated annealing algorithm, and particle swarm and have achieved good results within a certain range [5, 6]. Wang, Hui, Suo using the method based on the classification of the device and manufacturing systems function to research the layout of the production line [7–9]. Above for the research of layout design of the production line is based on the conditions of the specific constraints and objectives, use corresponding algorithm analysis and solving a layout problem, and made some achievements. But, the literature is mostly focused on sorting, and comparison of the algorithm leads to the results of the practical application that has a big gap to practical application. Lack of configuration based on the production line with production mode, buffer configuration, WIP, and many other factors of production, this paper study the problem of dynamic layout of the production line.

42.2 Configuration and Performance of Production Line System

Research on layout planning of production line should be based on production line configuration; production line configuration has a direct impact on system performance indicators, different configurations lead to different production line performance, general production line system configurations, including three forms which are series, parallel and hybrid, series, and parallel are basic configuration, the hybrid structure is then evolution of the basic configuration. Commonly used production line system configurations that include the following as shown in Fig. 42.1a, b are the basic configuration in figure, c, d, and e are evolved from the basic configuration, c1 and d1 are conversion from c and d. The most widely used system configurations in manufacturing now is mixed structure which comes from basic string and parallel structure.

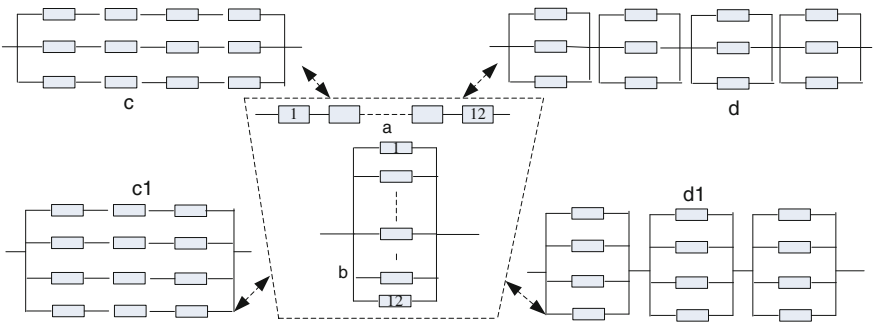

Fig. 42.1 Normal system configuration of production line

The production line performance is depended on its reliability, productivity, quality, cost, and scalability. Following the production line configuration topology, the reliability of the formula is given below:

$$R_a = \prod_{i=1}^{n} R_i \text{ (a Conformation)};$$

$$R_b = 1 - \prod_{i=1}^{n} (1 - R_i) \text{ (b Conformation)};$$

$$R_c = 1 - [1 - \prod_{i=1}^{n} R_i]^m \text{ (c Conformation)};$$

$$R_d = \prod_{i=1}^{n} [1 - (1 - R_i)^m] \text{ (d Conformation)};$$

where R_i is the reliability of the equipment or components of the system, n representative of series, m representative of the number of devices in each level. The reliability of different configuration can be calculated according to these formulas.

Based on the reliability of system equipment and set up equipment normal and failure state, to study the relationship between the different configurations and productivity, the system productivity can take advantage of the statistical formulas:

$$P_s = \sum_{i=1\ldots n} Ca_i R_i \cdot R_h \cdot \cdots R_n;$$

where $R_i \cdot R_h \cdots R_n$ is value of possible states of system running, Ca_i means production capacity of the system is in this state, and productivity is the product of all possible states. It can be seen in this formula, not only the higher of reliability the higher productivity, but also the increase productivity of hybrid form of the structure which accompany with parallel extension also increased, d configuration is better than c.

It is a better way to the use of variable flow theory to analytical processing based on the configuration structure in quality and performance analysis of the production line system. The quality error accumulation of hybrid configuration relative to other structure is larger; this is the reason why hybrid configuration of system should add the corresponding fault diagnosis equipment [10]. For the cost, scalability, and interrelated of the production line system configurations, based on incremental principles method can know that d configuration of the hybrid structure is better than c conformation.

For the above analysis, to meet the market demand which varieties variable volume, fast customized d configuration of the hybrid structure of the system configuration of the production line is the system structure and is chosen in this article.

42.3 Buffer Configuration Principle of Production Line

Buffer configuration of the production system is an effective measure to improve the production system balance and to improve production and profits, the buffer configuration principle of the existing studies have focused on optimizing the algorithm, but ignored the product of the actual processing time. Based on different processing time, the simulation method is used with the same number of machines. The result of simulation is shown in Fig. 42.2. The principle can be presented by simulation:

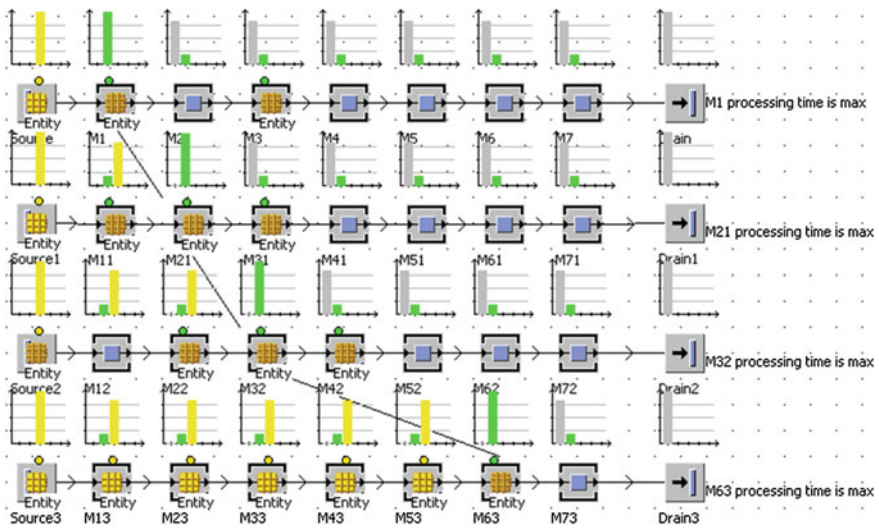

Fig. 42.2 The simulation result of buffer principle

(1) According to processing time to find the bottleneck process, add a new configuration or equipment to deal with bottleneck processes;
(2) System does not need to add buffer if the maxi processing time (MPT) is in first place of this system, or buffer should be added;
(3) Thereafter without considering buffer, if need to add, judge before MPT;
(4) Each of the local rows is checked to find the MPT value, if WIP is greater than 10, consider adding or delineated buffer reserve area.
(5) If WIP is less than zero and the absolute value is greater than 10, consider adding or delineated buffer reserve area.

42.4 The System Dynamic Machine Layout Spacing Model

As per the actual production process, except the system configuration, modes of production, and buffer configuration, the system WIP is also an important factor to affect the performance of production lines. The buffer configuration is related to the WIP. And the WIP impacts on the dynamic distance between the individual equipments of the system layout. For the production line system of many varieties and various batch mode, the production line layout has dynamic scalability. The dynamics of the system layout can improve system responsiveness and is an effective measure to meet the multi-species, variable volume. and customized market demand. In the actual process, because of the size and weight of the equipment, the device spacing is difficult to achieve through constantly adjusting the physical device. Based on the principles of production management and organization, rely on the adjustment of the production planning and scheduling and the logistics transmission and transmission time between the equipment, through the implementation of the system, it can be achieved.

Based on the researched system configurations, in order to reflect the dynamic nature of the system layout, in a given space constraints, assuming that each equipment line is in a parallel state and the devices are shaped in accordance with a rectangular, each working ground is indicated as a rectangular and has the necessary ideal function. The dynamic machine spacing model of the system layout can be established:

$$W_T = \Pr o \times \partial\left(\frac{t_j - t_i}{t_i t_j}\right);$$

$$M_{d1} = W_T \times G_p; 0 < W_T < a;$$

$$M_{d2} = (W_T - m) \times G_p; a \le W_T \le b;$$

$$M_{d3} = K \times G_p; b < W_T \text{或} W_T < 0;$$

where

W_T is the number of WIP between the adjacent processes and operation places, G_p refers to the standard length of the part geometry value for the products of the

same family, $\mathrm{Pr}\,o$ refers to production capacity of bulk value, ∂ refers to the influence coefficient of the work area (empirical reference value), and the t_i is the processing time of the No i places. a, b is the number of WIP based on different processing time and different work piece. m, K is the characteristic parameter of work piece. Based on the optimized configuration of the system and the above model, combined with the existing production system layout principles, system which includes variable mass production mode, the buffer configuration, and dynamic layout planning for the production line in WIP can be established.

42.5 The System Integration Design

Based on the above analysis of principle, establish computer-aided automatic production line layout planning and performance analysis system, the spatial extent of the system layout can realize parametric design and enter the adjustments. Each module of the system based on a unified database platform (SQL Server 2000), the data sheet as the media to achieve seamless integration between the various modules. In each module, resource management module is responsible for the management of basic information of the production tasks, process, and manufacturing resource. Iin support of basic information, mode of production, distribution planning, and performance analysis and simulation optimization module, coordinate with each other and generate different results the program reports. These programs are stored in a unified database.

The main features of computer-aided automatic production line layout planning and performance analysis system is agility, timely and accurate access to required information is the premise to ensure the dynamic layout of the production line quickly analyze and design. At present, most companies are using product data management (PDM) and enterprise resource planning systems, such as ERP for manufacturing integrated platform, through the establishment of interfaces with other systems, information can be shared enterprise-wide. In the specific implementation process, the public database integrates with other systems, namely establish an independent shared data tables and data area. The shared data area stores the share data between different systems in a consistent data model.

42.6 Examples

In this paper, based on the integrated design thinking above, a computer-aided automatic production line layout planning and analysis system is developed. Using the secondary language SimTALK provided by the simulation software Plant Simulation, the SQL Server 2000 and VC ++ 6.0 software environment combined with the modular modeling idea, and the development is completed. There is an example of 14 machines, the integration system is shown. System interface shown

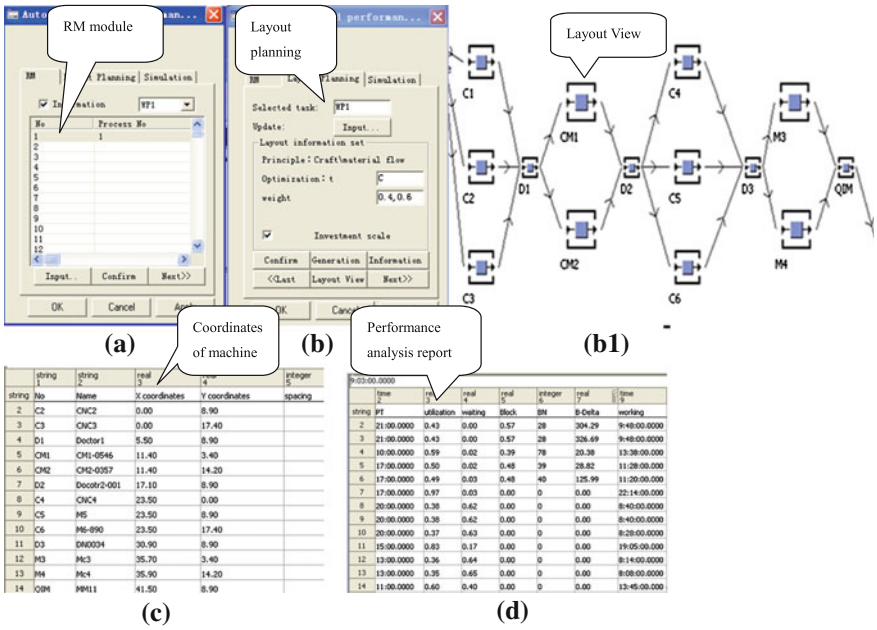

Fig. 42.3 The layout planning and performance integration simulation system

in Fig. 42.3. Resource management module (Fig. 42.3a) connects with the database to provide the basic information needed. Layout model bases on multiple factors of production generated by the layout planning module (Fig. 42.3b) layout program and can control the scheduling policy of interrelated input and output. The layout configuration coordinates information (Fig. 42.3c) according to the generated layout program that analyzes system layout, performance, planning and scheduling, equipment failure, scheduling plans, and other information associated. Reporting module (Fig. 42.3d), according to the planning results, production information, simulation and optimization results, formulates appropriate performance analysis reports, which can be referred and shared in LAN.

42.7 Conclusion

The work of this paper is supported by Shanghai Ocean University initial funding (No. 860610000113) and Shanghai Ocean University curriculum reform funding (No.2400110205). In this paper, a computer-aided automatic production line layout planning and performance analysis system is presented, and including of basic information, layout planning, and performance analysis and simulation optimization. And use the appropriate software environment to make the system development. The current layout configuration of production line system is studied. Based

on multi-processing time and simulation methods, the principles of the buffer configuration, the ways and means to achieve dynamic layout of the production line, production mode, the buffer configuration, and amount of the WIP are given. The system integration is stated. The system completes the layout planning and performance analysis and provides help and reference for the corporate workshop management solutions, planning strategy, and scheduling formulation. The system uses simulation modeling techniques to develop the program more scientific and reasonable and builds the connecting bridge of the planning department and the production workshop. Currently, the system has been applied to layout planning of a car seat production line. It can provide solutions and support tools for the layout planning of multi-species variable mass and mixed production in enterprises.

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