Conceptual Framework of Smart Manufacturing for PCB Industries

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A CONCEPTUAL FRAMEWORK OF SMART MANUFACTURING FOR PCB INDUSTRIES

M. Jabir[1*], G.Zailin[2], R.Mudassar[3], Y.Lei[4], H.Cong[5] and W.Hao[6]

[1-6]State Engineering Research Center of Digital Manufacturing and Equipment, School of Mechanical Science and Engineering, Huazhong University of Science and Technology, Wuhan, Hubei, China

jabirmumtaz@hust.edu.cn

ABSTRACT

Information sharing and communication technologies are infusing the industries to integrate the physical and virtual concepts through smart manufacturing. Printed circuit board (PCB) manufacturing industries tend to move towards more automated and complex manufacturing system due to increase in customer demand for more sophisticated products. With the increase in demand and complexity of the manufacturing systems, it is difficult to manage timely production and proper implementation of an effective plan without incorporating all the information of industry. Therefore, it is essential to collect and analyse the correct information of all departments of the PCB industry. In this paper, the existing status of PCB manufacturing environment and future development towards smart manufacturing system (SMS) are discussed. A cloud manufacturing system (CMS) paradigm is introduced in the existing PCB manufacturing environment to get easy access to resources, materials, manufacturing processes, planning problems and data sharing networks. The goal is to integrate the information sharing from planning problems, PCB assembly lines, retailer and shipment department to CMS for smart planning decisions to cope with the increasing demand and profit enhancement strategies. A conceptual framework is presented to introduce the smart manufacturing environment in the traditional PCB manufacturing system. The suggested framework of SMS helps to improve the performance of PCB manufacturing industries regarding smart planning and scheduling, intelligent monitoring of smart assembly lines for efficiency and production enhancement.

Keywords: Smart manufacturing, Printed circuit board (PCB), Cloud manufacturing system (CMS), Conceptual framework

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* Corresponding Author

1 INTRODUCTION:

In today's industrial era, the manufacturing industries are focusing on the improvements in the production systems to cope with the market competition and increase in customer demand. Computer integrated manufacturing (CIM) is commonly used technology these days because of entering into the era of automation. Therefore, for information sharing about planning problems, the collaboration of all departments of existing traditional manufacturing system with cloud computing manufacturing system (CMS) is essential. This integration of the physical manufacturing system with the virtual cloud manufacturing system CMS helps to reshape the industrial environment to compete with the business trends [1]. Smart manufacturing is the fourth industrial revolution in the manufacturing sector, and it is one of the most widely used paradigms describing the future direction of the production environment. A large number of researchers are focused on it and proposed various ideas to implement smart manufacturing in different types of industries. Kang et al. [2] have addressed a detailed overview of the implementation of smart manufacturing in different industries in Germany, US, and Korea to analyse and predict the future of smart manufacturing. Moreover, smart manufacturing is also incorporating with CMS paradigm and changing the competition trend of the manufacturing industries by introducing an easily accessible technology system [3]. In short, the smart manufacturing acts as a data-driven method in manufacturing industries by dealing with real-time information of industrial simulation and analytics for smooth delivery of resources by using artificial intelligence in all department of manufacturing industries [4,5].

Among all the advanced manufacturing industries, the printed circuit board (PCB) manufacturing industries are most famous because of high product demand due to the increasing trend of smart devices, i.e., mobile phones, laptops, computers, and other smart electronic devices. Various issues exist while dealing with the customer demand and production planning of the electronic devices. The manufacturing industries of the PCB boards face different type of planning and scheduling problems, i.e., line assignment, component allocation, feeder assignment, and component placement sequence problems are most prominent while assembly of PCBs [6]. Due to lack of proper planning and scheduling of the PCB manufacturing in the assembly lines, the PCB manufacturing industries face the issues related to service level of customers and economic losses. Therefore, it is essential to integrate the planning and scheduling problems with all other departments simultaneously [7]. The consequences of these planning problems are not limited to the production floor only. They are also linked with customer demand, order completion and with the breakdowns which occur within the production floor. Therefore, it is essential to make an integrated system to cover all the problems simultaneously.

In this SMS system, each department provides feedback to CMS to take a smart decision to overcome the problems immediately [8]. Currently, the advancement in information and communication technology is required in manufacturing industries to improve communication among different departments including customers and retailers. Therefore, smart manufacturing is considered as the driving force for the new revolution in the manufacturing era. Smart manufacturing consists of various technologies and strategies which can help to promote innovation in the manufacturing industries through communication, information, technology, and resources [9]. Therefore, in this research, the CMS paradigm is employed to assist the collaboration of the different departments of the industry to cope with all challenges related to PCB industries.

Various researchers have proposed different frameworks for SMS with the objective of fusion of current physical manufacturing system and virtual CMS for different manufacturing environments [10,11,12]. In the current study, an empirical and conceptual framework of the SMS is proposed to cope with all above-mentioned problems for PCB industries. CMS is considered as a brain of the proposed framework because it is a useful tool to connect real physical manufacturing system over the virtual digital world for quick computing. The

proposed SMS framework consists of a wide range of problems including smart PCB assembly lines, planning, and scheduling planning smart decisions, intelligent monitoring of shipment and customer orders flow through the retailer. Detailed information and feedback data flow within CMS is addressed.

The remainder of the paper is presented as follows: Section 2 provides the detail of existing problems in PCB industries, Section 3 provides the detail description of a smart manufacturing system with controls in the current PCB industries problems. Section 4 contains the proposed conceptual framework of SMS for PCB industries with detailed insight description of CMS and section 5 provides the conclusion and future work.

2 PROBLEM FORMULATION

The modern era of PCB manufacturing industries is progressing by automation in the manufacturing process, assembly lines with computer-integrated technology for optimisation. The PCB industrial environment can be divided into three major categories. In the start of the production, the raw material and electronic components are assigned to the assembly line through automated guided vehicles (AGVs). At this stages resources and material optimisation is considered. The second stage is machine optimisation in which the machine utilisation, efficiency, and energy optimisation are carried out. In the top stage, the manufacturing system is optimised through proper planning and scheduling of resources, material, and capacity of the assembly lines. Moreover, the customer orders, retailer and shipment information are also dealt in the computer server through CMS. Also, during component assembling on PCB board, there are various planning and scheduling problems occurs in the PCB assembly lines which are required to incorporate simultaneously. In this study, smart manufacturing is integrated with the existing manufacturing system for incorporating the planning and scheduling problems.
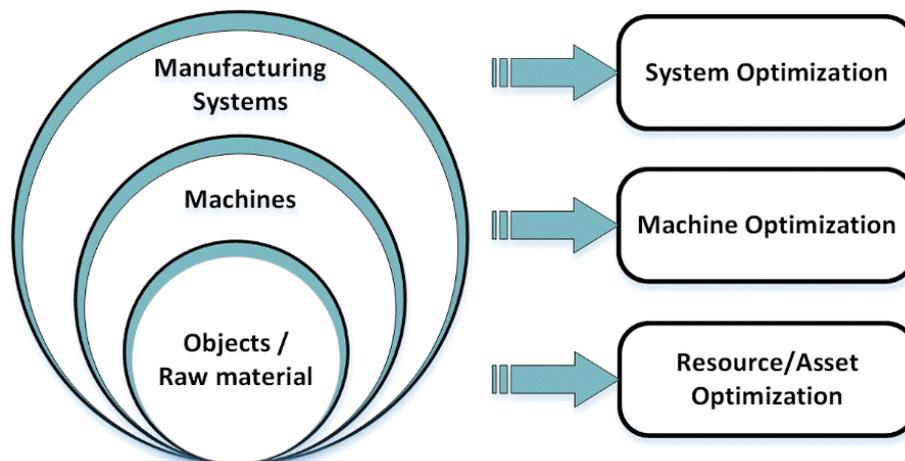

Figure 1: Industrial world towards optimisation

This integration is essential because the planning and scheduling problems are interlinked and play a significant role in the decision-making stage. A CMS paradigm is introduced to get feedback through databases of all departments using the cyber-physical system to make the planning and scheduling decisions more precise and accurate. Therefore, in this study, SMS is used to manage all problems simultaneously. The SMS is a fully integrated intelligent system that provides quick response to the existing problems, i.e., dynamic demand, supply network and decision making on the planning problems. Detailed information about the proposed smart manufacturing system in PCB manufacturing system is discussed in the next section.

3 SMART MANUFACTURING SYSTEM (SMS)

Smart manufacturing is one of the emerging forms of manufacturing systems, which includes a cloud-computing system as a communication technology, intensive modelling, simulation,

and control of the entire system. Smart manufacturing system utilises the idea of an intelligent cyber-physical system that includes big data analysis, artificial intelligence, internet of things, industry 4.0 and cloud computing concepts. Introducing the concepts of cyber intelligent manufacturing in the PCB manufacturing system leads the existing manufacturing system to the latest SMS. SMS can control various problems of the manufacturing system through sensors and centralised data management servers. Some critical controls of the smart manufacturing system for the PCB manufacturing system are discussed in the next section.

3.1   Controls of SMS

In the current problem, six significant controls (Figure 2) are considered for integration through smart manufacturing concept. The ultimate goal to define these controls is to show that how different PCB industry problems are interrelated. The six controls of smart manufacturing for the given problem are materials and handling process, planning and scheduling problems, customer orders and their due dates, manufacturing technology, and resources used in the production, maintenance, and energy optimisation, data collection, and their analysis as shown in Figure 2. These controls are specific to the problems of PCB manufacturing system and vary with problematic nature. Among all, the more focused control is the production planning and scheduling problems because this is linked with the overall production problems, profit, and cost of the industry and customer satisfaction. The detail of smart manufacturing controls is explained below.
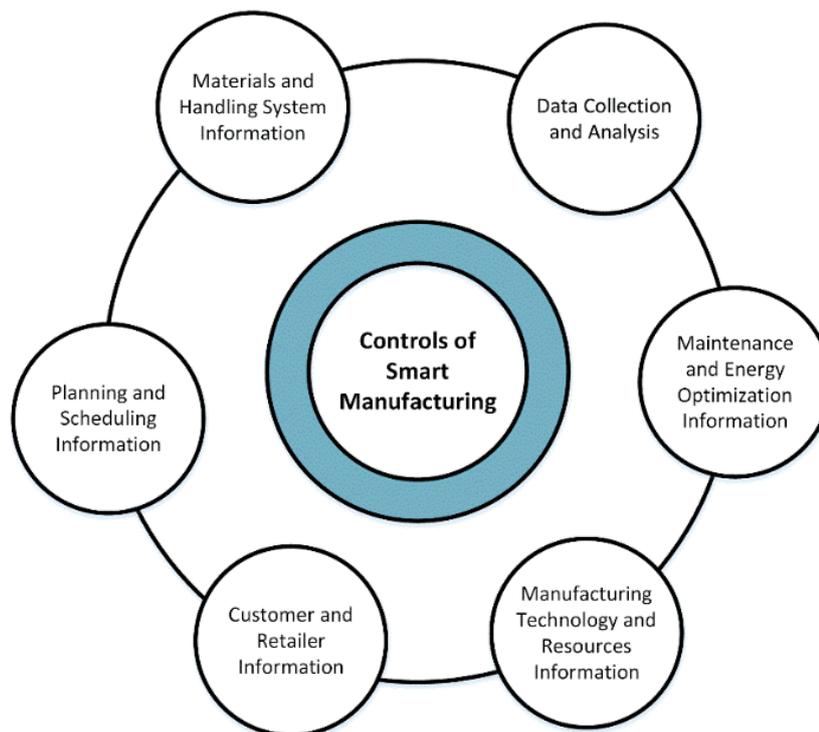

Figure 2: Controls of Smart Manufacturing

3.1.1 Material requirement and handling system

Manufacturing industries are facing complicated situation because of the uncertainty in market demand, customisation in the products. Besides, due to all these problems, the raw material, i.e., PCB bare boards and electronic components are required according to the demand orders and planning. Procurement of materials and material handling is essential to stay competitive in the market [3]. Therefore, the smart decision-making process is required to face the changing and handle the complexity of the system optimally. The smart manufacturing introduces the cloud computing system, in which all information available and

required material for future orders is available. It can quickly detect the shortage and excess of the material problem in any department to assign AGVs to the respective department.

3.1.2 Planning and scheduling problems

Production planning and scheduling problems are among the most significant problems faced by the manufacturing industries, specifically, PCB manufacturing industry [13]. In PCB industry various type of planning and scheduling problems exist which are sometimes tricky to handle simultaneously in the elaborate production environment. For instance, in common PCB assembly line, there are various planning, and scheduling problems exist which are discussed in detail in the proposed framework of SMS. In order to overcome these all planning and scheduling problems simultaneously, the updated information of the planning department is collected and analysed in the CMS.

3.1.3 Customer demands and retailers information

Due to high market demand and variety in the PCB products the customer demand orders and due dates are significant for the retailer to receive orders as per the availability of the resources. It is imperative to know about the available capacity and work in the process of the assembly line production in term of feedback. The information sharing system is introduced in the proposed smart manufacturing system in which all information from the production section of the industry is available, and it is easy to manage customer's order for the retailer.

3.1.4 Manufacturing technology and resources

The development in manufacturing technologies is significant relative to available resources. With the future, the emergence in the technology is significant to compete with the market demand and versatility. Involvement of latest technology in the PCB industry is preferred, for instance, a through-hole technology (THT), which was used mostly for the large size of PCB components, is replaced with latest and smart technology known as surface mounted technology (SMT) to make the process faster and accurate. Similarly, advancement in resources and technology is important to enhance the production of the PCB assembly lines. It can be possible if we have an updated status of the industry using a cloud-computing system introduced in the proposed smart manufacturing system. Besides, some sections of PCB industry where smart devices are not installed, the manual data input is used to transfer information to the database.

3.1.5 Maintenance and energy optimisation

Energy consumption by resources in industries has a significant environmental impact worldwide. There are various reasons for energy losses such as inventory, machine idle time, and maintenance issues of machines. To cope with maintenance issues regular feedback is required to take quick action. Therefore, it is crucial to integrate the information with the CMS proposed in this work for the maintenance and energy issues. In this way, energy can be optimised by introducing proper maintenance and energy optimisation actions.

3.1.6 Data collection and analysis

In this phase, data is collected from all the controls/departments and forward to the CMS for further analysis. Since all departments are interlinked and dependent on each other, collective feedback is required. Therefore, it is constructive to get an optimised manufacturing system by dealing with all planning and scheduling problems exists in the PCB industries. Collection of data from diverse sources (including materials, processes, planning and scheduling, orders and retailer) make the system more realistic and sensitive to changes. A conceptual framework is introduced to cope with all these controls of proposed SMS, which is explained below.

4   THE CONCEPTUAL FRAMEWORK OF THE SMART MANUFACTURING SYSTEM

In this study, an integrated framework of the SMS is proposed for PCB manufacturing system. The characteristics of the proposed framework are significant because it deals with various problems of PCB manufacturing system simultaneously. The purpose of integration of all PCB problems in the framework is to get information of the manufacturing system in a centralised CMS to make better production plans and forecasting for the future orders scheduling by considering all constraints. The objective of the proposed framework is to minimise the overall cost by increasing the productivity and on-time order completion ratio by dealing with the production planning and scheduling problems of the PCB manufacturing system. Besides this, it would be easy to forecast future production accurately and precisely, which increase the customer satisfaction level. The proposed framework of SMS for PCB manufacturing consists of five modules to be integrated with CMS through database storage as shown in Figure 3. These five modules are termed as PCB planning problems, PCB production information, energy optimisation and maintenance, retailer and customer orders information, and delivery or shipment information. First three modules are related to manufacturing system while fourth and fifth modules are related to customers. The detailed information of the five modules is discussed below.
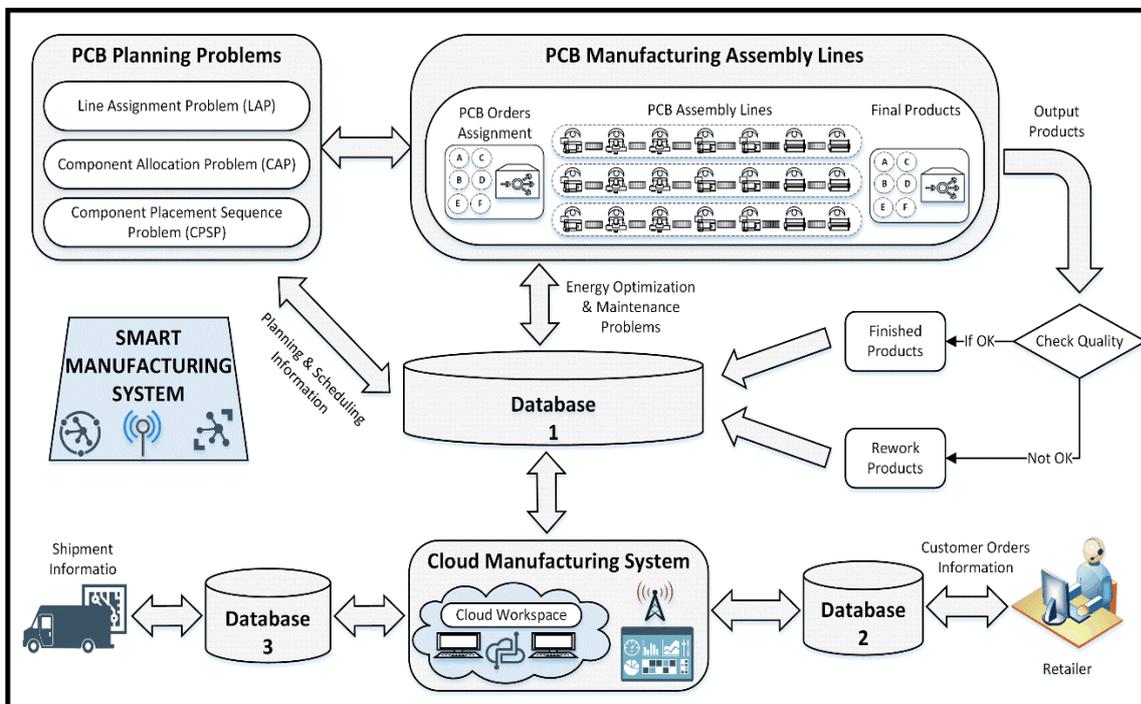
**Figure 3: Integrated Smart Manufacturing System Framework for the PCB Industry**

In PCB planning problems module, all information related to production planning and scheduling problems are transferred to the database of CMS. This module is a most critical module in PCB manufacturing system because it contains various planning and scheduling problems. The planning problems include line assignment problems to the PCB orders based on the availability and capacity of the assembly lines, component allocation problem to the SMT machines in the assembly line by taking into account the ability of the machine and workload balancing. In scheduling problems, the feeder assignment problem to machines and component placement sequence problem are imperative to deal while assembly of components to PCB surface. Likewise, there are other planning, and scheduling problems also exist which can be examined simultaneously. The second and third modules are related to parallel assembly lines of the PCB manufacturing system. In the second module, information containing the production of finished and rework products is transferred to the database of CMS while in the third module the machine utilisation regarding energy consumption and

maintenance issues information is forwarded to the database. Second and third modules contribute to maximising the production rate by optimising the machine utilisation.

Table 1 Database required for cloud manufacturing system

Database	Input data	Remarks
1	Planning and scheduling problem information, Energy optimisation and maintenance information, Final production information	Automated
2	Retailer and customer orders details	Manual and automated
3	Shipment of orders information	Automated (RFID)

Furthermore, the fourth and fifth modules are customer oriented and analysed the performance and system outcome based on the customer orders and completion rate. In the fourth module, the retailer sends the information of new orders from customers, and in contrast, the fifth module provides the information of shipment of the completed orders according to due dates. From all of the five modules, information is collected in the CMS through the database for further analyses. Information required from all modules through three databases to CMS that are given in Table 1. Since the CMS contains all information about PCB manufacturing system and customer orders, therefore it is termed as a decisive phase in which decisions are suggested to all modules based on the information collected. The insight of CMS is explained in the next section.
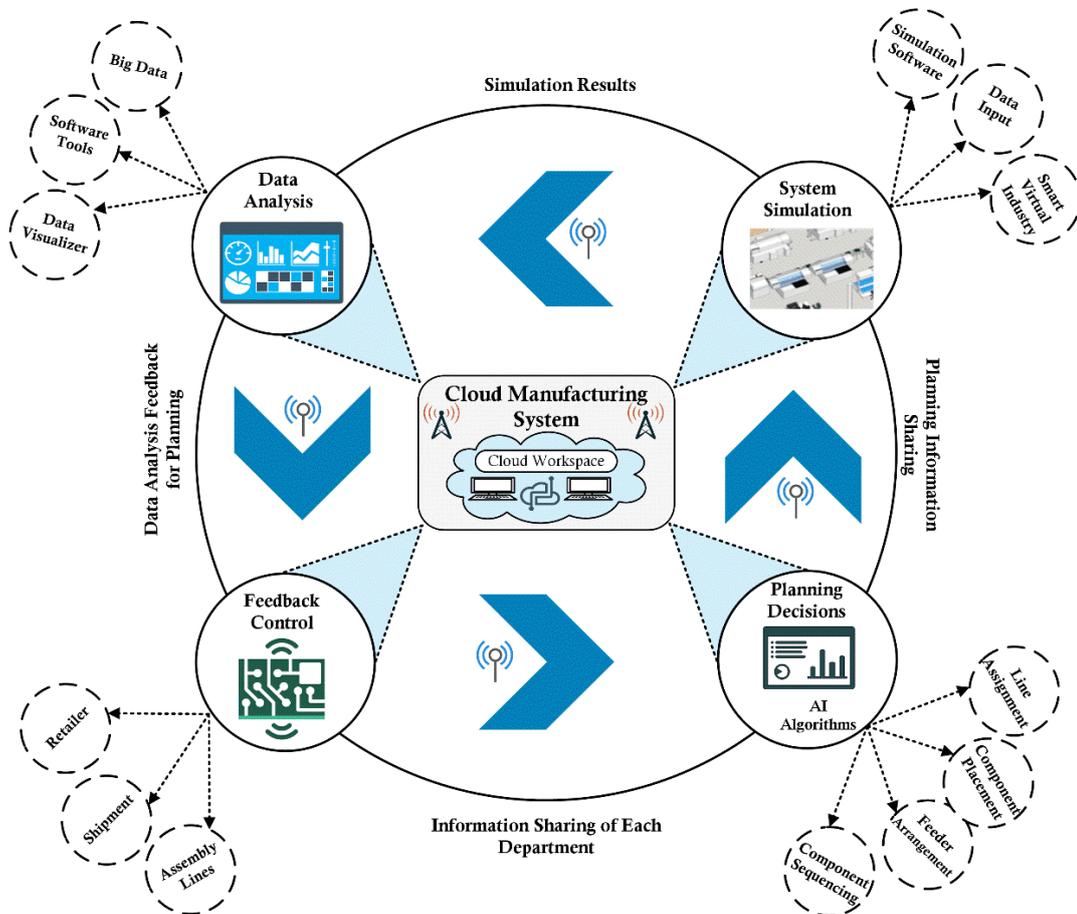
Figure 4: Insight of Cloud Manufacturing System

4.1   The insight of Cloud Manufacturing System

The insight of the proposed CMS for PCB manufacturing industries is illustrated in Figure 4. There are four necessary modules in CMS, feedback, planning and decision, simulation, data analysis. Feedback control module collects real-time information from the various departments of the PCB manufacturing industry, i.e., retailer, assembly lines, packing and shipping departments and shared information with the planning and decision module. Planning and decision module solve the line assignment, component placement, feeder arrangement and component sequencing problem of PCB smart manufacturing system based on real-time data with the help of Artificial Intelligent (AI) algorithms. After successful planning and scheduling, simulation module runs simulations for best and worst case scenarios. Results obtained from simulation are sent to data analyser module where results of both best and worst case scenarios are analysed using statistical analysis tools. Analysed data is further shared with the various departments of the industry for real-time implementation. Because of real-time information sharing, planning, decision-making, validation through simulation and statistical data analysis, PCB manufacturing industries can cope with the increasing complexities in the manufacturing process along with the dynamic customer demands.

5   CONCLUSION

In the study, distinct characteristics of PCB manufacturing assembly line system are investigated to identify the production planning and scheduling problems, and a new smart manufacturing system (SMS) framework is proposed to integrate all problems. The proposed SMS framework for PCB assembly line problems would help to collect information from all the departments at a centralised cloud manufacturing system (CMS). Besides this, the proposed framework of SMS after embedding in the existing manufacturing system would assist to strengthen the PCB manufacturing industries for market competitiveness.

The expected benefits from the SMS in PCB manufacturing system can be summarised as follows. The SMS is easy to customise and update the internal system using feedback from the existing system. Many critical performance measures such as on-time delivery, adequate inventory level, and productivity, and optimum production planning and scheduling can be improved simultaneously using the proposed framework. This framework can also deal with planning and scheduling problems and customers to retailer problems with minimum involvement of human intervention. Moreover, the SMS framework suggested in this study can be an effective and efficient paradigm for small and medium (S&M) PCB manufacturing industries and build an integrated information system for decision support between enterprise systems to operational system. In general, the integrated SMS can assist to optimise the planning and scheduling problem of PCB manufacturing system with the ultimate improvement of the productivity by minimising the delays in lead times of the customer orders.

The research outcomes of the current study can be helpful to develop further in-depth analysis in advanced planning and scheduling systems for any manufacturing industry such as semiconductor manufacturing because of identical characteristics as PCB manufacturing system. Moreover, this framework can be applied to solve many other constraints which are complicated to deal individually, are undergoing with the integrated smart manufacturing system significantly.

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