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A Collaborative Decision-Making System for Production Operation

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Abstract

To meet a large number of personalized demands caused by the increasing living standards of people, the production model of manufacturing enterprises has gradually shifted to small-batch, multi-variety customized production models. For customized production, the limited resources of a single manufacturing company have been difficult to independently and quickly respond to the personalized needs of high-frequency changes. It has become an inevitable choice to integrate the resources of each link in the supply chain for collaborative operation. This paper takes the production and distribution links that are at the core of the supply chain as research objects. Based on the Internet of Things technology, collaborative decision-making to support production and distribution effectively meets individual needs. Finally, the collaborative operation of the production and distribution of an air-conditioning manufacturing company is taken as an example to verify the effectiveness of the IoT-driven collaborative decision-making system proposed in this paper.

Keywords

Internet of Things, Collaborative Decision, Customized Production

1. Introduction

With the improvement of economic strength, consumer demand for products has rapidly changed to the pursuit of personalized demand. To meet the increasing individual demand and improve the competitive advantage of products, the production model of manufacturing enterprises gradually shifted from the traditional mass production model to the customized production model (Fogliatto et al., 2012). For customized production, the limited resources of a single manufacturing company have been difficult to independently and quickly respond to the personalized needs of high-frequency changes. It has become an inevitable choice to integrate the resources of various links in the supply chain for collaborative operation.

Production and distribution are two core links in the supply chain, and its operating efficiency and operating costs directly affect the overall operating efficiency of the supply chain. In the traditional production operation process, production and distribution are independently operated by the production department of the production enterprise and the logistics department of the production enterprise, or independently undertaken by the production enterprise and the third-party logistics enterprise. Production and distribution are two independent decision-making links that have different decision objectives and resource constraints to maximize their respective interests. There is a lack of timely information sharing and collaborative operation between the two links. When a link in the relevant decision-making often ignores the actual situation of another link, it is difficult to achieve the optimization of the overall operation. Therefore, in order to achieve optimal overall operating efficiency and maintain a high level of customer service, production and distribution must be globally optimized and coordinated (Fahimnia et al., 2013).

In recent years, the coordinated optimization of production and distribution from the perspective of global optimization has attracted the attention of relevant scholars and manufacturing enterprises. Scholars meet customer needs by studying the co-optimization of production and distribution under the conditions of different production configuration parameters, order constraint parameters, distribution parameters, number of customers and optimization target (Chen, 2010). Manufacturing companies help to improve their competitiveness by considering production in conjunction with the distribution. For manufacturing enterprises, the collaborative operation of production and distribution can lead to lower operating costs and improved customer satisfaction.

The effective coordination of production and distribution is inseparable from the support of intelligent enabling technology. The Internet of Things (IoT) is an important part of a new generation of information technology, which uses radio frequency identification, sensors and other information sensing technology to connect items to the Internet-based on specific management and application needs (Miorandi et al., 2012). It enables intelligent identification, location, tracking, monitoring and management of items (Al-Fuqaha et al., 2015). The comprehensive sensing, reliable transmission and intelligent processing features of the IoT can effectively meet the needs of current real-time manufacturing data collection, transparent production, accurate decision-making, and refined management. Based on the Internet of Things technology can effectively support the production and distribution of collaborative decision-making, which achieves the dynamic and intelligent operation of production and distribution.

Based on the above analysis, this paper takes the production link and distribution link that are at the core of the supply chain as the research object, and studies the Internet of things-driven production and distribution collaborative decision-making system to provide solutions for the intelligent collaborative operation of production and distribution to meet individual needs.

The paper is organized as follows: Section 2 reviews some previous research related to the proposed collaborative decision-making system. Section 3 analyzes the operation of production and logistics. Section 4 discusses the details about the collaborative decision-making system. In Section 5, a case study is provided to test the effectiveness of the collaborative decision-making system. The final conclusion is summarized in Section 6.

2. Literature Review

2.1. Internet of Things

In recent years, scholars have conducted extensive research on the application of IoT technology in the manufacturing industry. The IoT identifies, senses and collects data on various manufacturing resources, such as equipment, personnel, and materials, which provides the basis for real-time optimization of production and logistics. Parikh & Meller (2010) use the IoT technology to obtain the logistics information in the production process in real-time, and establishes a mathematical model with the minimum walking time as the objective function for the planning and design of the storage area shelf for the manned picking system under the random storage strategy. Fang et al. (2013) use the key event-driven mechanism for the tracking and management of WIP in the manufacturing process to realize automatic identification and visual traceability management of WIP. Makris et al. (2012) use the automatic identification function of RFID to classify various parts on the mixed flow assembly line, which effectively realizes the automatic identification and sorting assembly of the workpiece in the automatic assembly process.

At the same time, according to the real-time data collection of manufacturing resources, the dynamic adjustment of production and logistics operations is realized. Chongwatpol & Sharda (2013) use RFID technology to track manufacturing factors in the production process in real time, and develops real-time data-driven production scheduling rules by mastering the processing time and status information of each station. Zhang et al. (2014) propose a dynamic scheduling method based on the multi-agent manufacturing workshop, and combines with the genetic algorithm to realize the dynamic scheduling decision of real-time data-driven manufacturing tasks in the joint workshop. Based on real-time monitoring of vehicle status, Nielsen et al. (2017) propose a decision-making method to optimize the quantity and distribution order of materials. Ding et al. (2018) used RFID to realize real-time monitoring and scheduling of production and transportation tasks to improved productivity and flexibility through real-time monitoring, simulation and prediction of manufacturing operations.

2.2. Collaborative Optimization of Production and Distribution

The co-optimization of production and distribution is to improve the market competition ability by formulating the optimal production and distribution co-operation plan after considering the actual situation of production, inventory and distribution in the supply chain operation process. The research of co-optimization of production and distribution is a hot research topic in the field of operation management, which has been paid more attention by relevant scholars.

By analyzing the benefits and difficulties that can be achieved from collaborative optimization of production and distribution, Hall & Potts (2003) have studied a class of collaborative operations that includes multiple customers, multiple manufacturers, and individual suppliers, and has demonstrated through examples that collaborative operations can reduce the total cost of the entire supply chain system. Zhong et al. (2010) proposed a class of contract distribution mode of production and distribution scheduling, the goal is to minimize the total distribution cost. Bard & Nananukul (2009) coordinated optimization of distribution and production volumes in a three-phase supply chain operation problem consisting of multiple retailers, one production company and one supplier. Luo et al. (2017) realize the coordinated control optimization of production execution and logistics distribution through the ubiquitous computing technology. Cheng et al. (2015) consider an integrated scheduling problem of production and distribution for manufacturers.

3. Problem Analysis

3.1. Operation Process

As shown in **Figure 1**, the production-distribution operation process is a complex production logistics operation process consisting of product production, finished product storage and finished product distribution. The production-distribution operation process can be described as: 1) according to customer order requirements, multiple production workshops through the development of production scheduling plan to complete the production tasks of the product, and the use of forklifts to complete the finished products to the finished warehouse in a timely manner. 2) The finished goods warehouse allocates the space for the finished products that have been produced, and arranges the shipment of all the finished products in the same customer order after they have been fully prepared. 3) The third-party logistics company arranges for the delivery vehicle to load the finished product in the finished warehouse, and begins the delivery of the finished product after all the finished goods of all orders undertaken by the delivery vehicle itself have been loaded.

3.2. Operation Problems

With the improvement of consumer quality of life, more and more people pursue unique products with personalized characteristics. The personalized demand with small batches, multiple varieties, and high timeliness has many adverse effects on production and distribution operations.

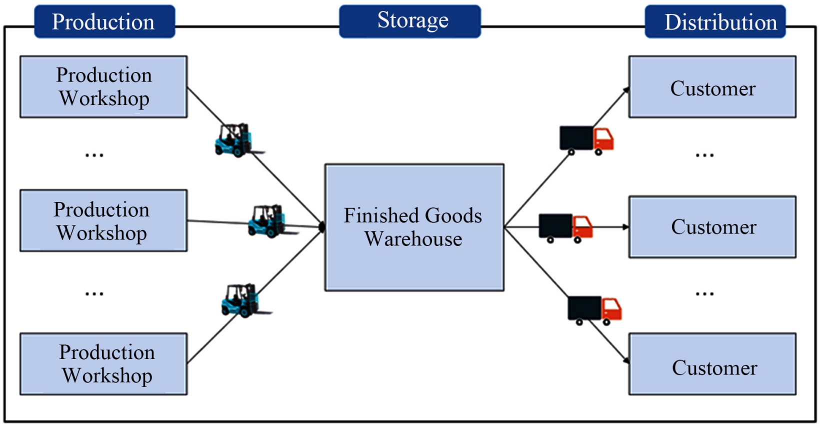

Figure 1. Production operation process.

1) The production time of the product is uncertain. The process of production operation is a complex operation process which includes a variety of factors of production, such as personnel, materials, equipment and processes. Changes in each factor of production may affect the normal execution of production operations. The individualized demand with great uncertainty makes the probability and number of problems of various factors of production increase greatly, which affects the normal operation of the production process. It is not possible to control the production process accurately, resulting in a large fluctuation in the down-line time and the number of off-line products.

2) The long waiting time for the order in the warehouse. Personalized demand orders often contain multiple kinds of products. Because of the widespread use of professional division of labor in production enterprises, a customer order contains multiple types of products that are usually split into different production floors for production, and then shipped until all production plants produce the product that completes the order and is in place in the warehouse. However, due to the high volatility of the off-line time of each production workshop product, it is difficult to synchronize the products produced by each production workshop, which leads to the order waiting in the warehouse for too long.

3) The distribution operation efficiency of the finished product is low. The number of delivery vehicles for third-party logistics companies is limited. When the greater the uncertainty of the order production line time, the greater the dynamics of the demand for distribution vehicles. At this time, it is difficult for third-party logistics companies to effectively integrate the distribution needs of individual orders to achieve scale effect. At the same time, due to the great uncertainty of the product offline, this results in the finished product that has been offline no vehicle can be distributed. Ultimately, customer satisfaction will be affected.

Therefore, production and distribution need to be optimized in a coordinated decision to achieve operational efficiency, reduce operating costs and maintain a high level of customer service.

4. IoT-Driven Collaborative Decision-Making System

The efficient operation of the entire production-distribution process cannot be achieved without a high degree of collaboration in production and distribution. Based on the AUTOM architecture proposed by Huang et al. (2011), an IoT-driven collaborative decision-making system is proposed to solve the production and distribution operation problems caused by personalized requirements, which realizes the intelligent collaborative operation of the entire process of the production-distribution operation system.

4.1. Basic Infrastructures

The collaborative decision-making system includes four layers: intelligent perception layer, intelligent gateway layer, analysis and processing layer, and application service layer, as shown in **Figure 2**. The specific levels are introduced as follows:

Intelligent awareness layer: this layer uses IoT sensing technology such as RFID tags, RFID readers, GPS positioning devices and sensors to perceive real-time multi-source heterogeneous data generated by the entire process of production system, to provide data support for the interconnection and collaborative decision-making of each unit.

Intelligent gateway layer: this layer collects, classifies and transmits the on-site operation information collected by the intelligent sensing layer to ensure the stable transmission and application of production site data.

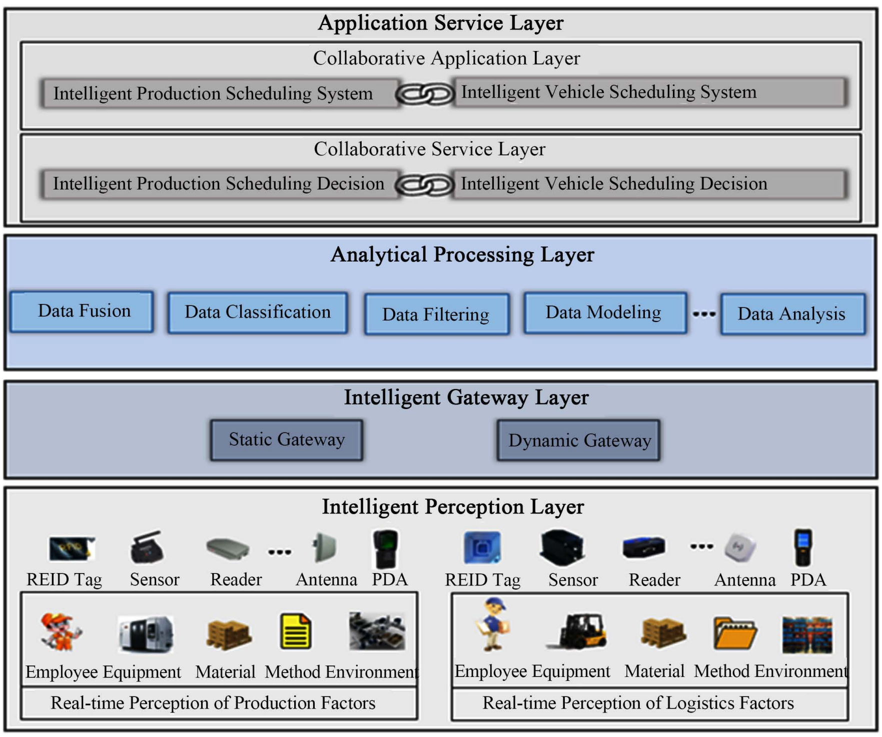

Figure 2. IoT-driven collaborative decision-making system.

Analysis processing layer: this layer performs data verification, filtering, fusion, classification, analysis and other processing operations on the production logistics data transmitted from the intelligent gateway layer. The original production logistics data is transformed into effective data supporting decision-making to realize the value-added application of mass production logistics data.

Application service layer: This layer driven by real-time data provided by the analysis and processing layer, independently analyzes and judges the production logistics execution process and the resources' own behavior, and provides intelligent production scheduling decision-making service and intelligent vehicle scheduling decision-making service to realize the coordinated decision-making of production and distribution. The layer also provides a human-computer interaction application system, users through intelligent mobile terminal or PC interaction with the application system for production and distribution of collaborative decisions to effectively meet personalized production.

4.2. Environment Deployment

The use of IoT-driven collaborative decision-making system to support collaborative decision-making in production and distribution requires operational environment deployment. Real-time acquisition and transmission of production execution data are achieved by deploying intelligent sensing equipment and data transmission equipment at important nodes. The "production-distribution" operation mainly involves three objects: the production workshop, the finished product warehouse, and the distribution vehicle. By deploying related equipment at these three objects, it supports the coordinated operation of production and distribution. The specific operating environment deployment is shown in Figure 3.

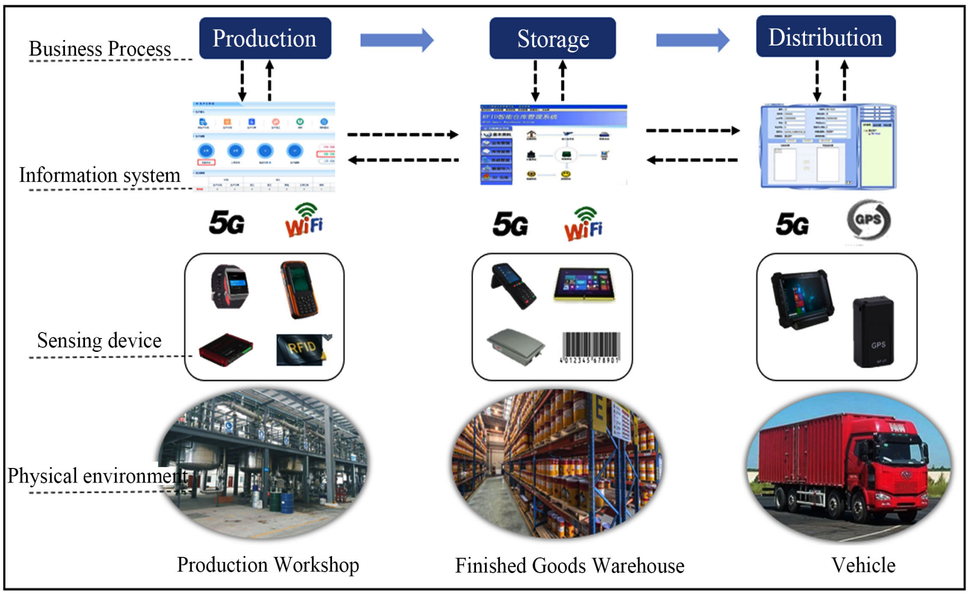

Figure 3. Operating environment deployment.

Production workshop: This key object is the core component of production and distribution operation, and the real-time access to dynamic data directly affects the efficient production and distribution coordination. Accurately capture and transmit real-time operating data such as equipment, personnel and materials and the environment of the production floor by installing smart sensing devices on production equipment, pasting RFID tags on materials and finished pallets, equipping workshop operators with smart wearable devices, installing RFID readers at station and workshop offline points, and covering wireless sensing networks such as 4G/5G and WiFi throughout the workshop.

Finished product warehouse: This key object is an important part of the production and distribution operation that plays a buffering role, and determines the continuity and smoothness of production and distribution. Real-time access to cargo locations by placing mobile access control systems at warehouse entrances, pasting barcodes on shelves, equipping forklift drivers with on-board tablet computers, configuring readers for warehouse staff, and covering wireless transmission networks such as antennas and 4G/5G throughout the warehouse Real-time operational data such as usage, finished product storage information, and forklift access.

Distribution vehicle: The relevant parameter data and dynamic operation data of this key object are important basis for the cooperative operation of production and distribution. By equipping delivery vehicles with on-board tablets to capture real-time finished products and customer location data. Through GPS positioning technology, dynamic operation data such as the location, speed, and loading rate of the delivery vehicles are obtained in real time.

5. Case Study

This chapter takes a home appliance manufacturing company as an example to illustrate that the IoT-driven collaborative decision-making system proposed in this article can effectively realize the collaborative operation of production and distribution. The company has long been deeply involved in the research and development, production and sales of home appliances. There are many types of home appliances under its control. The market demand for different types of home appliances is very susceptible to seasonal changes, resulting in large fluctuations in demand for different home appliances. At the same time, as people's pursuit of quality of life improves, more and more people choose to buy personalized home appliances, which further exacerbates fluctuations in demand.

In order to avoid operating risks caused by market fluctuations, the company adopts an operation mode of direct production according to orders. Through the deployment of the IoT-driven collaborative decision-making system, unified planning, optimization, and management of the production and distribution links can quickly meet customer needs while reducing production and distribution operation costs.

5.1. Intelligent Collaborative System

According to the IoT-driven collaborative decision-making system proposed above, an intelligent synchronization system has been developed that can effectively improve the collaborative operation capabilities of enterprises. The intelligent collaboration system can not only be used to formulate production scheduling plans and vehicle scheduling plans, but also can assist in the implementation process of production and logistics. The main functional modules of the system include five modules:

Download customer order. Through the interface with the enterprise ERP system, the customer orders to be produced are imported into the intelligent collaboration system.

Resource allocation. Facing the acquired order requirements, planners use the system to configure the order with optimized production resources, storage resources, and distribution resources.

Develop an initial production and distribution collaboration plan. Planners use the system to coordinate production departments and third-party logistics companies. Develop a globally optimized collaborative initial operation plan through the coordination of production and distribution.

Perform real-time data sensing. During the execution of production and distribution, the system monitors changes in order requirements, and monitors and collects product production information, finished product storage information, and vehicle information through IoT devices.

Collaborative decision-making. When the actual implementation situation deviates from the initial plan, managers use the system to dynamically coordinate production and distribution to dynamically modify the initial plan.

5.2. Application Effect

The intelligent collaboration system provides basic information and service support for effective collaboration between production and distribution. After using the system, the company's ability to obtain real-time data such as production operators, materials, and environment has been greatly improved, which has increased the operational transparency of the production and distribution process.

At the same time, driven by real-time data, managers can discover problems in time and coordinate production departments and third-party logistics companies to develop collaborative countermeasures, which improve the management and control capabilities of the production logistics system to meet individual needs.

6. Conclusion

In the complex production operation environment caused by the personalized demand of multi-frequency, small batch and high uncertainty, manufacturing enterprises need to integrate the resources of all aspects of the supply chain for collaborative operation. Production and distribution as two key links in the supply chain, the coordination of the operation of the two directly affect the overall operation of the supply chain. In view of the operational characteristics of production and distribution, this paper builds an IoT-driven decision-making system to provide an effective solution for the intelligent and collaborative operation of production and distribution to meet individual needs.

The main contributions of this paper are as follows: firstly, this paper studies the collaborative operation of production and distribution for customized production, which is not only conducive to the rapid response of manufacturing enterprises to high-frequency changes in customer demand, but also conducive to the improvement of customer satisfaction and market competitive advantage of manufacturing enterprises. Secondly, based on the intelligent technology Internet of things, the collaborative decision-making of production and distribution is realized, which provides an information solution for improving the intelligent management and control level of manufacturing enterprises.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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