Science and Technology Publishing (SCI & TECH)
ISSN: 2632-1017
Vol. 7 Issue 1, January - 2023

Supply chain Optimization of Distributed 3D Printing Smart Factory: A Research Agenda

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***Abstract*—With the continuous development of advanced information technology, more and more manufacturing enterprises begin to transform and upgrade as well as moving forward to the intelligent manufacturing advocated by the state. Under this background, this paper puts forward a research agenda on the supply chain optimization of distributed 3D printing smart factory, which provides a favorable idea for the development of manufacturing enterprises. In addition, how the distributed 3D printing smart factory will achieve low-cost operation through low-carbon and scheduling optimization of the supply chain has become a frontier problem of the times, but also conforms to the trend of the times and promotes the green and economic development of our country.**

Keywords—distributed production; 3D printing smart factory; supply chain; low-carbon; scheduling optimization

I. INTRODUCTION

With the arrival of the fourth Industrial Revolution, more and more countries began to formulate relevant strategic policies to promote the development of the Industrial Revolution, such as the proposal of Germany's "smart factory" plan and the concept of "Industrial 4.0", the formulation of China's "made in China 2025" policy and the implementation of the "Industrial Internet" strategy of the United States, etc. Manufacturing enterprises continue to transform and upgrade to emerging concepts such as "intelligent manufacturing", "resource sharing" and "cloud factory". With advanced technologies such as the Internet of things, 3D printing, data analysis, artificial intelligence and so on, the concept of intelligent factory gradually appears in the field of vision of scholars. Compared with traditional manufacturing systems, smart factories can make the manufacturing process information, intelligent and transparent [1], connect devices through the Internet of things, and the manufacturing process can be shared and monitored in the cloud system to achieve personalized production to respond to changing consumer needs [2-4]. In addition, compared with the traditional centralized production mode, distributed production mode has become a new trend of manufacturing enterprises [5]. When multiple 3D printing smart factories are distributed in different areas and interconnected through the network to complete the production of products together, they become distributed 3D printing smart factories, which can effectively improve production efficiency and enable all links of the supply chain to operate efficiently and flexibly, as well as reducing the cost Greatly.

At present, more and more manufacturing enterprises are carrying out production transformation. For example, Haier's interconnected factory has realized the visualization of the whole order, responded to the needs of users in a timely manner, subverted the traditional mode of production [6], not only reduced costs, but also improved production efficiency. It can be seen that the intelligent factory is the trend of future development. In addition, many countries are concerned about green development, in order to reduce carbon emissions and create a low-carbon living environment, environmental factors should be taken into account in the supply chain network [7-9]. And production scheduling is also very important for manufacturing enterprises, which can greatly improve production efficiency and reduce production costs. then the research on the supply chain optimization of distributed 3D printing intelligent factory provides a valuable reference for manufacturing enterprises.

For the research on supply chain low-carbon and scheduling optimization of distributed 3D printing smart factory, scholars have mainly studied the following aspects. For the research of distributed production, scholar Kai Ding et al. (2018) studied a variety of distributed production control mechanisms to achieve a personalized production system with high flexibility, rapid response and high coordination. Zhongshi Shao et al. (2020) proposed a hybrid enhanced discrete Drosophila optimization algorithm for distributed blocking flow shop scheduling problem, which solved the scheduling problem under distributed production. The research on 3D printing smart factory is mainly in the smart factory and 3D printing technology, but there is also a very small amount of research on 3D printing smart factory. Mahbuba Afrin et al. (2019) designed a multi-objective optimization model to solve the problem of robot work assignment in an intelligent factory, which achieved the purpose of optimal robot task allocation. Adnan Hussain (2022) studied the technological convergence of smart factories, and predicted future sustainable development technologies and made decisions for the government and enterprises. Hye-Yeong Park et al. (2019) proved that ceramic cores with high strength and high mechanical properties can be produced by 3D printing technology.

Mallikarjuna N Nadagouda et al. (2020) described the application of 3D printing technology in environmental science, which can not only reduce the waste of materials, but also reduce energy use, which is beneficial to the development of manufacturing enterprises. For the research of 3D printing smart factory, scholar Byung Do Chung et al. (2018) pointed out the importance of 3D printing and Internet of things in intelligent factory, and put forward a dynamic supply chain model and production operation plan to provide valuable reference for manufacturing enterprise operation. According to the research on low-carbon supply chain, scholars such as Muhammad Shabir Srudin et al. (2019) have shown that many sustainable low-carbon supply chain management practices are related to avoiding climate increase and the use of low-carbon energy. Astanti Ririn Diar et al. (2022) proposed a low-carbon supply chain model in order to improve the cost efficiency and green performance of the supply chain. For the production scheduling problem, Weishi Shao et al. (2022) showed that more and more enterprises pay attention to the production scheduling problem of distributed factories, and verifies the effectiveness of the NMA algorithm. Guozhi Ding et al. (2022) showed that the job shop scheduling method based on digital twins can effectively deal with interference and improve efficiency. On the whole, the hybrid research on supply chain low carbon and scheduling optimization of distributed 3D printing smart factory is still lacking. Therefore, the research agenda of this paper will be very valuable.

II. METHODS

We use the literature research method to summarize the supply chain architecture and characteristics of the distributed 3D printing smart factory, and analyze the necessity of low carbon supply chain and the necessity of supply chain scheduling optimization of the distributed 3D printing smart factory by inductive and deductive methods. And finally put forward the hybrid optimization problem of supply chain low carbon and scheduling of the distributed 3D printing smart factory.

III. RESULT

A. Supply chain Architecture and characteristics of distributed 3D Printing Smart Factory

1) Supply chain Architecture of distributed 3D Printing Smart Factory.

The transformation of manufacturing enterprises promotes the upgrading of supply chain structure, and different manufacturing enterprises also have different supply chain structures, so the supply chain architecture of distributed 3D printing intelligent factory studied in this paper is as follows:

a) Suppliers of raw materials：Throughout the supply chain, 3D Printing Smart Factory has many cooperative enterprises, including suppliers of raw materials. Modern supply chain can design personalized products according to the needs of consumers, and after waiting for customers to confirm orders, they can prepare bill of materials and contact raw material suppliers, which can not only respond to customer needs pertinently, but also reduce inventory to a great extent and increase enterprise efficiency [21].

b) Accessory supplier：If customers need more complex products, they can not only use 3D printing technology to complete the manufacture of high-degree-of-freedom products, but also purchase the necessary accessories from accessories suppliers for assembly and manufacturing. in this way, the time of product manufacturing can be reduced and the production efficiency can be improved [22].

c) Core enterprise: The core enterprise of this paper is the 3D printing wisdom factory, which can realize product personalization, design collaboration, supply agility, manufacturing flexibility, service initiative and intelligent decision-making. The specific parts are as follows [23-25].

- Intelligent design: The complex structure products needed by customers are analyzed and designed by using mechanical design software (CAD), engineering design software (CAE), three-dimensional process simulation, three-dimensional display and other technical analysis, and the personalized production of the products is realized. In the process of product design, engineers improve and verify the CAD files sent by customers to confirm whether the order can be made, and feedback to the customer and discuss with the customer. After the final decision, the production process can be carried out [26-28].

- Intelligent production: The intelligent processing equipment in 3D printing intelligent factory mainly includes automatic production line, numerical control center, 3D printer, robot and so on, which can realize the automation, personalization and flexibility of production. In the production process, with the combination of equipment management system (EAM), virtual workshop simulation system, quality management system (QMS), enterprise production process management system (MES), etc., not only can cloud manage the production workshop and real-time monitor the production situation, but also customers can real-time monitor the data collected by the Internet of things through the cloud system and review the process flow and bill of materials. The intelligent scheduling system can make a reasonable scheduling plan according to the situation of the factory in order to achieve high production efficiency [29-31].

- Intelligent logistics: Logistics links mainly include warehouse scheduling system (WCS), warehouse management system (WMS), intelligent transportation system (TMS) and so on. Using advanced information technology, such as sensor, radio frequency identification technology, global positioning system, bar code, Internet of things, etc., to achieve a high degree of automation, efficiency and transparency of goods transportation, greatly reduce

the consumption of resources and reduce the cost [32-34].

- Intelligent products and services: Intelligent products and services mainly include after-sales service management system, product quality traceability system, etc., a perfect after-sales service system can establish a continuous business relationship with customers, with more and more kinds of products, in the production of different batches of orders, if the quality is abnormal, it is necessary to trace the source of the product, accurately find out the problems of the product and avoid potential risks [35-37].

d) Outsourcing enterprise 3D printing wisdom factory: Through Internet plus, cloud system and other advanced information technology, the cooperation between alliance enterprises can be realized and the common manufacturing goal can be achieved. When the production capacity of a certain process of the core enterprise is saturated or the production is stagnant due to failure, the production of the product can be continued through the outsourcing enterprise. the core enterprise will formulate the product production scheduling plan according to the production capacity of the 3D printing intelligent factory of the outsourcing enterprise, carry out collaborative manufacturing through information technology and the outsourcing enterprise, and the core enterprise can also monitor the production process of the product in the outsourcing company in real time. This greatly improves the production efficiency of the product and avoids the loss caused by late delivery [38].

e) Consumers: After the product production is completed, the product delivery link is carried out, and the supply on demand is realized in the supply chain of the distributed 3D printing intelligent factory, which not only reduces the inventory cost, but also achieves the effect of rapid response to customer demand. It is possible to meet the individual needs of consumers. The supply chain of a perfect distributed 3D printing intelligent factory should have good coordination, so that procurement, design, production and logistics can be combined organically, and the resources such as logistics, capital flow and information flow can be distributed rationally. And so that the upstream and downstream enterprises of the supply chain can achieve common manufacturing goals and win-win cooperation.

2) Characteristics of distributed 3D Printing Smart Factory supply chain.

a) Personalized design: 3D printing smart factory uses cloud computing, big data, 3D printing and other technologies to collect data, process order information, and design a reasonable, efficient and low-cost product production plan according to the individual needs of customers. among them, 3D printing technology plays a role in personalized production. 3D printers use ceramic, polymer, metal and other material addition layers, which can produce products or product parts of the desired shape without a mold, and the types and shapes of products can be very wide. Therefore, 3D printers can perform the same function and have different designs to produce customized products. 3D printing can be produced based on CAD drawings, without the need for expensive tools for subtraction, such as grinding, drilling and so on. The production of the product is less restricted by the manufacturing process, and the degree of freedom of design is high. The hollow structure can be completed while ensuring the performance of the product. For example, Aruna Prasopthum explored that 3D printing can create scaffolds with micron faces [39]. H. Niknam verified that 3D printing technology can produce accordion-like cellular structures with sinusoidal structures [40].

b) Flexible production: Traditional mass customization belongs to modular design, which requires a high degree of integration of the supply chain. In the low-carbon supply chain network of distributed 3D printing smart factories, although there are some connections with mass customization, there are still differences. It is based on the Internet of things in manufacturing systems and information physical systems, and can produce a variety of products according to the diverse requirements of customers. The important advantage of 3D printing smart factory is that it can meet the diverse needs of customers, and can also respond to the market in a timely manner. With the development of 3D printing technology, 3D printing is used by more and more manufacturing enterprises. It has more advantages than traditional single products to test the market response by producing small batches of products of various colors, functions and sizes. Using 3D printing technology to produce products, there is no associated tooling cost, and as long as the raw materials of the products are the same, then any product can be produced. In addition, 3D printing smart factories can flexibly use processes to produce products based on available equipment or resources, or produce a product in a variety of ways

c) Flexible supply chain: Flexible supply chain means that devices in distributed 3D printing smart factories can be monitored, operated and shared in real time, and production can be outsourced to facilitate agile cooperation among intelligent agents, real-time data collection, 3D printing technology, and so on. With the increasing personalized needs of users, the wide variety of customized products brings a lot of uncertainty to enterprises, so the facility capacity of the shared network can be flexibly dealt with. In other words, if the specific process capacity of a 3D printing smart factory is insufficient, the product can be produced by an outsourced 3D printing smart factory by sharing processes and machines, which can not only make effective use of the resources in the supply chain. And can maximize the utilization of chemical plant capacity. Factories integrate product design, supplier selection, process planning,

production scheduling and logistics through information sharing, and share available capabilities to integrate the entire supply chain. In addition, in the supply chain, designers can change the design of the product at any time in response to customer demand, even if the product has reached the production stage, the manufacturer can redesign the product at any time according to customer demand, therefore, flexible supply chain should support the final change of customer demand.

d) Flexible strategic cooperation: With the introduction of advanced technology, the information capacity of the supply chain increases and the speed of information dissemination becomes faster. information about the design, production and sale of products can be tracked and collected in a variety of ways, such as radio frequency identification technology and the Internet of things. At the same time, it can be shared in the cloud system to achieve end-to-end collaboration. In order to improve the competitiveness of enterprises and respond to market demand in time, enterprises should develop strategic diversity and formulate appropriate implementation plans according to the changes of market environment and corresponding resources. Shamin Shirodkar proposed a flexible strategy to address internal or external uncertainties in the production of semiconductors. The capacity of each facility can be shared in the factory. Generally speaking, a product is produced in one factory, but if various uncertainties such as insufficient capacity occur, the product can be produced through the network in cooperation with another factory [41]. This will promote flexible strategic cooperation between enterprises, achieve efficient production and improve the competitiveness of enterprises.

B. The necessity of low-carbon supply chain of distributed 3D Printing Smart Factory

The development of modern low-carbon supply chain promotes the reform of production mode, and the concept of environmental management is valued by more and more manufacturing enterprises. enterprises should not only pay attention to their own interests and internal environment, but also consider external environmental factors. therefore, the design of low-carbon supply chain becomes particularly important for enterprises.

The formulation of relevant policies in many countries not only promote the development of low-carbon supply chain, but also promote the establishment of energy saving and emission reduction operation system, and contribute to the global ecological security. In addition, the concepts of smart manufacturing and smart factory are concerned and applied by more and more enterprises. Smart factory not only realizes automatic production, but also is more green than the traditional mode of production. It is the development trend of future manufacturing enterprises and promotes the sustainable development of society and economy.

The continuous growth of carbon dioxide emissions has led to global warming, which has caused great harm to the global ecological environment. This may make the sea level rise in coastal areas easily lead to floods or other natural disasters, bringing burden and pressure on the society and economy of the country [42]. The development of circular economy makes manufacturing enterprises reduce the consumption of resources, which is an important way to reduce carbon emissions.

C. The necessity of supply chain scheduling Optimization of distributed 3D Printing Smart Factory

Then the supply chain optimization problem of distributed 3D printing intelligent factory which will be studied in the future can not only help manufacturing enterprises to achieve flexible and personalized production, but also improve the production efficiency of enterprises.

Scheduling optimization can reduce the impact of production personnel in the process of manufacturing products. For manufacturing enterprises with large orders, if manual production scheduling is used, it will be very difficult and time-consuming [43], even if the production planners are very familiar with the production line, they may make mistakes, resulting in low production efficiency and can not guarantee that the enterprise can get the maximum profit. therefore, a good scheduling optimization model for manufacturing enterprises. Especially for the increasing number of 3D printing smart factories, it has become particularly important, reducing the uncertainty caused by personnel intervention.

A good production scheduling scheme can avoid production stagnation. While improving the balanced distribution ability and smooth connection of manufacturing enterprises to multi-order and multi-category product manufacturing under many resource constraints, it also ensures that enterprises can achieve the optimal time delivery of orders and the minimum exchange of production. It can realize the balanced utilization of production capacity, improve the production operation effect and production efficiency of the enterprise [44], further improve customer satisfaction, avoid late delivery, and even shorten the delivery cycle. In addition, it can also track the whole process of orders, effectively manage the production progress of products, and schedule production flexibly.

Scheduling optimization can improve the effective output of the factory. By considering the whole production plan, effectively coordinate the scheduling of upstream and downstream production lines, efficiently respond to important orders and emergency orders, and actively respond to the diversified needs of customers [45]. In addition, it can also optimize the process path of products, as well as the selection of outsourcing factories, which not only ensures the production quality of products, but also improves the production efficiency of products, and realizes the flexible and flexible production effect of the supply chain.

D. Hybrid optimization problem of low carbonization and scheduling in supply chain of distributed 3D printing intelligent factory

Different from the traditional supply chain, because the customer demand and products are unknown before the decision, it is difficult to produce highly customized products. Therefore, it is particularly important to let customers participate in the production process, understand the product characteristics and adjust the requirements of the product at any time. In terms of enterprises, under production constraints, it is important for enterprises to reduce inventory surplus, respond to customer needs in a timely manner, minimize costs, and reduce carbon emissions as much as possible.

In the low-carbon supply chain flow chart shown in Figure 1, it can be seen that it is very important to optimize the design and production scheduling of the low-carbon supply chain for distributed 3D printing smart factories. First of all, the customer sends the CAD file to the enterprise and applies for the order through the cloud system; then the engineer makes improvements and verifies whether the order can be made according to the CAD file sent by the customer, and then feeds back to the customer and discusses with the customer; next, the cloud system can monitor the real-time data collected by the Internet of things and review the process flow and bill of materials. Then, according to the order demand, production constraints and low carbon emissions, design the best low-carbon supply chain optimization model, and work out a reasonable production scheduling plan and select the appropriate supplier; after that, the customer will receive the process, scheduling plan, delivery time and other information, and confirm; then send the confirmed plan to the participants, the participants for factory scheduling; finally, each link of the supply chain to make a schedule and begin to implement. In this process, the distributed 3D printing smart factory can be transferred according to the designed low-carbon supply chain and scheduling scheme, which can greatly improve production efficiency, reduce various costs and maximize enterprise profits. The hybrid optimization problem of low carbon and scheduling of supply chain that will be studied in the future is based on the distributed 3D printing intelligent factory, which chooses to study the two-level low-carbon supply chain network, that is, the selection of suppliers and production process. Through the analysis of the fixed cost, production cost, transportation cost, purchasing cost and carbon emission cost of the 3D printing intelligent factory, the production scheduling optimization model of the product is constructed. At the same time of minimizing the total cost, it also completes the reasonable scheduling problem between factories, works out the best production plan, and realizes a flexible, personalized, automatic, intelligent and efficient production mode.

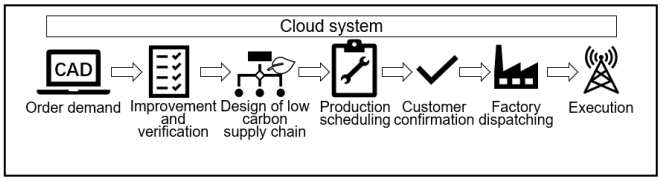

Fig. 1. *The process of Low-carbon supply chain.*

The secondary supply chain network to be studied in the future is shown in the example in Figure 2. The main body of the supply chain on the left is the selection of suppliers. If the supplier 2 that brings low-cost raw materials to the enterprise is selected as the raw material supplier of a product, then transported by road. Raw materials are transported to factories 1 and 2 that can perform process 1 (some of the raw materials are transported to process 1 of factory 2 for production because of the limited production capacity of process 1 of factory 1), where black represents a process that can be operated and gray represents a process that is not operational. The semi-finished products of process 1 are then transported to factory 2 where process 2 can be carried out for production, and so on, until all processes are completed, while ensuring that the total cost is minimized.

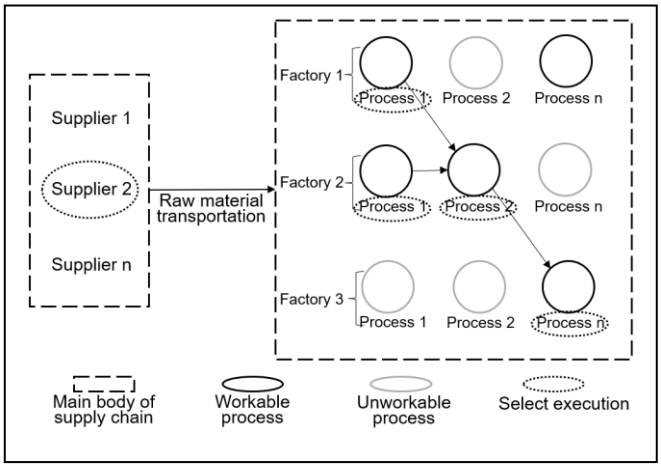

Fig. 2. *Two-level supply chain network.*

IV. Conclusion and Prospect

This paper first shows the supply chain framework of distributed 3D printing smart factory, and describes its characteristics, then expounds the necessity of low carbon supply chain and scheduling optimization of distributed 3D printing smart factory. The significance of this paper is emphasized. Finally, the hybrid optimization problem of supply chain low carbon and scheduling of distributed 3D printing smart factory is put forward. An example is given to illustrate the operation process of the two-level low-carbon supply chain network studied in this paper, which enhances the understanding of the future research content.

Under the background of distributed 3D printing smart factory, the future research will conduct a mixed study on supply chain low-carbon and scheduling optimization, and construct a low-carbon supply chain network and scheduling hybrid optimization model of distributed 3D printing smart factory to minimize the

total cost. And work out the corresponding scheduling plan according to the results, which provides a valuable reference for the transformation of manufacturing enterprises.

ACKNOWLEDGMENT

This work was supported by Liaoning Social Science Planning Fund [grant number L22BJY040].

REFERENCES

[1] M. Geng, "Application of Big-data and Cloud Computing in Smart Factory," Industrial Control computer, vol. 34(12), pp. 32-34, 2021.

[2] T. Fang, "Research on the Application of Internet of things Technology in Industrial Automation," Papermaking equipment and Materials, vol. 51(08), pp. 44-46, 2022.

[3] Y. He, M. Xia, "Research on large-scale personalized production mode based on Industry 4.0," Manufacturing Automation, vol. 43(01), pp. 25-29, 2021.

[4] X. Ye, "Small orders can also produce personalized and more market flexible manufacturing made in China," Decision Exploration (1), vol. 01, pp. 34-35, 2021.

[5] H. M. Xu, "Research on Multi-plant production scheduling in distributed Manufacturing Environment," CN: Shenyang University of Technology, 2020.

[6] R. R. Lv, "Smart Interconnection pilot all the way-- A record of Haier Central Air conditioning and Interconnection Factory," China Construction Informatization, vol. 22, pp. 54-55, 2017.

[7] S. Wu, J. Mao, "Analysis of the current green supply chain problems and countermeasures," China's Collective economy, vol. 28, pp. 103-104, 2021.

[8] Y. Mao, "Research on the Construction of Green Manufacturing system in Industrial Park in the New era," Quality and Certification, vol. 10, pp. 61-63, 2021.

[9] J. Cao, Y. Xi, Q. Deng, R. Hou, "Establish a green supply chain management evaluation system to promote the development of circular economy in China," World Environment, vol. 04, pp. 45-47, 2022.

[10] K. Ding, P. Jiang, "Incorporating social sensors, cyber-physical system nodes, and smart products for personalized production in a social manufacturing environment," Proc Inst Mech Eng Part B J Eng Manuf, vol. 232(13), 2018.

[11] Z. S. Shao, D. C. Pi, W. S. Shao, "Hybrid enhanced discrete fruit fly optimization algorithm for scheduling blocking flow-shop in distributed environment," Expert Syst Appl, vol. 145, pp. 17, 2020.

[12] M. Afrin, J. Jin, A. Rahman, Y. Tian, A. Kulkarni, "Multi-objective resource allocation for Edge Cloud based robotic workflow in smart factory," Future Generation Computer Systems, vol. 97, 2019.

[13] A. Hussain, J. Jeon, M. Rehman, "Technological Convergence Assessment of the Smart Factory Using Patent Data and Network Analysis," Sustainability, vol. 14(3), pp. 18, 2022.

[14] H. Y. Park, E. H. Kim, G. H. Cho, Y. G. Jung, J. Zhang, "Process development of fabricating ceramic core using 3D printing technique," Materials Chemistry and Physics, vol. C231, 2019.

[15] M. N. Nadagouda, M. Ginn, V. Rastogl, "A review of 3D printing techniques for environmental applications," Current Opinion in Chemical Engineering, vol. 28, 2020.

[16] B. D. Chung, S. I. Kim, J. S. Lee, "Dynamic Supply Chain Design and Operations Plan for Connected Smart Factories with Additive Manufacturing," Applied Sciences-Basel, vol. 8(4), pp. 16, 2018.

[17] M. S. Shaharudin, Y. Fernando, C. J. C. Jabbour, R. Sroufe, M. F. A. Jasmi, "Past, present, and future low carbon supply chain management: A content review using social network analysis," Journal of Cleaner Production, vol. 218, 2019.

[18] A. R. Diar, D. Yosef, D. P. Kartika, "Low-Carbon Supply Chain Model under a Vendor-Managed Inventory Partnership and Carbon Cap-and-Trade Policy," Journal of Open Innovation: Technology, Market, and Complexity, vol. 8(1), 2022.

[19] W. S. Shao, Z. S. Shao, D. C. Pi, "A network memetic algorithm for energy and labor-aware distributed heterogeneous hybrid flow shop scheduling problem," Swarm Evol Comput, vol. 75, pp. 20, 2022.

[20] G. Z. Ding, S. Y. Guo, X. H. Wu, "Dynamic Scheduling Optimization of Production Workshops Based on Digital Twin," Applied Sciences-Basel, vol. 12(20), pp. 16, 2022.

[21] X. Ye, "Study on Evaluation and selection of Raw material suppliers of BGB Company," CN: Huaqiao University, 2021.

[22] Z. Liu, S. Wang, "Supplier selection Analysis of Assembly components based on improved CRITIC-VIKOR method," Journal of Engineering Management, vol. 36(02), pp. 125-129, 2022.

[23] C. Yang, "Analysis on the Development trend of Intelligent factories in China," China Industrial Review, vol. 01, pp. 56-63, 2016.

[24] H. Jiao, J. Lu, "Summary of the research status of intelligent factory and its key technologies," Mechanical and Electrical Engineering, vol. 35(12), pp. 1249-1258, 2018.

[25] F. Li, "Application of key Technologies of Intelligent Factory lesson 6 data processing of

Intelligent Factory," Automation Expo, vol. 01, pp. 54-57, 2019.

[26] H. Shi, "Design and implementation of process Intelligent Design system for Metro vehicle Base," Modern Information Technology, vol. 6(18), pp. 15-19, 2022.

[27] X. Rui, "Application of intelligent design technology in mechanical R & D and manufacturing," Southern Agricultural Machinery, vol. 553(16), pp. 175-177, 2022.

[28] C. Ke, "Research on intelligent design method of electromechanical products for remanufacturing," CN: Wuhan University of Science and Technology, 2022.

[29] M. Chen, "Research on flexible Intelligent production Mode of Garment Enterprises," Jiangsu Silk, vol. 277(05), pp. 32-34, 2022.

[30] Z. Tong, "Research on intelligent production organization mode based on collaborative supply chain," Anhui Science and Technology, vol. 400(06), pp. 49-51, 2022.

[31] J. Yu, "Research on the current situation, problems and countermeasures of intelligent production enabling high-quality content," Introduction to News Research, vol. 13(09), pp. 1-3, 2022.

[32] J. Jiang, G. Zhang, X. Wu, "Research on the Application of Modern Information Technology in Factory Intelligent Logistics Operation," Modern Information Technology, vol. 7(01), pp. 169-172, 2023.

[33] X. Wang, "Discussion on Intelligent Logistics supply chain Management under Internet of things Technology," Shanghai Commerce, vol. 526(12), pp. 55-57, 2022.

[34] X. Wang, "Application and development trend of intelligent logistics equipment," China Storage and Transportation, vol. 265(10), pp.150-152, 2022.

[35] J. Li, Z. Sun, "The influence of virtual value theory on intelligent products and services in the new situation," Smart City, vol. 7(17), pp. 33-34, 2021.

[36] M. Zheng, "Research on the theory and method of intelligent product service ecosystem," CN: Shanghai Jiaotong University, 2018.

[37] C. Liu, Q. Zhang, W. Xu, L. Liu, "The Integration of Intelligent products and Services: a New Direction of Future economy," Industry and Science and Technology Forum, vol. 15(16), pp. 105-106, 2016.

[38] J. Zhang, "Research on the Development Mode and Strategy of Financial Outsourcing Enterprises in big data era," Volkswagen Investment Guide, vol. 409(17), pp. 136-138, 2022.

[39] A. Prasopthum, M. Cooper, K. M. Shakesheff, J. Yang, "Three-Dimensional Printed Scaffolds with Controlled Micro-/Nanoporous Surface Topography Direct Chondrogenic and Osteogenic Differentiation of Mesenchymal Stem Cells," ACS Appl Mater Interfaces, vol. 11(21), pp. 18896-18906, 2019.

[40] H. Niknam, H. Y. Sarvestani, M. B. Jakubinek, B. Ashrafi, A. H. Akbarzadeh, "3D printed accordion-like materials: A design route to achieve ultrastretchability," Additive Manufacturing, vol. 34, pp. 10, 2020.

[41] S. Shirodkar, K. Kempf, "Supply Chain Collaboration Through Shared Capacity Models," INFORMS Journal on Applied Analytics, vol. 36(5), pp. 420-432, 2006.

[42] Z. Liu, S. Chen, "Based on the concept of green development, the necessity and system design of levying carbon tax in China," Foreign Trade and Economic Cooperation, vol. 09, pp. 152-157, 2019.

[43] J. Liu, "Research on production scheduling of S Company based on PSO embedded SA algorithm," Information and computer (theoretical Edition), vol. 34(03), pp. 62-64, 2022.

[44] X. Pang, "Study on operation optimization method of multi-variety and small batch flexible mixed-flow production," CN: Shenyang University of Technology, 2021.

[45] W. Wei, "Construction of steel plant management platform based on advanced planning scheduling (APS) optimization algorithm," Metallurgical Management, vol. 02, pp. 55-60, 2022.