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Research on Collaborative Mode of Prefabricated Construction Supply Chain Based on Supply-hub

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Abstract. Confronted with the uncertainty in prefabricated construction supply chain, this paper applied Supply-hub mode to solve the uncoordinated or unmatched of logistics and information flows in prefabricated construction supply chain, established the collaborative operation model of prefabricated construction supply chain based on Supply-hub by integrating Supply-hub, multiple suppliers and general contractor with collaborative interaction platform based on BIM information flows, realized the vertical and horizontal coordination in supply chain through Supply-hub coordinated logistics and information flows of procurement, production and distribution of upstream and downstream, and provided several references for the application of Supply-hub mode in prefabricated construction supply chain.

1. Introduction

With the reform and development in the construction industry, prefabricated building has provided guidance for the future of the construction industry. The prefabricated building is of large volume, which involves complex products and multiple enterprises in the process of construction. However, due to technologies of prefabricated construction are still in primary stage, coordination level between the upstream and downstream is so low that the information among them cannot be shared effectively. As a result, the inefficiency of enterprises in construction supply chain and rising production costs. Supply chain collaboration, as a research hotspot in the field of supply chain management, has attracted extensive attention from scholars and experts [1]. Simatupang and Sridharan offered that supply chain collaboration is to meet the needs of end customers at a low cost, gain profits, share profits, and to win competitive advantages [2]. The scope of supply chain collaboration has been divided into horizontal collaboration and vertical collaboration by Barrat [3]. Shi-Hua M A put forward the supply chain cooperative operation mode based on Supply-hub is gradually formed as one of the most typical and effective ways of working in enterprise management practice [4]. Guo L.I. analysed the application of supply-hub management mode to eliminate or reduce the uncertainty of assembly supply chain system, which was effective to improve operation efficiency of the supply chain collaborative. Supply-hub is not only the coordination organization of integrated management of supplier inventory but also the management platform of logistics information [5]. The support of advanced information technology is the prerequisite of supply chain collaborative management based on Supply-hub in which the bidirectional flowing of information reflects and controls the logistics and capital flow [6]. Owing to the core concept that BIM technology can realize information sharing, the rapid development of it will support the coordinated management of logistics and information flow of enterprises in the prefabricated construction supply chain [7], and the application of BIM technology



can establish advanced platform of information communication, combining with the moving technologies such as GIS and RFID, and adjust and optimize processes relevant to supply chain operation to implement logistics synergy of supply chain [8]. However, there is little research on how to apply information sharing technology, especially BIM, into the management practice of Supply-hub mode. The development of construction information technology—BIM, provides a strong foundation for the ultimate objective to realize the synergism of industrial chain as well as the future of the prefabricated construction. Therefore, this paper will integrate the Supply-hub mode with the prefabricated construction supply chain in which BIM technology is applied to realize information sharing, and then develop the collaborative operation model of prefabricated construction supply chain based on Supply-hub to achieve information sharing between upstream and downstream in the whole process of prefabricated building and collaborative work.

2. Analysis of uncertainty and collaborative demand of prefabricated construction supply chain

2.1 The SCOR-based Prefabricated Construction Supply Chain

The concept of prefabricated construction supply chain was first proposed by Koskela who had applied the concept of manufacturing supply chain into construction industry [9]. Prefabricated building has changed the traditional construction process, with reference to the basic process of supply chain operation reference model (SCOR), the prefabricated building supply chain is divided into planning, procurement, manufacture, assembly, delivery and return, as shown in figure 1.

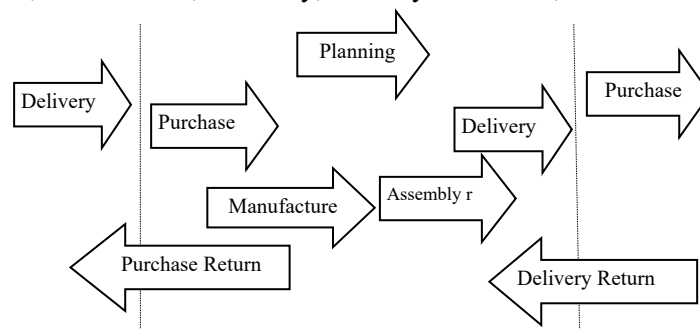


Figure 1. The operation model of SCOR-based Prefabricated Construction Supply Chain (PCSC).

2.2 The Uncertainty analysis

Uncertainty of demand and supply between upstream and downstream in supply chain, which generally is the main reason why construction enterprises frequently face the problem of higher inventory costs, including supply uncertainty and production uncertainty and demand uncertainty [10], as shown in figure 2. From the perspective of downstream of the prefabricated construction supply chain, due to numerous components in prefabricated buildings and varying complexity degrees of build process at different stages, the changeable needs of the clients usually lead up to design changes and adjustment of construction schedule, general contractor should timely response to these requirements and then execute relevant programs including product design and procurement of materials and equipment for the prefabricated building subassemblies. In certain construction procedures, the demand for materials and equipment fluctuates greatly, but it is difficult for the general contractor to store a large number of building components in advance because of the spatial constraints of construction site, which is likely to cause project delay. Likewise, from the angle of the upstream supply chain, because of the complexity and a lack of standardization of the production process of the units, suppliers are difficult to provide timely the product components required by the general contractor to meet the construction requirements, which causes usually the loss of stock or the delay in delivery.

2.3 The requirements analysis of vertical and horizontal collaboration

It is difficult to control and solve the supply/demand uncertainty of supply chain [11], especially for the complex assembly supply chain system. The prefabricated buildings with a collection of engineering design, production and installation, usually involves with many participators, parallel-cross working process, thus the large-scale standardized production of many prefabricated components requires close cooperation among multiple suppliers. However, due to the geographically separated in production and installation of building components, the process synchronization of manufacture, distribution and assembly at construction site, requires the collaborative operation of upstream and downstream firms in supply chain. The prefabricated construction supply chain, which is composed of multiple suppliers and the general contractor respectively located in the supply chain upstream and downstream, as shown in figure 3. In the condition of information resources highly shared, the supply-hub operator, through the coordination of supply and demand information, integration and optimization of resources, can not only achieve vertical collaboration between suppliers and customers but also make for the horizontal collaboration based on lean manufacturing among suppliers.

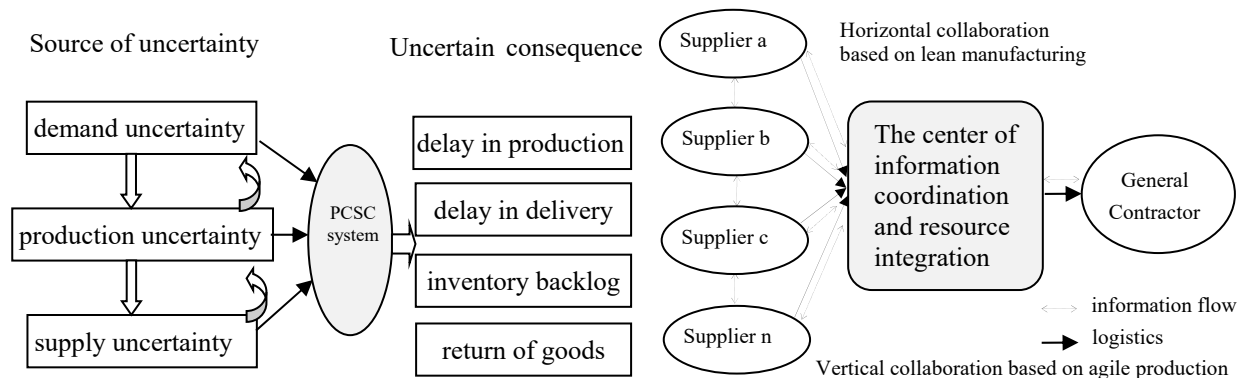


Figure 2. The uncertainty effect analysis of PCSC system.

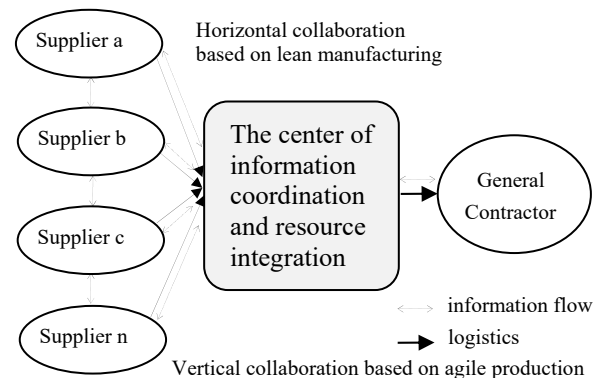


Figure 3. The conceptual model of PCSC collaboration.

3. The collaboration of prefabricated construction supply chain based on Supply-hub

3.1 The BIM-enabled supply chain logistics and information flow

BIM, as a building product model, supports materials flow and the information flow in the product information structure model in the whole process from designing to building of the prefabricated building. Many BIM tools can be used to manage and compare material performance and quality to ensure that the purchased materials conform to the specific requirements of project and construction specifications. And then through integration with barcode, RFID, and GPS, BIM can be used for tracking and monitoring material distribution to improve supply chain visibility [12]. Meanwhile, BIM also will be also combined with automatic algorithm for inventory optimization to manage the material flow and maximize material utilization. The features and functions of product modeling and project information diffusion facilitate information sharing based on BIM by offering information interaction model among participants, in which IFC standard document as the standardized solution of product information can ensure information consistency [13]. In the process of information sharing and interaction of supply chain, the digital management of logistics and information flow through BIM-based collaboration platform will provide data support for the application of Supply-hub mode in prefabricated building supply chain, that will support collaborative management among partners.

3.2 The model of prefabricated construction supply chain based on Supply-hub

In this paper, a collaborative operation model of prefabricated construction supply chain based on Supply-hub is constructed, as shown in figure 4. The Supply-hub, which may be a contractor or a third

party, organizes and coordinates logistics and information flow through the information collaboration platform based on BIM, in order to accomplish the goals that horizontal collaboration among suppliers and vertical collaboration between upstream suppliers and downstream general contractor. By making full use of the information interactive platform, the Supply-hub can not only realize collaborative manufacturing, distribution and inventory management of upstream suppliers, but also quickly respond to the changes in material requirements from contractor at construction site to realize JIT (Just-In-Time) logistics.

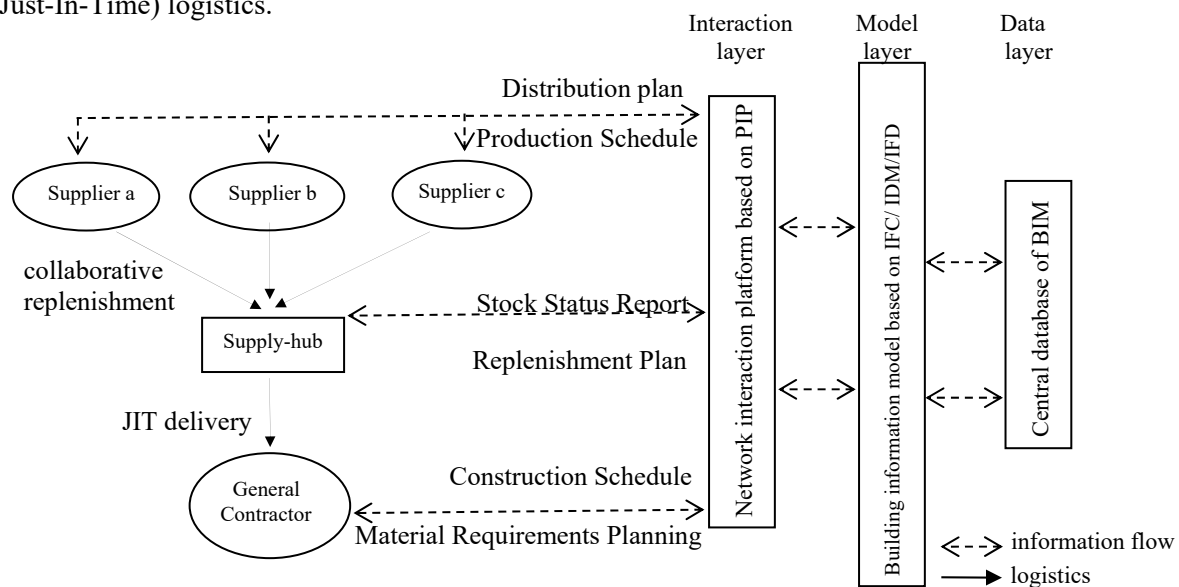


Figure 4. The collaborative operation model of PCSC based on Supply-hub.

The prefabricated construction supply chain is of supply chain based on mass customization, client demand-driven and product-centric, which adopts BIM technology to carry out modular design of products, standardization and generalization of product model, and then makes full use of advanced computer integrated manufacturing system to realize agile manufacturing and satisfy customer's needs timely. Furthermore, the distinctive feature of BIM is interactivity that help participants effectively perform work in parallel through timely transmission and exchange of BIM models. Thereby, in order to solve the problem of information synergy such as safe storage of information, information transfer and sharing, application in prefabricated construction supply chain based on Supply-hub, the BIM technology can effectively implement centralized management of data and information interaction in the prefabricated construction supply chain based on Supply-hub. In this study, the framework of the information collaboration platform has a three-layer with data layer, model layer and interaction layer.

In the Data layer, as both the basic layer of realization of supply-chain information synergy and the core of building information storage, the BIM central database is divided into different modules, each of them, dealing with data, resources and processes from different subjects and professions, serves as a the object-oriented data center with integration, parameterization and intelligence in which the structured, semi-structured and unstructured information of the total project life cycle can be centrally stored and managed.

In the model layer, the building information model based on IFC/IDM/IFD standard, connecting the data layer and the interaction layer, is a data interaction and management center for integrating information model. IFC standard, namely Industry Foundation Classes, can define the format of data exchange and data storage for BIM model information. IDM, which is the Information Delivery Manual, regulates the contents of the information exchanged information exchange between the participants in each process of the whole life cycle of project. The IFD standard, called the International Framework for Dictionaries which records and aggregates all information about interrelated attributes through creating a globally unique identifier for each concept in the IFC model.

And thus, BIM technology based on IFC/IDM/IFD standard can be applied to transfer and exchange information about physical space, design, procurement and construction among various professional actors.

In the interaction layer, it will obtain data from the model layer to service for users. The Network interaction platform based on PIP is that PIP technology is applied to realizes the simultaneous sharing of data and information from the parametric model generated by BIM sharing between project participants, and engineering information exchange, document management and online collaborative work, which can offer an information-sharing environment of cross-time and cross-space for all participants in the construction supply chain, and efficiently resolve the geographical separation of its actors.

3.3 The collaborative operation of prefabricated construction supply chain based on Supply-hub

3.3.1 Synergy of Supply-hub in logistics and information flow. As a coordination organization between suppliers and the general contractor, the Supply-hub mainly undertakes the function of collection and distribution between the upstream and downstream, which provide the services for them by integrating logistics and information flow in the supply chain.

The Supply-hub, acting as the general contractor, is responsible for centralized procurement related to the required building parts, raw materials, equipment and others. And then multiple providers, through the sharing of delivery information, carry out collaborative replenishment on the basis of the respective production ratio and quantity of distribution of the components. Therefore, the Supply-hub can control centrally inventory of material. Meanwhile, in accordance with the weekly plan or daily plan of the general contractor in materials demands, the Supply-hub will arrange to dispatch the raw materials and components after treating by select, classification, group and sort to the construction site, so as to realize the JIT delivery and coordinate material supply.

From the above, the Supply-hub with the function of collection and distribution, can achieve the vertical and horizontal logistics collaboration only under the condition of highly information sharing between enterprises in supply chain. Thus, the Supply-hub is required to share information such as order information, warehouse inventory and delivery plan with multiple suppliers, and exchange information such as material requirement, and construction schedule with the general contractor, and then integrate information flow of the whole supply chain, as shown in table 1.

Table 1. Information flow of assembly construction supply chain based on Supply-hub.

Participants	Collaborators	Information exchanged
Client	G-contractor	Investment planning, product design requirements, quality requirements, schedule control
General Contractor	Client, Subcontractor, Supply-hub	Construction schedule plan, material purchase demand, component production plan
Supply-hub	G-contractor, Supplier	material inventory, supply plan, purchase plan
Supplier	G-contractor, Supplier, Supply-hub	production plan, delivery information, component production information, inventory information

3.3.2 Vertical and horizontal information collaboration based on BIM. By taking advantage of BIM technology, as shown in figure 4, in the information collaboration management platform based on BIM technology, according to the client's demand and construction schedule, the general contractor, extracting the building information model and combining with construction technology for the further design of BIM 3D parts, such as type, size, can calculate the quantity list of preassembly elements and the number of mechanical equipment to provide effective information of the demand and supply for the central Supply-hub. Through the web interactive platform based on PIP, the Supply-hub, after inventory status check according to the actual construction schedule and the material list, can assure procurement plans of building parts, coordinate timely with multiple providers to perform relating

activities, including replenishment inventory, component production, to meet requirement of construction. Similarly, suppliers through the interactive platform can obtain procurement information issued by the supply-hub and reasonably arrange the production and distribution of prefabricated components with the requirement of completion time about batch and the construction schedule of the general contractor.

4. Conclusions

In this paper, the problems of uncertainty are the biggest obstacles for realizing the collaboration management of the prefabricated construction supply chain. With the uncertainty analysis and requirements analysis of vertical and horizontal collaboration in SCOR-based prefabricated construction supply chain, the thesis established the collaborative operation model of prefabricated building supply chain based on supply-hub. Since information collaboration is the bedrock of supply chain collaborative management. The BIM technology was applied to the interaction of information among upriver and downriver partners in the assembly building supply chain based on Supply-hub, and the way to build the information collaboration management platform was clearly analyzed. With this platform, the Supply-hub can achieve the integration management of information flow and optimization of logistics in supply chain to promote the synchronous operation of the upstream and downstream enterprises in material procurement, manufacturing, delivery and field mounted, which will facilitate operation procedures and production efficiency of the whole prefabricated construction supply chain, and implement the lean manufacturing and agile production to enhance the overall competitiveness of supply chain and economic benefits.

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