# Visualization Framework for Container Supply Chain by Information Acquisition and Presentation Technologies

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***Abstract*—The purpose of this paper is to propose a visualization framework for container supply chain by modern information technologies. The concept of container supply chain is studied. The approaches of modeling and visualizing container supply chain are discussed. The model of container based data acquisition is studied. A holistic framework of visualizing container supply chain is built. The paper is clearly only conceptual and theoretical. Much empirical testing and case studies are yet to be done. The paper focuses on the container supply chain to cater for the increasing importance of containerization. How we can model the container supply chain and utilize the real-time information by container-based modern technologies is studied to support the inspection, management and control of the supply chain. With the development of domestic economy in China and international trade, it will be necessary to study this specific type of supply chain.**

***Index Terms*—supply chain management, container transport, container supply chain, visualization, data acquisition**

## I. INTRODUCTION

The developing scale and scope of transport is a direct reason for containerization. Container becomes a uniform storage and transport unit in big business activities. Container supply chain (CSC) emerges under such context to be an important aspect of traditional supply chain. Containerization simplifies the organization of commodities in supply chain, while it helps to develop wider and deeper business in geography scale. The supply chain can be more complex and efficient by containerization. Therefore, CSC is a practical supply chain. There are few literatures on CSC, which is not consistent with the importance in industries.

Container acts as a devices that can be applies modern technologies, while it is the "container" of commodities. This convenience makes container to be a carrier of not only commodities but also technologies. Container is like an agent of inner commodities to accept the functionalities and effects of the technologies. In the business scope, these technologies can be used to manage and control the supply chain. Therefore, the status of the container and the inner commodities can be tracked and recorded. Finally, they are used to represent or deduce the business process. In order to make these functions friendly, visualization of CSC is a critical module. Visulization is common skill to help the decomposition of complexity and generate intuitive perceptives [1-3]. Supply Chain Visualization provides the technologies for managers to physically construct and interact with models of how products flow between their business, thier suppliers and their customers. It lets managers use complex numerical simulation techniques as part of "what if ?" conversations about possible changes to the way they do business. CSC visualization focuses on the dependence of containerzation to be a unit of commodities and technologies.

The main contributions of the study include the following points. First, the modeling approaches of CSC are discussed. Container is an important component in CSC that is taken as graph model with variants. Second, the visualization approach of CSC is studied. The traditional information system and GIS-based visualization approach are studied. Then, the data acquisition of CSC is studied. The four-dimension model is proposed and the data acquisition framework of container is built. Finally, the visualization framework as an entire solution for visualizing CSC is proposed to incorporate the above studies.

The remaining of this paper is organized as follows. In Section 2, we introduce the background including CSC and the visualization approaches and technologies. In Section 3, some issues on technologies, models and framework in CSC visualization are studied. In Section 4, a systematic framework is designed for the visualization of CSC. In Section 5, we conclude the paper with some remarks as well as future research directions.

## II. BACKGROUND

### *A. Container supply chain*

Container transport is playing a more and more important role in the international trade. According to the statistical data from World Trade Organization (WTO), there are more than 200,000,000 containers for transport in the international trade. In order to support the development of container transport, a large amount of high technologies are employed in this field [4-6]. Container transport is a hot research area in logistics.

The modern logistics is developed into the stage of containerization[7-9]. The logistics management approaches to logistics management and engineering integration. And the logistics management and technology is transferred into the management and technology of supply chain. Many research directions and


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subjects now are organized under the system of supply chain. Therefore, it is nature to propose the concrete type of supply chain, container supply chain (CSC). CSC implements and enable the activities in the container transport related industrial process to achieve the objectives of higher efficiency, security, environment protection for the integration of container loading/unloading, transport, storage, device, information, management. CSC incorporates the entire processes from the business contract with containerized cargo sources, through the activities of loading/unloading, transport, flow manufacture, distribution and information, to the delivery to the final customers.

It is difficult to find an authorized definition of CSC. CSC is a specific type of supply chain with concrete features and function more than a formal theoretical definition. In [10], a subjective risk analysis approach is proposed for CSC. CSC is not well defined. The various flows in CSC are analyzed. In many other literatures [4, 11-14], although CSC may be not proposed as a whole concept, containerized supply chain or transport is focused. They also can be classified into the category contributing to CSC studies.

### *B. Visualization by information acquisition and presentation technologies*

The modern business requires not only the interface data but also the business flow information. The traditional systems, such as MRP and ERP can produce a map of the business in an independent view liking a black box. Although there is some way to get the information of the cooperators, it is difficult to recover the entire diagram of the business. The business can only be inspected in the predefined time stones, where the critical or periodical business actions take place. The wire connections among the independent systems make the integration and ensure the data sharing[15, 16]. Such conditions are determined by the undeveloped information technologies and the business modal.

However, the situations are changing with the development of modern information technologies and the globalization of business. The companies demand to manage the whole process flow of the business in the view of supply chain. ERP and MRM systems are transferred to be parts of supply chian so that the fuctions of traditional systems are expanded. The studies of ERP and MRP now trend to be conducted in the context of SCM [15, 17-19]. The correlated business actions are all necessary to be managed or coordinated to achieve the best economical performance. There are some novel and mature technologies that make it possible. First, the location technologies, GPS (global positioning system), RFID (radio frequency identification) and WSN (wireless sensor network) can collect the position information of the commodities [4, 20, 21]. Therefore, the geography location status can be managed. By RFID and WSN, the position in a very limited space can be recognized. Second, the status awareness technologies, represented by sensor technology, can collect various types of information of the inspected entities. They provide a way to manage the real-time status of the attach devices or commodities. Third, WSN and wireless communication make the remote data transformation possible. WSN can perform the short distance wireless communication in a local area. By the network of wireless communication, it is possible to collect the remote data. Fourth, the enterprise application integration (EAI) technologies support the management of distributed information systems (DIS) [22-24]. By them, the general business transaction management can be conducted beyond the connected companies. However, it is difficult to manage the flow and status except for the predefined time stones. Finally, the location and other status, and the business flow information can be presented in GIS in friend and intuitive forms [25]. For supply chain, the application of the above technologies is critically obvious. Visualization has become a key technology for supply chain management [1, 2].

In the context of CSC, there are some convenient situations for applying the above technologies. First, the containerization indicates the unit of inspection, management and control. Second, the container provides an easy way to apply the various data acquisition technologies. Third, the containerization simplifies and unifies the supply chain so that it is possible to provide consistent way of management. However, the container is seldom fully managed by these technologies. The advantages of CSC can be sufficiently shown without such technologies to embody the chain in time, space and business dimensionalities.

## III. VISUALIZING CONTAINER SUPPLY CHAIN

### *A. Modeling container supply chain*

CSC is a specific type of supply chain, where the device, container is focused. Commonly, because the container is focused on and is taken as a unit in the supply chain, the supply chain is therefore simplified and unified. The details of manufacturing are neglected. However, for the simplification and uniformality, the management of the supply chain will be more effective. Container transport is well-studied by the researchers. With the development of it, CSC in fact is becoming an independent concept that propels the international or long-distance business.

By containerization, CSC can be abstracted as a graph, where the elements include two types: the hosting elements (vertex) and the transferring elements (arc). The first type of elements deals with the container of goods and therefore makes the delay of the supply chain. There are maybe three types of features of the processes. First, it is in the time dimension. The process delays the supply chain. Second, the container does not make differences in the space dimension. Or the change can be neglected. Third, the status of the commodities in the container may be changed during the processes. Therefore, these types of information can be collected by the center management system. The arcs enable the container' moving in the chain. The changes are made in the dimensionalities of time, space and business. All they are deduced with the transport with distance.

Compared with the importance of CSC in industries, the researches on it are weaker. However, it is not difficult to enumerate the suitable modeling technologies for it when the graph model is presumed to be a structure model for it.

Many graph-based modeling technologies are proposed and diversified. Simple directed or undirected graph model[26], and PETRI-net[27, 28] are typical models that can be employed for CSC. As studied above, the main tasks of modeling CSC are to model the hosting nodes and the transferring arcs. All these technologies can be tried. In this study, they are not compared. The most dominant features of CSC may include the following points: first, the hosting elements produce time delay; second, the transferring channel may be multimodal; third, the evaluation criteria of the elements may be not singular. These features are typically considered in the model of multimodal transportation [29, 30]. Another type of modeling technologies involves modeling the dynamic and business-oriented features of the supply chain. The typical representations include workflow technology, service oriented technologies (SOA)[31], and GIS-based graphic models[32, 33].

The above analysis is summarized in Fig. 1.

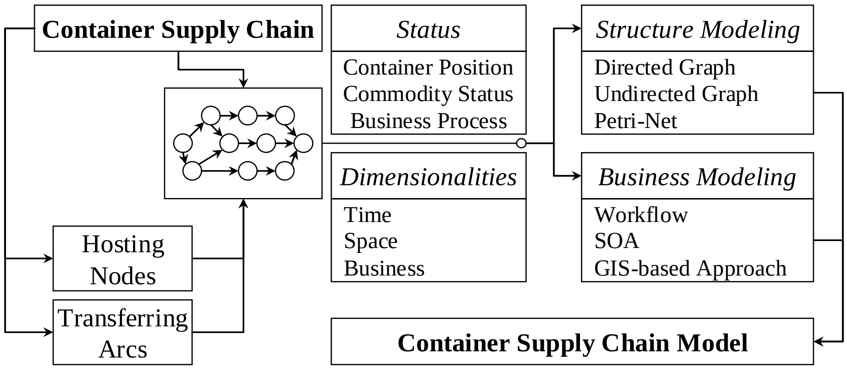


**Figure 1. Modeling technologies for CSC**

The modeling technologeis for CSC take the practical contaier supply chain as the input and produce the container supply chain model as the output. The representation of model facilitates the visualization of CSC. Therefore, it is essential to extract the structural information and the dynaimic business information of CSC and change them in the forms of computerized models. In Fig.1, the CSC is intuitively a connected graph with nodes and arcs. There are all structural information. The nodes are named as hosting nodes, where the containers are delt with. The transfering arcs enable the shifting of containers in the dimentionalities of time and space. At the same time, the status of containers constructs the third dimension. All these dimenstions indicate the flow of business. Corresponding to the element types of the model, the modeling technologeis also are classified into two catagories: structure modeling and business modeling. Apparently, business modeling technologies deal with the dynamic relations and activities take place upon the structural elements.

The structural modelling technologeis are well studied yet in moding supply chain and other business cocepts. Due to the complexity of them, the graph-based modelling technologies obtain increasing importance. Only the concrete meanings of specific elements should be redefined or slightly adjusted according to the specific requirements in CSC. However, the business modeling technologies are not so emphasized. Or the concepts are not well-accepted. In this study, the technologeis to model the business flow are taken as this type. Especially, in the field of software system implementation, the pratical flow should be represented and mobilized in the software system by them. Workflow are SOA are hot technologeis in system integration of business, whereas GIS-based appraoch provides a more intuitive way with better presentation to across the time and space distance.

*B. Visualization of container supply chain*

The visualization of CSC has several characteristics, or difficulties. First, the globalization makes it composed of far more than a single company. Therefore, the integration view should be supported in the visualization framework. Second, the business commonly goes across multiple companies and regions in a wide scale so that the business flow varies in time, space and different business applications. Third, the containerization encapsulates the status of commodities, while it hides the inner information that must be revealed in the visualization framework. Based on the above analysis, it is believed that the visualization of CSC should work in a 4-dimension model, as shown in Fig. 2.

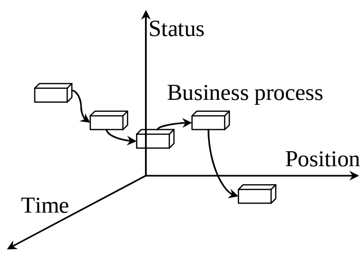


**Figure 2. The 4-dimension model of CSC**

The containerization make the container be a unit in the 4-diemension model of CSC. Time and space are two common dimensions for transport system. The functions of container are mainly to be storage and transport device (with the attached truck). The dimension of status in fact represents the status of the commodities in the container, not the container itself. By extending the functions of container, various sensors can be supported to collect the signals from the commondities. In this aspect, containerization is not only for transport, but also for information. The technologeis discussed above all can be applied to commodities by applying them to the container. The three dimensions are basic for CSC. One goal of them is to support the fourth dimension, the business. The business process takes place in specific time and specific position with specific status. The ultimate goal of visulation is to visulize the business flow of business processes.

There are two types of visualization approaches. The traditional one is non-GIS based approach. MRP/MRP II, ERP and common information management systems belong to this type. Before the popular of GIS, they play an important role in business processing. When the business scope is not so wide, and the globalization is weaker, it is sufficient for many types of business. The visualization of supply chain by them is mainly the business transaction management by time stones or event-based processes. The business flow in the supply chain is divided into events that are triggered by time of business actions. The visualization is to shown the varying conditions of such events in friend interfaces. This approach is a logical solution more than an intuitive visualization.

The second visualization approach is based on GIS and other information acquisition technologies as studied above. It is commonly not independent with the first one. The GIS-based solution takes charge the visualization interface, where the information system deals with the business flow. The data acquisition module assists the two systems and provides the status information, commonly real-time data. In the context of CSC, because of the containerization, the visualization also takes the container as the visualizing unit, which simplifies the process and makes the concrete visualization more feasible.

The visualization approaches of CSC are shown in Fig. 3. Attached with the CSC, there are several components, the hosting nodes, the containers, the time stones by time or events, and the sensors with wireless communication capabilities. The data including sensor's status and the business information is collected into the local and center databases. In hosting nodes, there is commonly local MIS. All data are collected by the center database. The traditional visualization approach utilizes the data in the center databases to produce various views of the supply chain. However, the GIS-based visualization approach will present the CSC by map engine on the map which is provided by map data. It is noted that the sensors in Fig. 3 includes GPS and RFID devices, and other types of sensors.

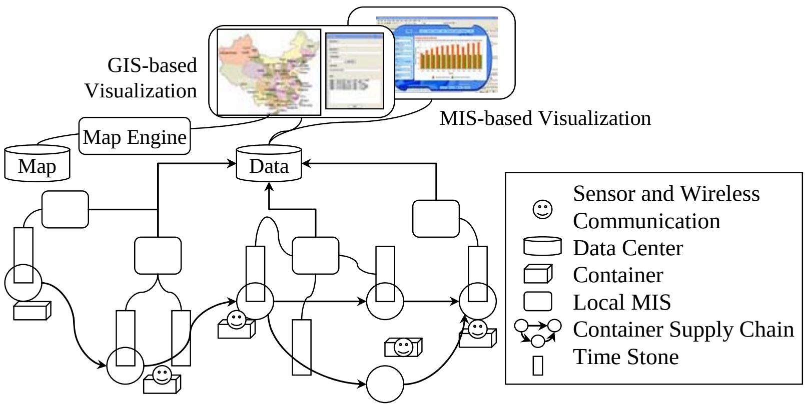


**Figure 3. Visualization approaches of container supply chain**

Commonly, MIS mainly manages the information from the time and space dimensions. Upon them, the business processes are supported. Therefore, it can be said the traditional transport or logistics systems manage the mobility in time and space. However, by morden technologeis, the commodities in the container can be inspected. Moreover, the business dimension can be floating in the GIS-based interface. Therefore, by incorporating the two approaches of visulization, the information and activities in the four dimensions all can be utilized and managed. In this aspect, the visulazation capability of GIS-based systems as Fig. 3 does extend the visible scope and depth of business.

What can be displayed in the GIS-based visualization interface? It is determined by the collected data and the adopted model of the CSC, which have been studied in Section 3.1. In other words, it is determined by the collected information in the four dimensions. The followings are some typical types of information that can be visulized by the system in Fig. 3.

(1) The deployments of the hosting nodes construct a special layer of positions. They can be visualized by business process, workflow, or other category criteria.

(2) The track information of moving containers are visualized to be a moving item in the road layers and the hosting nodes. The operational types and stages can be displayed or queried in this type of visualization.

(3) The status the containers are extracted from the database stored by data acquisition modules. The evolution of them can be shown in the map to indicated

the specific conditions of the inner commodities.

(4) CSC often involves the long distance trasport of containerized commodities. Therefore, in the business dimension, the visualization by the proposed system can also produce more attractive and straight vision.

### *C. Data acquisition in container supply chain*

GIS-based system is the upper architecture for visualizing CSC, whereas the data acquisition modules are the foundation of visualizatin.

Containerization makes it possible to collect the various types of information of the "floating" commodities in the supply chain. In the common supply chain, it may be more difficult to manage the supply chain through the same way as studied in this study. Container is not only the unit of commodities in the CSC, but also the information interaction unit, which provides many convenient forms of data acquisition and control. First, container is a "container" for commodities. Second, container is a device of data acquisition, communication and control. Many functions of modern developing technologies can be applied in CSC by add-ins to containers.

In Fig. 4, the diagram of data acquisition is shown. The main types of data acquisition are incorporated into the device of container. First, GPS is a global location device to locate the longitude and latitude values, which can be utilized directly by GIS map engine. Second, RFID card records the identification information of the container and the commodities. However, RFID readers (and/or writers) should cooperate with the RFID cards to collect the identification data at the predefined gates. Another type of important collectors is sensors. In this study, it is believed that they exist in a network, named WSN (wireless sensor network). The WSN can be installed in the container or attached in the outer area of the container. In some literature, the container with WSN is intelligent container [11]. There is a third type of device that can control the other attached devices, named controller. Inversely, it is controlled by the remote application which is bond with the visualization module. The above components do not have the capabilities of remote communication. Therefore, the fourth type of component takes charge of wireless communication. In the side of center application, the communicator accepts the remote sensor's data and sends the control commands to the controllers.

The system shown in Fig. 4 is a highly distributed communication architecture. Compared common distributed computer network, it has more complex points. First, the center managerial systems and the systems in the hosting nodes in a whole construt a common commputer distributed network. It may be wire or wireless connected network. Secong, the devices, mainly including the various sensors and communication modules, attached with containers, construct a local network of intelligent agents. The wire connections among them will ensure the more reliable communication. It can be said that they construct a inner environment of information for commodities. These systems are higher distributed. Third, the above two types of systems are connected by wireless communication. Therefore, it is a very complex and composite network of computers, containers, sensors and other electronic devices. The management of such a system is challenging. The fourth type is the embeded devices with relative fixed positions to collecting the floating information. In Fig. 4, the RFID readers/writers are this type. Because they have fixed positions, commonly they are connnected to the local hosting nodes or the center computer systems.

The visualization of such a system that collects the detailed structural and dynamic information is attractive to promote the service quality and business efficiency.

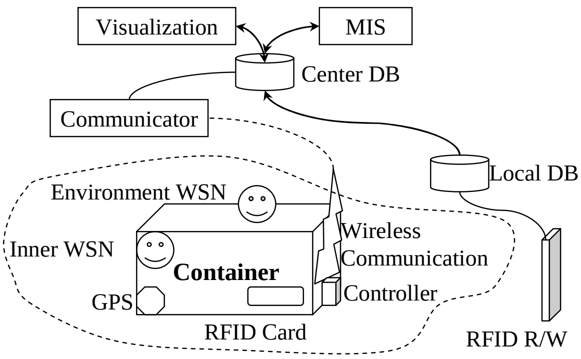


**Figure 4. Data acquisition for container supply chain**

## IV. The visualization framework for container supply chain

The studies in Section III are incorporated into a visualization framework for CSC. The framework is composed of the following modules in logical view. First, container module is a set of devices attached with container. Various sensors, GPS signal acceptor, RFID card and other digital signal devices make the container to have specific functions of data acquisition and control for the final visualization. Second, the wireless communication and other peripheral devices (including RFID R/W) are taken as the connection between the "floating" containers and the (local or center) information system. Third, local information system representing the hosting node of the CSC is another type of components. Fourth, the center information system takes charge of the global view of the supply chain. The two types of information system both may have the forms of traditional MIS or GIS-based MIS. GIS-based system achieves the best visualization presentation by utilizing the business data and the map data by GIS engine. The final component is the integration module, which in fact is universal in the distributed systems. In this framework, it has two usages. One is the integration of the systems in different hosting nodes and the center. Another is to integrate with other legend or cooperative systems out of the framework.

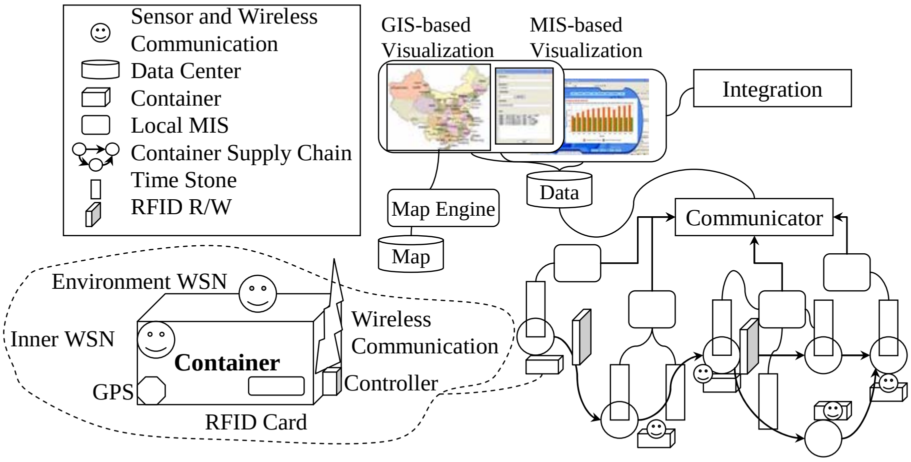


**Figure 5. The visualization framework for container supply chain**

## V. Conclusions

Containerization simplifies the business process in supply chain while it constructs another system, named CSC. CSC is the result of economy development. The functions of container are largely extended in CSC. In CSC, the real-time status of container and the business processes can be accessed, managed and controlled by modern technologies. First, the modeling technologies of CSC are studied. Then, the two types of visualization approaches are analyzed, which is followed by the data acquisition framework of container. Finally, a holistic framework of CSC visualization is designed. In this study, the general framework and visualization issues of CSC are focused on. However, under these topics, there are many problems that are not detailed, such as the modeling theory of CSC, the organization of container-contained devices, and the status judgment. In future study, these details will be further studied.

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