Industrial Engineering and Innovation Management (2019) 2: 14-23
Clausius Scientific Press, Canada
DOI: 10.23977/ieim.2019.21003
ISSN 2522-6924

Brief Analysis About Digital Twin Supply Chain Model and Application

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Keywords: Digital Twin Technology, Supply Chain, Digital Twin Supply Chain

Abstract: With the rapid development of information technology, the real-time monitoring and management of the supply chain can be better realized only by quickly obtaining the operation information of each link of the supply chain. The digital twin technology proposed in recent years provides a new idea for the whole process management of supply chain. This paper give a definition about digital twin supply chain and propose a concerned model, and analyze the applications of digital twin technology usage in links of whole supply chain, like procurement, manufacture, storage, logistic and sales part as well as give a prospect of further development.

1. Introduction

Nowadays, with the rapid development of business, the operation of supply chain is increasingly combined with the Internet of things technology, which makes a large amount of data generated in every link of the supply chain all the time. How to make good use of these data to maximize its value and improve the operating efficiency of the whole supply chain has become an urgent problem to be solved. Digital twin technology aims to physical objects, through the means of digitization to build a same entity in the digital world, so as to realize the understanding, analysis and optimization of physical entities. If we can apply the digital twin technology to the operation process of the supply chain, the supply chain will be real-time, visible, perceptive and adjustable, and will finally realize the transformation from the traditional supply chain model to the digital twin supply chain model.

2. Digital Twin Technology

2.1 The Definition of Digital Twin

Today's digital technology is changing the world. In the future, all enterprises will become digital companies, which not only requires enterprises to develop products with digital characteristics, but also means to change the whole process of product design, research and development, manufacturing, supply and service through digital means, and connect the internal and external environment of enterprises through digital means. All these require enterprises to have complete

Digital capabilities, and the foundation of which is Digital Twin, namely Digital Twin Technology.

Digital twin, as its name implies, aims to the physical world of objects, through the means of digitization to build a digital world in the same entity, so as to realize the understanding, analysis and optimization of physical entities.

2.2 The Development History about the Concept of Digital Twin

In 2002, Dr. Michael Grieves from University of Michigan firstly proposed the concept of digital twin in one of his published papers. He believes that through the data of the physical device, a vital entity represented the physical device and his sub-system can be built in the vital space, and the connection is not unidirectional and static, but a kind of connection through the whole product life cycle.

Apparently, not only did this concept restrict to the designing part of product life cycle, but also extend to the manufacturing and service phases. But due to the limitation of the digital technology at that time, the concept of digital twin is pending on the stage of product design part, and use digital model to express the prototype of physical device [1].

After that, digital twin's concept gradually extended to the simulation, virtual assembly, 3D printing and some other areas. After 2014, more and more industrial products and industrial equipment have the characteristics of intelligence with the development of Internet of things technology, artificial intelligence and virtual reality technology, digital twin technology has also extended to the complete product life cycle including manufacturing and service phases, and gradually enriched the form and concept of digital twin.

2.3 The Meaning of Digital Twin

2.3.1 More Convenient and Suitable for Innovation

Digital twin technology use many digital means like design tools, simulation tools, the things of internet and virtual actualization, map various attributes of physical devices to virtual spaces and form a removable, reproducible, transferable, modifiable, deletable, repeatable digital image. It greatly accelerate the operator's understanding of the physical entity and make many operations, such as simulation, batch replication, virtual assembly, etc., which must rely on real physical entities and cannot be completed due to physical constraints, become accessible tools. It also inspire people to explore new ways to optimize design, manufacturing and service quality.

2.3.2 More Overall Measurements

It is an eternal truth in manufacturing industry that "As long as you can measure it, you can improve it." It need precise measurement to find out all the attributes, parameter, operating status of physical entity to realize precise analysis and optimization no matter in design, manufacture, supply or service part. However, traditional measurement methods must rely on expensive physical measurement tools, such as sensors, acquisition systems and detection systems, to obtain effective measurement results [2]. This will undoubtedly limit the coverage of measurement, and it is often helpless for many indicators that cannot be directly collected and measured.

With the help of the Internet of things and big data technology, the digital twin technology can collect direct data of limited physical sensor indicators and infer some indicators that cannot be measured directly through machine learning with the help of large sample database. For example, we can use the historical data of a series of indicators such as lubricating oil temperature, winding temperature and rotor torque to build different fault feature models through machine learning and

indirectly infer the health indicators of the generator system.

2.3.3 More Overall Analytical and Predictive Capabilities

Digital twin technology can be combined with many technologies to realize the assessment of the current state, the diagnosis of problems in the past and the prediction of future trends, like the data collection technology of the Internet of things, the big data processing technique and the modeling analysis of artificial intelligence to. It also provides the analysis results, various simulating possibilities and more comprehensive decision-making support to us.

2.3.4 Experience Digitization

In the traditional fields of industrial design, manufacture, supply and service part, experience is often in a vague status difficult to get, and it is hard to use it as the basis for accurate judgments. But the key advances in digital twin is that we can use digital measures to digitize previously unpreserved expertise, and provide the ability to preserve, copy, modify and transfer it. For example, for the issues from the process of large equipment, we could use history data from sensors to exercise out the digital model aimed at different kinds of break down issues, then combined with expert records to form the basis for accurate judgment of equipment failure status in the future [3]. As well as the feature library can be enriched and updated based on different status of the faults and finally realize the autonomous intelligent diagnosis and judgment.

3. Digital Supply Chain Model

The end-to-end supply chain covers information flow, logistics and capital flow from all suppliers to all customers, covering all product details and time cycles in the supply chain (depending on the specific business of each specific industry).This is not only a physical supply chain network, but also a time cycle (such as a rolling supply chain planning cycle).

While most of today's supply chain processes and software are set up based on a portion of the supply chain, the digital twin supply chain should have the ability to integrate the lowest and highest level of details of all the elements together and provide a real-time level of management decision making ability [4]. Specifically, this model has following three levels of competence as showing in the figure 1.

1, First Level (The physical layer): End-to-end horizontal physical layer of supply chain network;

2, Second Level (The simulation layer): A digital model which can reflect real-time status of supply chain;

3, Third Level (The analysis layer): Analyze, describe and predict the challenges and opportunities of the business supported by the supply chain, and make real-time business decisions for different parts of the business.

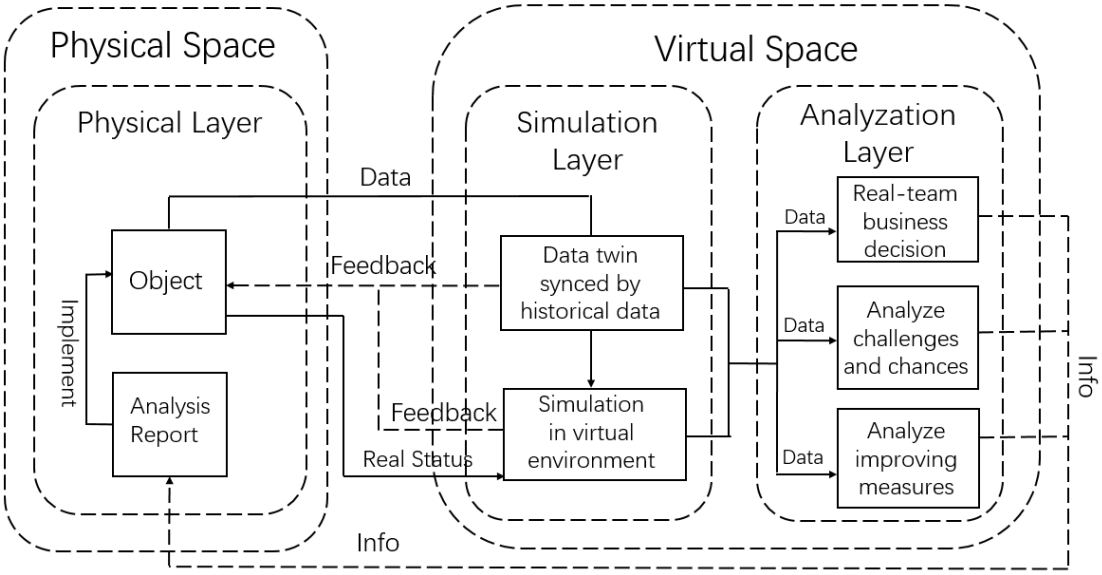

Figure. 1 Digital Supply Chain Model

3.1 The Physical Layer

The physical layer is composed of end-to-end horizontal supply chain network, in which the specific design links of the supply chain network include: procurement -> manufacturing -> storage -> logistics -> sales. With the development of technology, there produced a large amount of data in today's physical layer, and the Internet of things technology has played a very important role in promoting the collection and recording of information.

3.2 The Simulation Layer

The works of the simulation layer are mainly divided into two parts. One part is to synchronize the data of physical layer for digital twinned processing, which means to dynamically synchronize the real-time data of physical entities' running status as well as the history data of operation and maintenance collected by the control unit and sensors to the digital twin module for the iterative optimizations. Another part is to proceed the one to one simulation in the virtual circumstance based on the actual running state reflected by the physical entity and the real-time captured/processed data. That means to build a virtual environment that reflects the real one and simulate optimized twin data in the virtual space, then imitate physical entity’s activity in the real environment.

3.3 The Analysis Layer

The main work of analysis layer is to analyze the data processed by digital twin technology from simulation layer and the data acquired after simulating current work processes, then export the final business decision, challenges and opportunities from different links of whole business line, also optimized measures and improvement for the current process’s flaws. Finally farther feedback the analysis to physical entity to improve the design, manufacture and running attentions.

4. The Application of Digital Twin Technology in Each Link of Supply Chain

4.1 Digital Twin's Application in Procurement Link

Procurement part links resource marketing with enterprise's design and manufacturing phases. Procurement process is not only a business flow process, but also a logistics process, so procurement work mainly has two goals: minimization of cost and minimization of procurement cycle time [5]. That means the sooner the buyer gets the information, the easier it is to control the cost and cycle. We will discuss the applications about digital twin technology in procurement process from two aspects as shown in the figure 2:

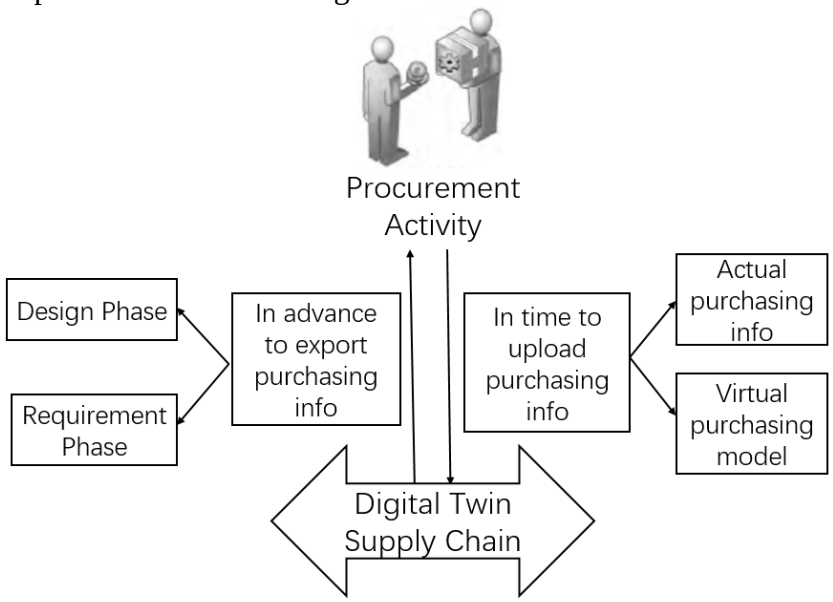

Figure. 2 Digital Twin Technology in Purchase Activity

4.1.1 The Digital Twin Supply Chain Outputs Information to the Purchasing Department

As early as in the stage of demand analysis and product design, the digital twin supply chain outputs purchasing information, such as purchasing object and minimum purchase quantity, to buyers according to the analysis results in this link, and helps with buyers about decision like purchasing plan, purchasing process and negotiate time with suppliers as early as possible. At the same time, the digital twin supply chain should also open a certain port to the procurement department, so that the procurement department can adjust the procurement plan based on the latest researching and developing progress in real time.

4.1.2 The Procurement Department Inputs information to the Digital Twin Supply Chain

The actual purchasing information obtained by the purchaser will be timely uploaded to the simulation layer as part of the purchasing data in the digital twin supply chain. The purchasing information is of great reference value for the subsequent development and cost control. In addition, the digital twin supply chain should also collect the corresponding models of the purchased parts itself in the virtual world, such as CAD model, batch information, model information, etc., which can be used for simulation modeling in the simulation layer to optimize the process of such kind of purchasing activities in the future.

4.2 Digital Twin's Application in Manufacture Link

Workshop is the basis of manufacturing activity, and digital twin technology provides a technical means for the efficient operation of manufacturing process. In recent years, the concept of digital twin workshop is gradually emerging. Here we will discuss the operation structure of digital twin workshop in manufacturing link from the perspective of digital twin supply chain [6].

Digital twin workshop (DTW), is a fresh model of workshop under the driven of new generation of information and manufacturing technology. It works through the bidirectional real time reflection and interaction between physical and virtual workshop, realize the integration and combination of all features, data and whole process among three layers of the digital twin workshop [7]. Also iterate the twin data in physical, simulation and analysis layer of the workshop, realize workshop's production factor management, production plan making, production process controlling. Then reach to an optimal situation of workshop's control which is satisfied with specific goals and constraint condition. Its basic structure showing in the figure 3:

4.2.1 The Physical Workshop

Physical layer is the main part of the workshop, including robotics, machine tools, special processing equipment, personnel, automatic guided vehicles (AGV), conveyor belts, three-dimensional warehouses and products/parts and other entities, as well as industrial computers with the ability of data acquisition and communication, programmable logic controllers (PLC), sensors, radio frequency identifications (RFID) with speaking and writing function. They are organically combined to realize the production activities like processing, assembling, transporting, storing and etc.

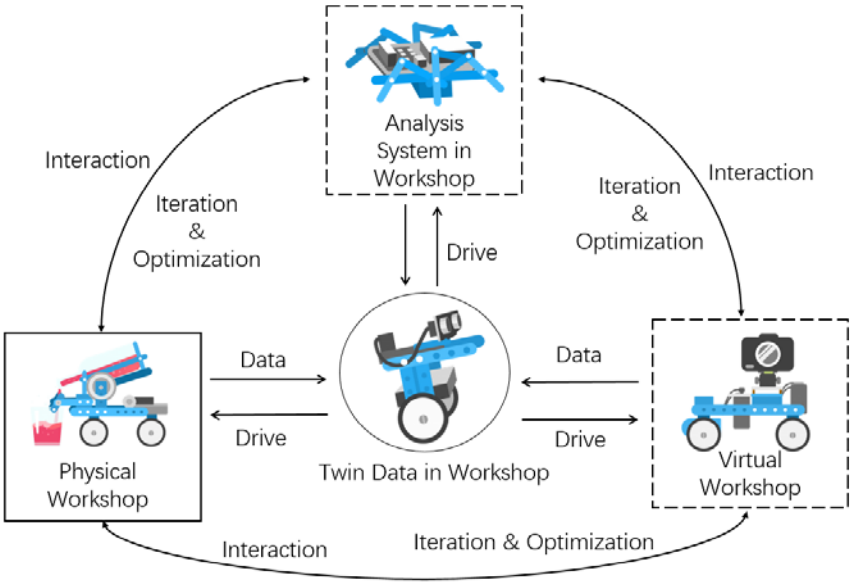

Figure. 3 Basic Structure of Digital Twin Workshop

4.2.2 The Virtual Workshop

Virtual workshops are essentially collections of models. Before production, the virtual workshop conducts iterative simulation analysis on the production plan output by the workshop analysis system based on the model that is highly close to the physical workshop entity, and simulates the

whole process of production, so as to find possible problems in the production plan in time, then adjusts and optimizes in real time [8]. In production, the virtual workshop continuously accumulates real-time data and knowledge of the physical workshop, and continuously regulates and optimizes its operation process on the premise of high fidelity of the physical workshop.

4.2.3 The Analysis Workshop

The workshop analysis system is mainly responsible for real-time analysis and system support for intelligent management and control of the workshop driven by the twin data of the workshop, such as the control and optimization services for production factors, production plans/activities, production processes, etc.

For example, after receiving a production task, the workshop analysis system, driven by the workshop twin data, generates resource allocation plans and initial production plans that meet the requirements and constraints of the task. Prior to the start of production, the workshop analysis system based on the simulation, evaluation and optimization data of the production plan of the virtual workshop to modify and optimize the production plan. In the production process, the production status of the physical workshop and the simulation, verification and optimization results of the virtual workshop on the production task are fed back to the workshop analysis system continuously, so as to adjust the production plan in real time to adapt to the change of actual production demand. The digital twin workshop effectively integrates the multi-level management function of the workshop analysis system, realizes the optimized allocation and management of workshop resources, the optimization of production plan and the collaborative operation of production factors, which can create the greatest benefit with the least cost, thus further improving the efficiency of the digital twin workshop as a whole.

4.3 Digital Twin's Application in Storage Link

The similarity between the factory floor and the automated warehouse is becoming more and more obvious, which leads to the tendency of warehouse operators to borrow strategies directly from the manufacturer's operation manual. It is worth noting that the general concept of warehouse emulation is not new. For decades, many facilities have been using software to digitally simulate layouts and maximize basic efficiency in manual or basic automation environments that primarily use visualization. With the increasing risks of smart warehouses and the increasing diversity and complexity of technologies, the need for more advanced modeling and complex virtualization of warehouse equipment and businesses is becoming more apparent. In the context of warehouses, where the speed and accuracy of material handling and machine downtime are now critical, digital twin technology and modeling capability allow operators to do more accurate test about new layouts, equipment and processes in virtual software applications.

In recent years, warehouse automation has moved beyond basic transportation systems, the automated storage and retrieval system (AS/ RS) use a variety of mobile robots, truck loaders/unloaders and automatic packers as distribution centers and fulfillment facilities, all of this adds more complexity in terms of configuration and optimization. The increasing number of robots in the warehouse also increases the complexity of the integration, which means that the existing warehouse management system (WMS) suite will be difficult to realize the optimization about same-day delivery, storage keeping unit (SKU) diffusion and product line changes, which are typical current material handling problems.

One of the key value propositions of using digital twin technology for warehouse planning is to digitally experiment with new processes, workflows, and processes, also to simulate the results and evaluate benefits using key performance indicators (KPI). Due to the severe impact of seasonal

peaks on the profitability and efficiency of fulfillment centers and distribution centers, the use of modeling tools for cost/benefit analysis of scaling up or downsizing operations or reconfiguring complex logistics equipment networks is a major advantage.

According to proposals from manufacture industry, warehouses will use digital twin technology and complex models to increase the flexibility and efficiency of devices, and will take advantage of the Internet of things. This creates huge opportunities for warehouse operators and technology vendors to develop clear strategies for integrating adjacent software applications where possible and providing the real value beyond simple visualization.

4.4 Digital Twin's Application in Logistic Link

In the field of logistics and transportation, digital twin can be applied to various application scenarios of the whole value chain, including the management of container fleet, delivery monitoring or the design of logistics system. For example, IOT sensors deployed on individual containers can show their location and monitor cargo damage or contamination. This data will flow into a digital twin of the container on the network, which uses simulation and machine learning to ensure that the containers are efficiently deployed.

Digital twin technology according to create digital twin model about every details in the process of the logistic, realize the virtualization of logistics entity system. Also use history data to simulate as well as use machine learning to make rapid calibration and continuous upgrade for all kinds of logistic system, so as to create the best operation status of logistic system. And this way also apply to pressure test of big data in front distribution warehouse of e-commerce logistics system.

The digital twin logistics system not only includes the digitization of physical logistics network, but also includes the digitization of the logistics system itself, operation process and equipment. By building the digital twin system of the whole process of logistics operation, the whole process of logistics system can be digitized, the innovation level of intelligent logistics system and the efficiency of logistics operation can be improved, as well as the flexibility and intelligence of logistics system can be realized.

As early as 2017, Deppon Express officially launched its digital twin center, introducing the digital twin technology into the application scenario of express to provide assistance for on-site management. Deppon logistics center is a digital monitoring system integrating the collection, transfer, transportation and dispatch of all links. Also, through the real-time operation of big data platform, the logistics management efficiency can be greatly improved by early prediction and early warning.

4.5 Digital Twin's Application in Sales & Marketing Link

Marketing activities include offline activities, television advertising and other means, supported marketing materials also have manuals, print advertising, video advertising and other forms. Marketing materials used to be uncertain for the following reasons:

(1) Based on physical products, marketing activities must be carried out after the physical products are manufactured;

(2) Apart from the physical product, there is a risk that the actual product will not match the advertised product before the physical product is manufactured, which is eliminated by the marketing based on the digital twin technology.

As shown in figure 4, the digital twin will output marketing information synchronously. When the digital twin is modified in the design stage, the marketing materials will also change together to ensure that the product information advertised by the marketing materials is consistent with the product actually designed.

Delays in marketing activities can be avoided by using marketing materials that are synchronized with the design, and marketing activities do not need to depend on the production schedule of the physical manufacturing department. Nowadays, graphic marketing materials can be easily read from geometric information of digital twin, and marketing pictures can be taken from virtual products. However, the technology of obtaining video materials from virtual products are making progress and some applications have been found, such mechanical products' output from workshop production simulating animation.

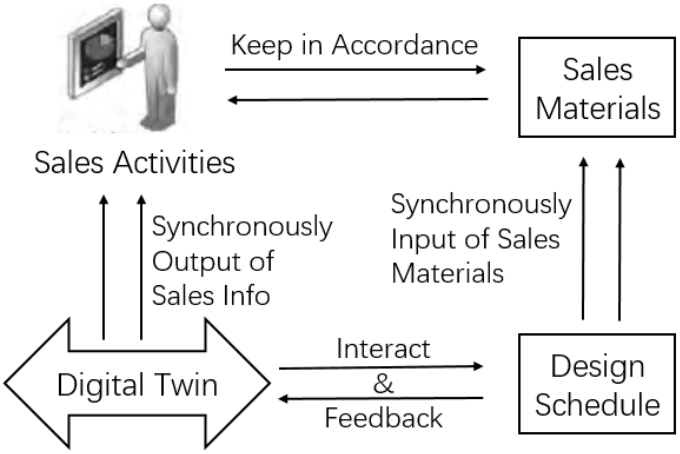

Figure. 4 Digital Twin Technology in Sales & Marketing Activity

5. Expectation about Digital Twin Technology in Supply Chain

At present, China's economic and social has entered the digital era, the construction of national intelligent logistics backbone network also needs to drive the network operation through data, to achieve the physical logistics network and virtual logistics digital network "soft and hard combination", which need appropriate digital twin technology. The national intelligent logistics backbone should also encourage innovation in business models, so that the builders can have market returns and public infrastructure attributes, so that the network can be shared and serve the whole society [9].

As a whole, digital twin technology covers the entire range of supply chain business processes, from the highest level of large processes and network assets to the lowest level of work instructions. Such a complete model would be impossible without artificial intelligence, involving everything from machine learning (including deep learning) to image and language processing. In the whole process, digital twin technology involves human behavior pattern analysis, mathematical modeling and decision making to seek better operation and decision-making model. At present, digital twin technology can achieve a degree of predictability and self-improvement that is more accurate than any previous model. At the same time, the progress of Internet of things technology is crucial to the success of digital twin. Sensors or Internet of things technology can be used to collect a large amount of data, so as to realize the interaction between model and reality. Using traditional simulation technology to simulate the whole business problem is equivalent to giving up the use of real-time data of business operation to improve the business. Therefore, the application level of digital twin can be regarded as an important factor to improve business operation and competitive advantage.

With the increasing importance of digital twin, manufacturers will have an incentive to create a

set of digital twin for each customer and even each product. In this case, supply chain management stakeholders must participate in the development of digital twin as early as possible, to define and perfect digital twin projects and products based on the perspective of supply chain globalization. Analyzing large amounts of data is cumbersome and costly, and the process of constructing digital twin is time-consuming. However, the author believes that using a digital twin in the supply chain to provide world trade visualization to the shipper, cargo agents, carriers, such as the node enterprises of supply chain is so much valuable, and it is the key to pre-build the extensible frame of the supply chain digital twin for all the stakeholders' profit. So, as we can see in the future, the supply chain by using digital twin technology has huge potential to create new value.

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