Front. Eng. Manag. 2018, 5(1): 78–87
https://doi.org/10.15302/J-FEM-2018075

RESEARCH ARTICLE

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Smart construction site in mega construction projects: A case study on island tunneling project of Hong Kong-Zhuhai-Macao Bridge

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Abstract The construction sites of mega construction projects (MCP) often have numerous participants with interfacing work within a highly complex system. It is critical how to realize collaborative work and information sharing among such participants. The information and communication technologies (ICTs) provides a technical guarantee for solving this problem. Existing research has been achieved the partial processes digitization of construction site, but certain problems still exist: 1) information perception of the construction site is passive. 2) common collaboration and coordination problems in the construction industry have not been addressed. The emerging trends of ICTs have resulted in the integration of various computer technologies such as CPS, BIM, big data, and cloud computing into construction process, which would changes behavioral and management mode of construction sites. These new ICTs have been applied successfully in MCP, in particular, Hong Kong-Zhuhai-Macao Bridge project. A new management mode of construction sites is inspired by these case. In this paper, a new management mode of construction site for MCP has been proposed, namely, smart construction site. The ultimate goal of smart construction site is to accomplish safe, efficient and high-quality construction. This study put forward the conceptual framework for smart construction site, and have identified three key elements of smart construction site, including information support platform, collaboration work, and intelligent construction management. A case study on Hong Kong-Zhuhai-Macao Bridge project work as an evidence to support the practicability of the proposed mode. Significant contributions of this study is to propose a new management mode for MCP in construction industry, which would enrich the body of knowledge or the construction management community. Future research should be dedicated to further explore the potential of smart construction site in MCP management.

Keywords mega construction projects, smart construction site, information perception, collaborative work, intelligent construction management, information and communication technologies

1 Introduction

According to the Oxford Handbook of Megaproject Management, the mega construction projects (MCP) are large-scale, complex ventures that typically cost $1 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people. The European Cooperation in Science and Technology (COST) categorizes the mega projects as having extreme complexity (both in technical and human terms) and by a long record of poor delivery. Megaprojects attract a lot of public attention because of substantial impacts on communities, environment, and budgets, and the high costs involved. In general, MCP refers to a class of large-scale projects with closely related structures, high technical requirements, difficulties in construction, and complex environment, all of which considerably affect social development and

Received October 12, 2017; accepted December 13, 2017

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This work was funded by the National Natural Science Foundation of China (Grant No: 71390524).

involve a wide range of knowledge and more participants. Compared with common projects, MCP involving many different interested parties are characterized by the complexity of the interface between different construction activities, dynamic evolution of the construction site conditions, large technical/space-time span and system complexity. Based on the management idea of construction complexity, the construction site management of MCP requires significant technical means to implement collaborative work and information sharing among the participants (Sun and Zhang, 2011; Kennedy et al., 2011). However, it is difficult to organize and coordinate the cooperation of participants in traditional construction site management. Thus, from the perspective of construction site management means, it is critical to innovate mode of construction site management in MCP.

The applications of information and communication technologies (ICTs) enable the extensive and intensive interworking, real-time access of mass data, and address the issues of cross-domain collaboration (Rajkumar et al., 2010). At present, ICTs have been applied to the construction process, thereby improving the efficiency and benefit of construction projects (Taxén and Lilliesköld, 2008; Succar, 2009; Lu et al., 2011). However, current studies have been fragmented and have only achieved a locally optimized construction site management effect in construction projects. With the extensive applications of the Internet, cloud computing, big data, BIM, and other new information technologies in construction projects, especially the emergence of cyber-physical systems (CPS), it is inevitable to realize real-time perception, dynamic control and information service of MCP by combining the 3C (Computer, Communication and Control) technologies (Mikusz, 2014; Rudtsch et al., 2014). This will bring profound changes in the behavioral pattern and management model of engineering construction projects.

ICTs have been applied successfully in MCP, such as Hong Kong-Zhuhai-Macao Bridge. During the construction of Hong Kong-Zhuhai-Macao Bridge, the combination of ICT with the construction site enabled real-time perception and acquisition of considerable information on the construction site, covering environment, quality, safety, material supplies and project schedule. All participants, such as owners, contractors, suppliers, consultants, etc., can exchange and share this information through the Internet and IoT. That enable all participants to operate effectively through the network. Furtherly, smart construction site management in Hong Kong-Zhuhai-Macao Bridge project could be partially realized. For this reason, the experiences of Hong Kong-Zhuhai-Macao Bridge is summarized and discussed, and a new management mode of construction site is proposed for MCP, namely, smart construction site.

The smart construction site mode is inspired by the case study of Hong Kong-Zhuhai-Macao Bridge project. This case study work as an evidence to support the practicability of the proposed mode. This paper adopts case study method. The discussions of this approach are arranged as follows: Part 2 summarizes the literature related to this paper. Part 3 presents the conceptual framework of smart construction site. Part 4 illustrates the essence of the smart construction site concept through a case study on the assembly of immersed tunnel in the island tunneling project of Hong Kong-Zhuhai-Macao Bridge. Finally, Part 5 provides the conclusions and offers the future research direction.

2 Literature review

2.1 Perception of construction site information

2.1.1 Construction quality information

Using RFID and sensor technologies, the quality tracking management of prefabricated components and the statistical management of construction quality information, such as quality information of cast-in-place concrete components, would be implemented (Wang, 2008; Yin et al., 2009). The 3D laser scanner technology is adopted to conduct point cloud extraction of spatial data from the selected part, and to promote the rapid establishment of a 3D point cloud model. Construction deviations are revealed with the measured data output through a comparison with BIM model, thereby ensuring the authenticity and objectivity of data and improving the quality inspection efficiency (Akinci et al., 2006). The application of real-time video surveillance system cannot only control the construction quality effectively but also reduce the occurrence frequency of risks and/or safety accidents (Teizer, 2015).

2.1.2 Construction safety information

RFID and GPS technologies enable real-time positioning of construction workers and machinery, real-time monitoring and safety warning to the spatial location of the workers and construction machinery, which could prevent worker falling, high-altitude strike, mechanical collision, and other safety accidents (Chae and Yoshida, 2010; Teizer et al., 2010; Pradhananga and Teizer, 2013). At the same time, RFID and GPS technologies can also timely check both the use of safety protection apparatuses and/or devices, and the number of times that workers enter dangerous areas, which specific safety training is organized to reduce the probability of potential accidents and guarantee personnel safety (Kelm et al., 2013). The use of various types of sensors enables the acquisition of safety information on site and real-time safety warning (Ding et al., 2013; Riaz et al., 2014). Potential hazards are identified using 3D laser scanner. The results of point cloud data in two passes are superimposed. Moreover, the change trend of such hazards is identified by differentiating the point cloud data in two passes (Cheng and Teizer, 2013).

2.1.3 Project progress information

The application of RFID in the information acquisition of construction progress enables the dissemination of relevant information to the BIM model, which reveals the deviation between the plan and the actual situation in the BIM model, and solves the real-time progress track and risk control (Ju et al., 2013; Alizadehsalehi and Yitmen, 2016). By combining project WBS and the Gantt chart of project plan, GIS technology provides access to visualization of the project schedule, and the specific project plan at any time, which significantly reduces the risk of any project delay caused by misunderstanding (Bansal and Pal, 2009; Poku and Arditi, 2006). The 3D laser scanner is installed on the construction site, and enables the all-weather scanning of construction entities. The high-density and high-precision 3D point cloud data would be real-timely acquired to track construction process, and the exactly evaluate project progress (Teizer et al., 2007).

2.1.4 Material supply information

Using RFID technology, information on the in-out stock operations and inventory of construction materials is acquired automatically in real time, so that all materials are managed dynamically to guarantee accurate and timely supply, and to reduce the buffer inventories and construction costs of construction site (Ju et al., 2013; Sardroud, 2012). The combination of GPS and RFID can provide the positioning information of construction components and materials to meets the relevant requirements in logistics management (Torrent and Caldas, 2009; Razavi and Haas, 2010).

2.2 Construction information integration and collaborative work

Computer-integrated construction (CIC) focuses on the integration of data and applications in the construction field to provide better support for the specific work of different participants (Boddy et al., 2007). Generally, the integration of construction information can be achieved by using the BIM technology. Using the BIM, BLM, and IFC standards for reference, an integrated collaborative construction management platform may be created to integrate information about contracts, quality, and supply chain effectively (Liu et al., 2014). A BIM-based whole-life framework has been proposed to develop a BIM-based data integration system (Zhang et al., 2012).

2.3 Intelligent management of construction site

At present, intelligent management of construction site has been rarely reported, and studies on safety and material supply management are limited. The material supply process may be tracked using barcode, BIM, GIS, and Web services, with the relevant information displayed in visual form and early automatically warning of any delay (Irizarry et al., 2013). With the advancements in sensing technology, workers entering dangerous areas may be identified. Construction workers entering pre-defined hazardous areas may also be tracked with warnings (Carbonari et al., 2011). Using ultrasonic sensors combined with multi-sensor information fusion technology, the accurate positioning of obstacles may be achieved for safety judgment and collision alarm (Li et al., 2012).

2.4 Summary

The abovementioned studies are essential to achieving the partial processes digitization of construction site to improve information acquisition in construction site and facilitate the exchange and communication of data and information among participants. However, certain problems still exist:

1) The current perception of the construction site is passive.

2) The common collaboration and coordination problems in the construction industry have not been addressed.

The emerging trends of ICTs have resulted in the integration of various computer technologies such as CPS, BIM, big data, and cloud computing into construction management. These new computer technologies are closely linked with construction sites and thus, the wide area and deep interconnection and the real-time acquisition of massive data may be implemented with the passive perception of construction site information turning into an active mode. In addition, through the mobile network, information on workers, machines, material supplies and the construction environment may be integrated to achieve collaborative work among participants. Ultimately, smart management of construction site would be implemented to greatly improve the effectiveness and efficiency of the construction site management

3 The conceptual framework for smart construction site

The smart construction site model is designed to realize real-time interconnection, mutual recognition, and effective communication among workers, machines, material resources, and the construction environment using ICT means. The construction site information sharing and integration with the aim of supporting the collaborative work among all participants on site, including owners, contractors, vendors, and supervisors, and implementing safe, effective and high-quality site construction can be achieved through the big data processing platform.

The essential features of smart construction site are as follows:

1) Information perception: Real-time perception and acquisition of information on all procedures, equipment, construction environment, and systems from each participant, can realize the digitization of the whole-process on site.

2) Information interconnection and collaborative work: Through the network, workers, machines, material resources, and the construction environment are interconnected organically, thereby achieving the collaborative work among participants and the seamless connection of all construction procedure.

3) Intelligence construction management: Through both the interconnection of construction information and the collaborative work among participants, various data and information on the construction site become transparent, which allows participants to be more "intelligent" and realize the intelligent construction management.

In the process of construction, the more thorough perception and the more extensive interconnection and collaboration are necessary to effectively complete the construction. To achieve this goal, smart construction site requires the application of ICT in creating a smart construction site environment. Only when construction site information sharing and collaborative work among participants are achieved will the smart site management be obtained. Hence, Fig. 1 proposes a conceptual framework of smart construction site.

1) Smart construction site environment

Using different information acquisition technologies such as GIS/GPS, RFID, video surveillance, sensors and laser scanners, information on the construction environment, quality, safety, material resources, and progress is perceived and acquired at real time from all participants on construction site according to different construction requirements. A smart construction site environment is

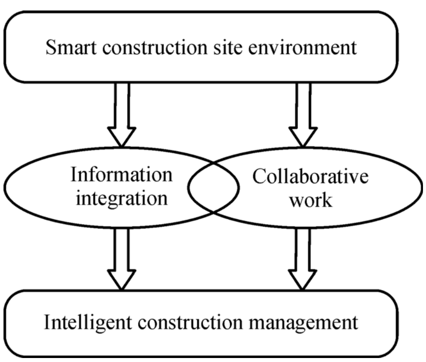

Fig. 1 Conceptual framework of smart construction site

formed by means of these information interconnection through network.

2) Information integration and collaboration work

On the basis of the smart construction site environment, construction site information integration and sharing, including longitudinal (internal) integration of a participant and the horizontal integration among participants, are implemented effectively using the BIM technology. The construction schedules of different participants are managed on a collaborative basis, thereby achieving collaboration work among all participants on construction site and the construction management objectives covering costs and duration.

3) Intelligent construction management

Intelligent construction management is the core of smart construction site mode, and is based on ICTs. Through the interconnectivity and interoperability of construction information and collaboration work among participants, all participants is more "intelligent," which would realize the security risk pre-control, quality tracking management, intelligent construction logistics and intelligent scheduling of construction schedule, etc.

For creating smart construction site mode, key elements of smart construction site must be identified. The procedure of key elements identification is based on conceptual framework of smart construction site. First of all, smart construction site mode is inseparable from information support, which requires an information perception and information interconnection environment. Furthermore, these construction site information should be integrated to form a data center for supporting various construction activities. Therefore, the information support platform is essential for smart construction site, which can achieve information sharing and integration of the construction site. Secondly, the construction process also requires the synergy of all resources, technologies, organizations, and information during the construction, which is realized through collaborative work among all participants. Based on information support platform, collaborative work among all participants can effectively achieve the seamless connection of all construction procedure. Thirdly, the goal of smart construction site is to support intelligent construction management of all participants. Intelligent construction management can greatly improve the level of project management. So, key elements of smart construction site should include information support platform, collaborative work and intelligent construction management.

3.1 Information support platform

The construction site is inseparable from information support, and the information support platform is essential for smart construction site. The goal of information support platform is to integrate information on various construction activities and BIM during the construction, thereby achieving information sharing and integration of the construction site, and ultimately forming a smart construction site environment for supporting the intelligent construction management of all participants.

During the construction, with construction as the center, different construction activities are supported by different information technologies, forming a data center to support an intelligent construction management. Figure 2 shows that the architecture of information support platform is divided into several layers, including the management layer, data center layer, construction service layer, information acquisition layer, and network layer.

1) The data center layer is designed to standardize data format, store data, record all information on the construction processes, integrate information on the construction process and the BIM, convert 3D data into *n*D data, achieve construction site information sharing and integration, and promptly meet the needs of intelligent construction management.

2) The construction service layer involves various construction activities or sub processes, including site construction, supervision, material supply and support activities. The implementation of such activities requires information support, and generates a significant amount of information to be transported to the data center for intelligent construction management.

3) The information acquisition layer is designed to acquire different information on construction environment, quality, safety, and material supply according to different construction requirements using different information acquisition technologies such as GIS/GPS, RFID, video surveillance, sensors, and laser scanners.

4) The network layer is essential to achieving the data transmission, inter-module data communication, and interconnection of construction site information through different information and network technologies such as the Internet, mobile network, IoT, optical fiber, satellite, and microwave.

3.2 Collaborative work

Collaborative management seeks to complete the con-

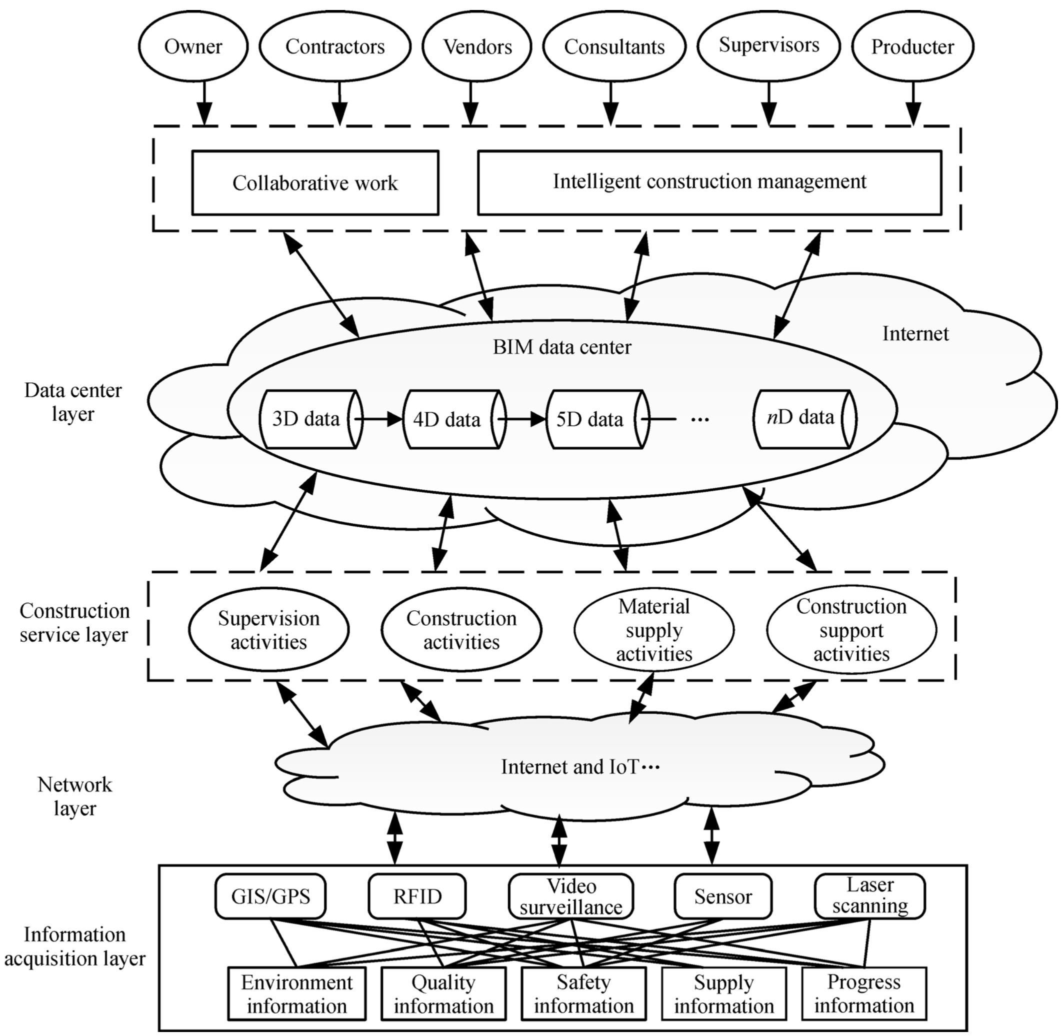

Fig. 2 Architecture of information support platform

struction in the most economical manner through the synergy of all participants in the construction work, information, and resources. In the smart construction site mode, the construction work among all participants and the deployment of various resources are achieved mainly through information collaboration. The information support platform provides a technical guarantee for all participants to complete their construction tasks. The information support platform adopts the BIM technology for the construction site information acquisition, thereby enabling the synergy of all participants during the construction to be achieved. During the construction, all participants upload their construction progress information to the information support platform, and access information necessary to complete their construction tasks on the platform. Through the information feedback of task process, the task implementation process may be tracked, which ultimately achieves the traceability, schedule control, and query of task implementation process.

3.3 Intelligent construction management

All service process information is linked up on the information support platform, making construction site information transparent, allowing participants to monitor and control the real-time dynamics of construction progress, quality, and material supply in a timely manner, and eventually laying a solid foundation for intelligent construction management.

The intelligent construction management, based on information acquisition of construction process, natively provides relevant participants with intelligent construction management function covering construction schedule, cost, safety, quality, material supply on a timely and effective basis, through real-time perception and integration of information on the construction schedule and process, quality, material consumption, and construction safety.

4 Case study

4.1 Background

The Hong Kong-Zhuhai-Macao Bridge (HZMB) is the longest sea-crossing bridge in the world with a length of 50 km. The designed service life of the bridge is 120 years. A scheme using a bridge and tunnel combination has been adopted for the offshore bridge and tunnel part to avoid interfering with navigation. The tunnel section is approximately 6.7 km long across the Lingding West Channel and Tonggu Channel, and the bridge section is about 22.9 km. For the transitions of the bridge to tunnel sections and to accommodate tunnel ventilation shafts, artificial islands are being built at each end of the tunnel. The bridge and tunnel sections provide a dual three-lane carriageway with a design speed of 100 km/h. The length of the immersed tunnel is 5664 m with tunnel width of 2×14.25 m and a vertical clearance of 5.1 m. The immersed tunnel is assembled using 33 tunnel elements with a typical tunnel element length of 180 m and weight of 75000 t. Maximum water depth of tunnel element immersion is 44.5 m (Li and Chen, 2011; Yin, 2014).

All the huge tunnel elements are prefabricated by a flow line, and involved standardized production in a factory located on an island near the construction site. Tugboats will transport the prefabricated tunnel elements to the construction site. After immersion, the tunnel elements will be connected undersea by positioning deep water unmanned automatic element immersion and positioning adjustment system.

4.2 System framework of smart construction site in HZMB project

Based on the idea of smart construction site, an instantiated framework of smart construction site is adopted to support the manufacturing, transportation, and assembly of the tunnel element, as shown in Fig. 3.

In the offsite manufacturing stage, the detailed design information for the tunnel elements is obtained from the BIM for prefabrication production. Several automatic production systems, including full section automatic hydraulic segment prefabrication form system, belt conveyor, and distribution system for full section concrete cast of tunnel element, and multiple-point hydraulic support, and synchronous jacking system, work collaboratively for the prefabrication production of tunnel elements. All production information is uphaded to the data center.

In the transportation and assembly stage, related Information is acquired through sensors, GPS, sonar systems and weather systems, and is transmitted to data center. For ensuring the quality and safety of transportation and assembly, multiple monitoring and control systems (e. g., meteorological and hydrological forecasting system, real-time attitude of tunnel element monitoring system, deep water unmanned automatic element immersion and position adjustment system, and command system) can work together to support the tunnel element transportation and assembly processes. The data center is composed of the data center of construction site command center in Zhuhai and the meteorological and hydrological database of national marine environmental forecasting center in Beijing.

The following subsection will focus on the details of the construction-related information acquisition and transmission and collaborative operations in the transportation and assembly process and on illustrating the preliminary practice of smart construction site.

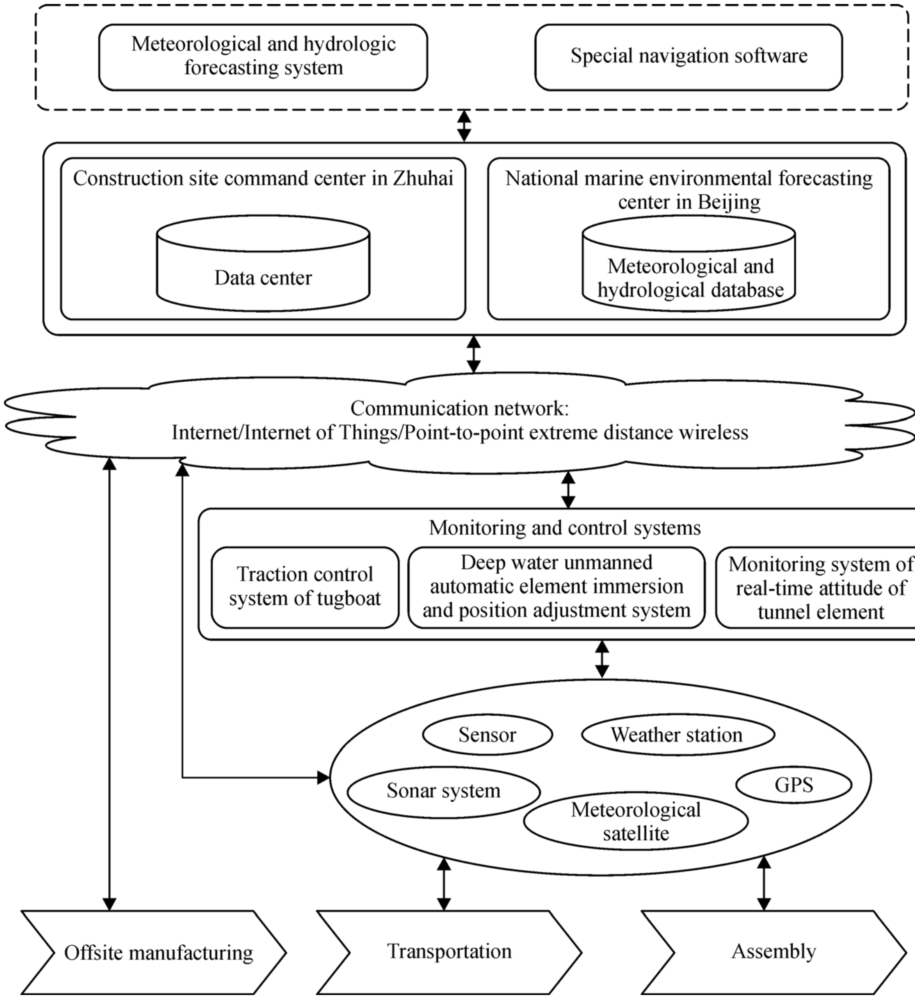

Fig. 3 System framework of smart construction site in HZMB project

4.3 Construction-related information acquisition and transmission

Meteorological and hydrological information in construction site and attitude data of tunnel element are very critical to the successful transportation and assembly of tunnel elements. Various sensor technologies and communication network have been adopted to acquire these data and information.

4.3.1 Meteorological and hydrological information acquisition and transmission

The transportation and assembly of tunnel element are seriously affected by meteorological and hydrological conditions; thus, multiple meteorological and hydrological information monitoring equipment and ocean weather stations have been scattered in the construction site, which can observe ocean currents, waves, and weather information continuously 24 hrs a day. Meteorological satellite is also used to monitor the meteorological information of the construction area.

All meteorological and hydrological information acquired in the construction site is transmitted to the data center located on land. Long-distance wireless networks combined with optical fiber have been adopted for the communication between construction site on the sea and command center located on land. In particular, point-to-point extreme distance wireless broadband transmission is used to communicate between the construction site and wireless transmitting/receiving end on land, which is connected to the command center by optical fiber.

4.3.2 Real-time attitude data of tunnel element acquisition and transmission

During the suitable meteorological window, the prefabricated tunnel element will be transported to assembly site by tugboats after outfitting. A real-time attitude of tunnel element monitoring system has been developed. In the monitoring system, 3D positioning information of immersed tunnel element is acquired by GPS, RTK (Real-time kinematic), and sonar system. Micro mechanical gyro angle sensor, high speed angle sensor, and six dimensions measurement system, such as movement direction, speed, accelerated speed, swing frequency, oscillation amplitude, monitor the movement state data of immersed tunnel element in real time. The real-time attitude data of tunnel element is transmitted to data center through the abovementioned communication network.

In the case, construction environment information (e.g., the meteorological and hydrological information) and construction information (e.g., attitude data of tunnel element in transportation and assembly process) are successfully acquired and transmitted to data center by using several kinds of sensor technology and abovementioned communication network. According to the idea of smart construction site, these construction-related data and information acquisition and transmission are the foundation of smart construction site that make the achievement of collaborative operations in the transportation and assembly work of tunnel element possible.

4.4 Collaborative work in transportation and assembly process

Three kinds of participants are involved in the transportation and assembly process of the tunnel element:

(1) Decision makers, consisting of three members who determine when to start transportation, the closure of navigation, and assembly.

(2) Construction site commanders consisting of nine captains who send shipping and assembly instruction to operators.

(3) Operators who manipulate various machines, equipment, and control systems.

Based on the acquired construction-related information, several systems including meteorological and hydrological forecasting system, comprehensive situation analysis system, and command system are utilized to support collaborative operations among the different participants in the transportation and assembly process of tunnel element.

According to the acquired meteorological and hydrological information, the suitable transportation and assembly time window will be analyzed. In particular, the acquired meteorological and hydrological information is transmitted via internet to national marine environmental forecasting center in Beijing. After computing and analyzing by supercomputer at national marine environmental forecasting center, the meteorological and hydrological forecasting service is provided to the command system. The decision makers determine the suitable transportation and assembly time window.

In the transportation process, the huge tunnel element will be transported by tugboats from prefabrication factory to the construction site. The commanders synthesize the acquired meteorological and hydrological information and real-time attitude data of tunnel element and sensor data of tension force of tugboat's mooring ropes, and provide shipping instruction to the operators. The operators manipulate the traction control system of tugboats to adjust the attitude of tunnel element, which avoid deviation from voyage route or grounding.

In the assembly process, the commanders will provide assembly instruction to operators supported by the acquired real-time attitude data and positioning data of immersed tunnel element. The operators handle the deepwater unmanned automatic element immersion and position adjustment system to control the immersion and position process of tunnel element.

4.5 Intelligent construction management

Solving the extensive collaboration and coordination problem is the main purpose of smart construction site. In the case based on the acquired construction-related information sharing, several decision support systems are developed including meteorological and hydrological forecasting system and special navigation software, for helping decision makers to determine suitable time windows of transportation and assembly operation. Meteorological and hydrological forecasting system can proactively acquire meteorological and hydrological information of construction site, forecast the trend of meteorology and hydrology by using calculation function of supercomputer. Considering actual situation of construction site, tugboat towing transportation scheme is adopted to transport tunnel elements on the sea, which includes the combination of longitudinal and horizontal towing. The special navigation software has been used to coordinate assignments between different tugboats to ensure the collaborative transportation of tunnel elements.

4.6 Discussion

By the end of May 3, 2017, the entire length of the immersed tunnel has been successfully assembled on the seabed. The smart construction site mode is inspired by this case study, which work as an evidence to support the practicability of the proposed mode. In this case, ICT has been widely used in construction processes of immersed tube assembly to realize perception and interconnection of construction information, collaborative works of equipment, systems, and participants. Smart construction site management in Hong Kong-Zhuhai-Macao Bridge project could be partially realized. The smart construction site mode is inspired by the successful practice of Hong Kong-Zhuhai-Macao Bridge. Although many improvements of smart construction site mode should be made in the future, it has some implications for other projects. First, in this case, all immersed tunnel elements are prefabricated on an island near the construction site. These immersed tunnel elements are installed at the bottom of the sea. Command center of immersed tube assembly located on land. Construction site often has the characteristics of geographical distribution. In addition, construction processes of immersed tube assembly is often affected by meteorological and hydrological conditions. How to construct the information infrastructure of construction site is critical, which can overcome negative construction site environment condition. Second, information support platform of immersed tube assembly incorporates real-time attitude data and meteorological or hydrological information. Relying on these data or information, commanders will provide assembly instructions to operators, and that operators can follow instructions to manipulate various devices for controlling the immersion and position process of tunnel element. Without a good information support platform, it is difficult that all participants work together. Third, for realizing collaboration work among participants, all participants must actively perceive and share construction information in immersed tube assembly process. Subsequently, smart management would be realized through the decision management system. In other words, construction site information must be more transparent for all participants, which is the foundation of smart management. In the future, smart construction site would transform the model of project construction, which would reinforce collaborative work among participants for the entire construction processes, and provide information support for the operation and maintenance of facility after the project is put into operation.

5 Conclusions

The advancement in ICT has changed the way people work today, which can eventually solve collaboration work problem in different application fields. However, such implementation is still in the primary stage. In the construction process, the collaboration work and information sharing among participants will become more general. In addition, achieving effective collaborative work among the different participants and smart management of all the participants is critical. Existing research work appears a piecemeal fashion, and limited research in the construction industry cannot completely meet requirements of managing MCP. Therefore, researchers should focus on thinking of effective collaborative work among different participants through ICT technology.

Based on the literature review, this study has developed the smart construction site for MCP, which is a relatively new concept in construction industry. This concept emphasizes the implementation of effective collaborative work and information sharing among various participants through digitization of construction process. Three key elements of the smart construction site have been identified: (1) information support platform; (2) collaborative work; and (3) intelligent construction management. Therefore, the conceptual framework for smart construction site has been proposed. It can be a powerful tool for providing information to improve collaborative work among participants. Moreover, intelligent construction management would be achieved by information integration and collaborative work of construction site. The case study results demonstrate that the idea of smart construction site is important to construction management, although the case is a very preliminary successful practice of smart construction site.

The smart construction site can solve construction management of MCP. Future research should be dedicated to further explore the potential of smart construction site in construction industry. The next stage of this smart construction site will concentrate on utilizing information support platform for a variety of construction example to establish a standard principle of collaborative work and intelligent construction management.

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