Study on Collaborative Management Pattern of Integrated Design of Infrastructures in Large-scale Park

Jun Fang, Ding Yuan Wu, Su Ping Ren and Gui Ying Zhang

ABSTRACT

Infrastructure construction is the main battlefield of the implementation of large-scale park strategy. However, there are relatively few theoretical and practical researches on integrated design of large-scale park infrastructure. In addition, the large-scale park infrastructure involves more systems and participating design bodies. Therefore, it is of great practical significance to study the integrated design pattern of infrastructure in large-scale park from the perspective of collaborative management. This paper firstly clears the large-scale park infrastructure and other related concepts. Then, based on the research of collaborative management and on the analysis of integrated design in a large-scale park infrastructure of collaborative process, a large-scale park infrastructure design collaborative management models can be respectively build from the four big synergy elements, which are organization, process, resource and objective. And it is also discussed in this paper to realize the possibility of a large park infrastructure integrated design collaborative management by BIM technology. In the end, a collaborative conceptual model for the comprehensive design of large-scale park infrastructure based on BIM technology is constructed.¹

INTRODUCTION

Large-scale parks under take all levels of governments’ policy experiments, institutional innovation and the realization of industrial agglomeration, upgrading and radiation of economic development tasks. But at present, the construction of

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large-scale park infrastructure generally adopts the pattern that the design units do parts of the design according to the system or region division. Due to geography, communication and other reasons, the design units are unable to share information in time, resulting in low design efficiency [1]. Therefore, the integrated design of large-scale park infrastructure is very necessary [2]. In addition, large-scale park infrastructure construction is a complex large-scale system, whose integrated design management has the characteristics of large-scale of management objects, complex structure, difficult prediction of objectives and hard concretion of tasks, etc. And the coordination and close cooperation of all kinds of specialties and various work design is the inevitable requirement of the current large-scale complex project collaborative design. Therefore, the integrated design of large-scale park infrastructure must establish a collaborative management model. The research on collaborative management applied in the field of architectural design is relatively mature. Katz (1990) proposed to build computer supported collaboration work in the field of building engineering[3]; in "design information flow management integrity", Eastman (1996) proposed the project planning and design, implementation and other related processes are interspersed through the development of the project management database maintenance scheme [4]; Barbosa (2002) proposed to deepen collaborative design with "virtual prototype" [5]; Leah Meeks, David E. Rosenberg (2013) argued that the size and complexity of water resources networks often require a large number of intensive computational simulations to test the impact of network structure or management change and adopt new methods and new tools to detect water resources networks [6]; Duska Rosenberg (2000) proposed to analyze the work environment that is conducive to network integration and to address more design issues related to the network visualization of the building environment in order to keep the network in a normal working condition without being restricted by the physical workplace[7]; Thomas M. Korma and C. B Tatum (2000) had integrated the independent design of the professional contractors in the initial design phase by establishing a corresponding knowledge base to achieve collaboration of the MEP system [8]; KarstenMenzel, Martin Keller (2000) elaborated in detail the way in which computer-aided facilities management (CAFМ) and planning tools can be combined to achieve systemic effects [9]; Duthinh, Emil Simiu (2010) studied the multi-risk collaborative design problem and suggested that multi-design risk would have a certain impact on the life cycle cost [10]; Dong Li and Hui Song (2013) described the synergistic effect theory of audit management at the beginning of the project and concluded that the key to the overall efficiency of the project was to optimize the objective subsystem and strengthen the overall synergies [11]; Michael Pulask, Teresa Pohlman et al. (2003) examined the integration of positive factors in the transformation of the Pentagon, which revealed the inherent synergies between sustainable design and constructability[12]; Michael J. Horman et al. argued that in terms of the health care industry, the synergistic effect was bound to be greater than the sum of each unilateral factor [13].
Based on the above literature review of collaborative management in the field of architectural design, the paper will study respectively the collaborative management patterns of large-scale park infrastructure’s integrated design from the aspects of organization, process, resource and objective, and have some related discussion on applying BIM technology to realize the collaborative management of large-scale park infrastructure’s integrated design.

RELATED CONCEPTS

Large-scale Park Infrastructure

In the "world development report" (1994 edition), infrastructure is defined as permanent engineering equipment, buildings and facilities provided for the production of all enterprises, and services provided to businesses and residents for living needs. According to the different attributes, it is divided into social infrastructure and economic (productive) infrastructure. The former mainly covers science, education, culture, health and service infrastructure, while the latter is represented by transportation, posts and telecommunications, energy and other facilities. In this paper, the large-scale park infrastructure refers to facilities serving the park's economy, production, life in a large-scale park. So it belongs to the generalized infrastructure, including both economic and social infrastructure, and has the service function of general infrastructure.

Large-scale park infrastructure does not have specific service objects, and the products and services it provides are shared by all the objects in the park. Long term construction process of a large-scale park involves multilateral interests and potential social effects as a result of the collaborative communication workload, and its infrastructure needs to meet the current needs of the park, but also consider the future needs of the park. Thus, the large-scale park infrastructure has the characteristics of sharing, advance, complexity and wide range of influence, in addition to its own basic nature.

Collaborative Management Pattern Of Integrated Design

Collaborative management pattern is a relatively efficient management mode, widely used in modern project management. In this management mode, managers make the internal collaboration among managed men by making management mechanism, so that we can make full use of the resources inside and outside the organization to solve problems and achieve overall goals together. The information flow in the collaborative management pattern is roughly shown in Figure.1.

Therefore, the collaborative management of large-scale parks’ integrated design is based on the previously developed collaborative management mechanism and the corresponding management policies, around the "tasks
relevance", "information flow" and "culture integration", each professional design project collaborative management elements has reasonable integration, so as to effectively solve the problem of information transfer and achieve the balance among the main interests of participants and the overall goals of integrated design.

Figure 1. The information flow in the collaborative management pattern.

FRAMEWORK CONSTRUCTION OF COLLABORATIVE MANAGEMENT FOR INFRASTRUCTURES’ INTEGRATED DESIGN IN LARGE-SCALE PARK

Collaboration Process

The collaboration work of the large-scale park infrastructure’s integrated design can be divided into several processes, such as the initial design, the design, the design contradiction collaboration, circulation, collaboration completed, etc. among different specialties, which is shown in Figure 2.

In Figure 2, the area in the circle represents all the design tasks to be achieved, and different lines represent the contents of the different professional designs. Figure a is displayed in the design stage, each major has just begun their professional design, due to not intensify contradiction between the professional design, does not involve the design interface problem, so the work of design units is so easy to coordinate during the stage; in the design process, with the gradual deep of professional design, there will be the collision and cross of the design content, which is shown in Figure b, at this time each designer's design goals and work conflict, work into the competition mode, Need to rely on information collaboration platform to achieve many design goals and reconcile the contradiction between the two sides; at this point each designer's design goals and work conflict, the collaboration work enter the competition mode and need to rely on information collaboration platform to achieve many design goals and reconcile the contradiction between the two sides; in the subsequent stage c, the
professional design units began to share the ideas through the sharing of knowledge, and then get rid of the existence of various problems; d stage for the integrated design is the key collaboration, each levels of this period are gradually fit, making the designers have Continuous thinking platform, which can solve the problem of disadvantages of decomposition task. Finally, the professional design continues until the collision occurs again; in the integrated design system, the collaboration work cycle, the situation shown in figure e will be in a state of coordination based on the completion of the design work.

Figure 2. The logical model of collaborative design work.

**Conceptual Model Of Collaborative Management For Integrated Design**

**ORGANIZATION COLLABORATION**

The multi-party participants involved in the integrated design project of the large-scale park have formed a relatively loose whole by means of contractual agreement due to the same goals (namely, integrated design of a project). But each subject also has its own goal of interests, and usually, it will be more likely to pursue its own personal interests after basically satisfying the overall benefits, which will result that the formation of the integrated design organization of large-scale park infrastructure has more vulnerable fluctuations of stability, compared to the general size of the project organization[14].
Organization is the decisive factor for the realization of the system goal, scientific and reasonable analysis of the large-scale park infrastructure design pattern of organizational elements is the premise of its organizational synergy. According to the characteristics of the integrated design management process and business process, members of the integrated design organization can be divided into three levels, namely, decision-making, coordination management and business execution. Among them, the decision level is the main owner, located in the organization's top level; the coordination of management level is located in the middle, composed of the head of units, third-party design review units, integrated design technical review committee, integrated design coordination management committee; the third level is the business execution layer, which is composed of the design units involved in the comprehensive design. From the level analysis, the organizational level of the integrated design team can be divided into two levels, the first level is the group leader unit, and the second level is team member unit. The unit leader has the responsibility of managing, supervising and managing the unit members, and the unit members have the duty and responsibility to cooperate with and obey the group leader unit.

![Figure 3. Organization hierarchy of the large-scale park infrastructure’s integrated design pattern.](image)

According to the above analysis, the organization structure of the integrated design pattern of the large-scale park infrastructure is shown concretely in Figure 3.

Based on the organization hierarchy chart, achieving the organization collaboration of the large-scale park infrastructure’s integrated design needs three steps: (1) Integrate the culture of each design subject, so that it has a certain integrity and coordination [15]. Through cultural synergy, cultivate the overall sense of mission, shape the core values, establish a common vision goal, highlight the advantages of cooperation and competition, so as to improve the efficiency of integrated design management; (2) Design a complete set of rules, so that each
participant is closely related to the project, in order to achieve the common goals of the project as the primary task, to carry out the design of collaborative work, and to stimulate the potential of teamwork within the team. In the integrated design project of large-scale infrastructure, the rule system mainly includes the management pattern, the terms of the contract and project management system, among them, the management pattern is to fully consider the premise of the ability of the main design, divide the project into several divisions; the contract clause refers to the contract to define the rights, responsibilities and interests of the subject; the project management system is mainly used to regulate the behavior of the participating subject after the establishment of the organization; (3) Establish the organization collaboration platform based on advanced network technology. Through the construction of collaborative operation network and collaborative management information system so that each design participant from the beginning will be connected to the collaborative operation of the network, pass their own design information into the network for sharing, in order to achieve information flow, workflow and logistics coordination, to avoid impeding the implementation of the entire project due to poor communication happening in traditional organization.

From the above analysis of the steps, we can extract the three elements of the integrated design organization collaboration platform, namely, technology, system and culture. So the organization collaboration platform of large-scale park infrastructure’s integrated design can be established as Figure.4.
PROCESS COLLABORATION

Integrated design of large-scale park infrastructure is from a shallow process to a deep process, each stage has different participants and design tasks, and information the design unit master is somewhat different during each stage, therefore, for each design phase, based on the hierarchical structure of Fig. 3, the design level should be deepened with the design stage, and the design content is refined according to the information feedback. Therefore, taking the municipal engineering and housing construction projects as an example, the collaborative operation pattern of overall process in large-scale park infrastructure’s integrated design is shown concretely in Figure 5.

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<th>Design participants</th>
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Figure 5. The collaborative operation pattern of overall process in large-scale park infrastructure’s integrated design.

In general, the integrated design of large-scale park infrastructure covers a large number of professional design, before the integrated design of large-scale park infrastructure, the primary task is to unify the modulus and standard of each professional and individual projects, clarify the design order, and establish the data sharing library of energy and ecological environment. After entering the integrated design stage of the large-scale park infrastructure, based on a reasonable overall
planning, determine the size of each professional design, timing, content and processes, take full account of the work of other design units, and use existing resources to avoid waste of resources due to duplication. Therefore, the process collaboration of various specialties under the overall process of large-scale park infrastructure’s integrated design is shown in Figure 6.

Figure 6. The process collaboration of various specialties in large-scale park infrastructure’s integrated design.

RESOURCE COLLABORATION

The essence of the integrated design of large-scale park infrastructure is to build a scientific combination of the park resources, especially the natural resources, according to their industrial structure and resources’ advantages in a certain region. In the early stage of large-scale park design, the current situation of the park and the sustainable development in the future should be taken into account coequally.

In terms of resource collaboration of the large-scale park infrastructure’s integrated design, there are mainly two levels of collaboration, namely, the collaboration of various technology resources and information resources in the design, and the collaboration of a park and its natural environment and resources.
The implementation of resource collaboration should make resource requirements planning for different specialties to improve the efficiency of internal resources’ allocation within the organization. By optimizing the design environment, having a comprehensive look of the overall situation, distributing the design profits rationally, encouraging excellent designers to share internal resources and restricting the unfavorable thoughts of different professional design for their own array.

In addition, the resource system for realizing the integrated design of large-scale park infrastructure can be combined with the state and structure of environmental resources in the process of comprehensive design, and the concept of ecological carrying capacity can be introduced (under the premise of ensuring the rational utilization of resources and the virtuous cycle of ecological environment, in a fixed geographical space and a certain period of time, the capacity of economic strength, population size and social total amount that a particular ecosystem can sustain). Fully consider the matching degree of infrastructure scale and the environment. For example, in the design process of water supply and drainage system in the park, it is necessary to first make clear the regional water system structure, water resources category, pollution category and so on, and then calculate the carrying capacity of the water system in this regional.

OBJECTIVE COLLABORATION

A series of stage objectives have been initially set up before the integrated design of large-scale park infrastructure. But the characteristics like relevance, multi-index and hierarchy that the objective set itself has, result that it is difficult to achieve the complete reunification of the interests of both sides’ objectives in the design practice. And thus the hierarchy of design objectives for different specialties and the sequential processes among different work divisions may be put in a double squeeze. Therefore, on the basis of making full use of resources, it is necessary to synthetically collaborate with the quality, schedule and so on, accord the design objective, and achieve the ultimate purpose of the collaborative management of the large-scale park infrastructure’s integrated design-- process control.

The overall objectives and long-term objectives of the design projects are the core goals pursued by the integrated design. For a large-scale park infrastructure design project, from the perspective of project whole life cycle, it needs to not only consider the problems appearing in the design stage, but also take full account of the problems appearing after the project is completed and put into operation. Put them into the objectives management system to achieve the collaboration of three goals in the entire project life cycle, namely, quality, investment and progress. On this account, the goal of pursuing the maximum value-added for the project will be achieved.
IMPLEMENTATION OF COLLABORATIVE DESIGN BASED ON BIM TECHNOLOGY

Multi-specialties Collaborative Design Under BIM Technology

In terms of engineering field, the integrated design of large-scale park infrastructure mainly includes roads, bridges, water supply, drainage, gas supply, heating, electricity, communications, landscaping, medical education and other aspects with huge amounts and complex types. The design work of each specialty is serial, isolated and loose, and the corresponding information and design results are widely distributed and dispersely stored. The integrated design of large-scale park infrastructure needs to collaborate with many specialties and links, which is different from the traditional design method and has a greater degree of difficulty. Therefore, the multi-disciplinary collaboration of infrastructure integrated design is essential to improve the quality of the project design and implement the subsequent stages successfully.

Driven by multiple requirements and objectives, the design method based on BIM technology can give full play to its unique advantages, and achieve multiple specialties and objectives collaboration. The comparative analysis of the traditional design and the collaborative design based on BIM is shown in Figure 7.

![Figure 7](image)

Figure 7. The comparative analysis of the traditional design and the collaborative design based on BIM.

The constructed "visualization" BIM model based on three-dimensional or multi-dimensional digital technology can provide all design parties and their stakeholders with "simulation and analysis" collaboration platform. Each professional designer can minimize the error and enhance the efficiency of communication within the organization on the basis of clear understanding of other professional design intentions, making the design objectives unified. Taking pipeline wiring design as an example, realizing the visualization of construction projects under the
support of BIM technology can not only reduce the difficulty of drawing audit and optimize the drawing design, but also display the spatial relationship among the pipe networks in a stereoscopic way. Thus the pipeline collision problems in the construction process can be foresaw in advance and avoided through optimization in the design phase to make the whole design work parallel, interactive and integrated[15].

**Process Collaboration Under BIM Technology**

Process collaboration of the integrated design is to coordinate various stages in the process of project design, eliminate various professional design interfaces’ contradictions in the design process and remove the incongruity between design and later construction process. The integrated design of large-scale park infrastructure needs to consider the whole life cycle of the project, including decision-making, design, construction and operation. By strengthening the connection of all the project stages, on the one hand, the relationship among all participants involved in the construction process can be coordinated, on the other hand, problems such as the waste of resources and poor information can be avoided caused by the separation of the different procedures of the construction process.

The keys to the effective collaboration of the integrated design of large-scale park infrastructure lie in the drive of BIM information interaction platform and its strong innate advantages and the in-depth analysis and integrated optimization of multiple participants’ own goals, the professional design goals, the overall design goal and so on. And then objectives collaboration of the integrated design of large-scale park infrastructure will be achieved. On this basis, technology resources, information resources, park resources and natural environment resources are integrated through cultural integration, teamwork and so on so as to achieve the purpose of resources collaboration. According to the organizational hierarchical structure established by the previous analysis and the drive of BIM integrated information, the organization collaboration and process coordination are to be realized, and finally the collaborative management of the integrated design of large-scale park infrastructure will be completed. The concrete process collaboration diagram based on BIM technology is shown in Figure 8.
CONCLUSIONS

The integrated design of large-scale park infrastructure can solve all kinds of problems appearing in the construction of the park currently, which is conducive to the realization of the sustainable development of the park. Based on the literature research of collaborative management in the field of architecture design, the definition of relevant concepts and the analysis of collaboration process, the paper studies the collaborative management patterns of large-scale park infrastructure’s integrated design. And collaborative management models of the integrated design of large-scale park infrastructure are respectively established from the perspective of four collaboration elements, namely, organizations, processes, resources, objectives. Finally, the path model for realizing the collaborative management of the large-scale park infrastructure’s integrated design based on BIM technology is established from the specialty collaboration and process collaboration.

REFERENCES