Organizational innovation of integrated design of infrastructures in large-scale park

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Abstract

Infrastructures in large-scale park are the most basic substance to realize the function of the park, and the important basis for the sustainable development of the park. Because infrastructures in large-scale park involve multi-system and multi-specialty such as municipal traffic, electric power energy and communication network and then were designed by different design units according to different reference standards, infrastructures in large-scale park have inconsistent design standards, unharmonious design schedule, unshared design achievement and so on, therefore, the integrated design pattern should be taken. This paper will give an overview of integrated design of infrastructures in large-scale park in the first place, and then put forward organizational operation mode and communication mode of integrated design of infrastructures in large-scale park on the basis of the thought of organizational adhesion, and finally construct organizational game model of integrated design of infrastructures in large-scale park in virtue of the theory of positive game and analyze income distribution of each member in integrated design organization by the use of Shapley value method.

Keywords: Infrastructures in Large-scale Park; Integrated Design; Organizational Innovation; Positive Game; Income Distribution

1 Introduction

With the development of society and economy, all kinds of parks have been continuously constructed, and their supporting infrastructure construction has been paid more and more attention. So the quality of design determines the success or failure of infrastructure construction in large-scale park. At present, infrastructures in large-scale park are designed on the basis of "cutting the cake" model and divided according to the system or region, and then each design unit undertakes part of design tasks. Due to region, time, communication platform and so on, each design unit cannot share information and has low design efficiency and benefit [1]. So it is very necessary to take integrated design model, and integrated design organization of infrastructures in large-scale park safeguards the completion of integrated design [2].

Historically, three theories that have a significant impact on organization theory and practice are respectively classical school, new classical school and modern management theory. For organizational innovation, many domestic and foreign scholars have carried out extensive research. Baker (1999) pointed out that continuous reform and innovation of the organization helped the organization to gain new knowledge and produced an important impact on organizational core competence [3]. Scott (2008) considered that organizational innovation included several stages such as discovering problems, seeking fund support and completely solving problems [4]. From the perspective of virtual study team, Johnson (2002) et al. described project team how to build team norms, implement role orientation and resolve team contradiction and so on in the process of design and formation of team process.

And for organizational innovation of architectural design, domestic and foreign scholars have carried out some research. Dorothy Goslett (1984) gave a relatively overall introduction to design management, such as how to discuss together with customers and formulate design plan, how to quote and calculate design fee and how to communicate with customers and do business [5]. Henry Dreyfuss (2003) put forward a proposal that "designers should make communication easier by formal and informal way" and showed the importance of organizational communication of design [6]; Carlynn Black et al. (2004) thought that good communication and coordination were essential for successful project partnership [7]; Colin Gray et al. (2001) started from the program of architectural design, constitution of design team and other basic concepts, and expounded the tools and procedures to improve design management, and means and method for action [8]. In the study of integrated design management in architectural engineering, S.J Fenves (2000) formed the design environment aimed at helping architectural designers to cooperate and extend design. The above-mentioned research focused on pipeline design in architectural engineering, failed to construct organizational model of integrated design (operation and communication), and did very few research on game relationship and benefit distribution between members.

This paper will do research on organizational model of integrated design of infrastructures in large-scale park, mainly including the thought of organizational structure, organizational operation model and organizational communication model, and do game analysis of integrated design of infrastructures in large-scale park.

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2 Organizational model of integrated design of infrastructures in large-scale park

2.1 THE THOUGHT OF ORGANIZATIONAL ADHESION OF INTEGRATED DESIGN

Infrastructures in large-scale park involve many specialties and have complex design tasks, so they need all engineering design professionals and many design units to participate.

Because design organization alliance can effectively integrate various resources of multiple design units and hide specific constitution of each organization within design alliance, it is conducive to grasp the overall characteristics of integrated design, can help integrated design to seize the key of management and avoid the increasing difficulty of management due to complex design. The thought of organizational adhesion just conforms to the thought of "invigorating large enterprises while relaxing control over small ones" and "seizing the main while relaxing control over the minor" of organizational management in integrated design. The basic ideals of organizational adhesion of integrated design are shown in figure 1.

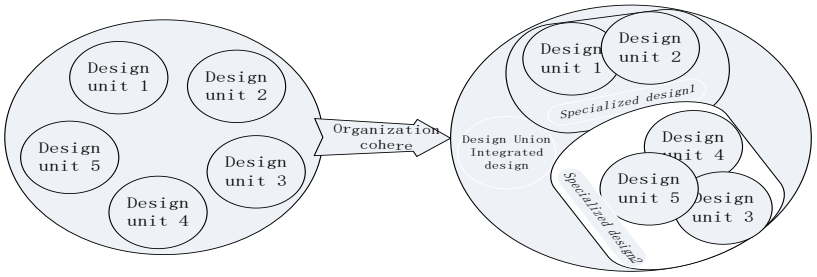

FIGURE 1 The basic idea of organization bonding of integrated design

According to similarity and complementary, each unit within integrated design team bonds and establishes special design business group (or a large-scale design unit is responsible for several expert designs), and the leader of integrated design team grasps the overall progress of each design business by unit.

2.2 ORGANIZATIONAL OPERATION MODEL OF INTEGRATED DESIGN OF INFRASTRUCTURES IN LARGE-SCALE PARK

Like the general project, the participants of infrastructure construction in large-scale park mainly include the owner, the builder, the designer and consulting service provider. Organizational structure of infrastructure construction in large-scale park is shown in figure 2.

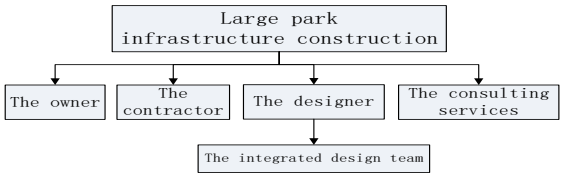

FIGURE 2 The structure of the organization of large park infrastructure construction

Design stage has an important impact on the quality of construction projects. If design achievement is wrong, it will cause the problem with construction quality, and affect service life and function of construction projects. Therefore, it is very important to control design. For infrastructures in large-scale park, integrated design is particularly important.

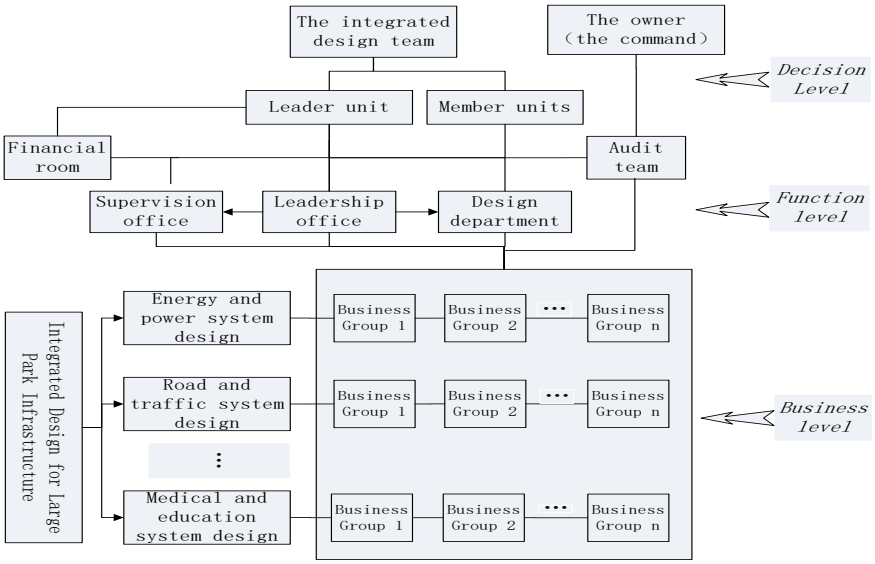

FIGURE 3 The organization operation pattern of integrated design for large park infrastructure

Organizational operation model guarantees the completion of integration design of infrastructures in large-scale park. This model is mainly divided into three levels: the first is decision-making level, the second is functional level, and the third is business level. Organizational operation model of integrated design of infrastructures in large-scale park is shown in figure 3.

The decision-making level of integrated design determines the design's quality, schedule, investment and other targets and is composed of the owner (command post) and integrated design team. The functional level of integrated design mainly involves integrated design's leadership office, supervision group, engineering department, financial office and audit group throughout the whole process. The business level of integrated design determines the different business groups on the basis of different professional systems and different specialties (or different points in time) of infrastructures in large-scale park, and forms various design business groups by organizational adhesion according to the needs of design tasks of projects and the different situations of various participants.

2.3 ORGANIZATIONAL COMMUNICATION MODEL OF INTEGRATED DESIGN OF INFRASTRUCTURES IN LARGE-SCALE PARK

2.3.1 Knowledge interaction between main bodies

Each participant in integrated design of infrastructures in large-scale park can be regarded as the collection of different resources, and cannot grasp all the resources that are needed to finish integrated design, and needs to acquire resources from other participants in integrated design organization in order to finish his or her task and gain benefits.

Each participant needs to communicate a great deal of information in order to finish the tasks of integrated design. Therefore, integrated design organization of infrastructures in large-scale park can be regarded as the information communication system with multiple main bodies that are composed of multiple participants, and take exchange of resources as target and resource information as communication subject [9].

2.3.2 Level structure of information communication system with multiple main bodies of integrated design organization

Information communication system with multiple main bodies of integrated design of infrastructures in large-scale park includes various constituent parts such as design participants, resources, communication interface and information, and mutual relationship between various constituent parts. According to the analysis of constituent parts and mutual relationship, the system can be divided into four levels, mainly including information level, communication interface level, participant level and resource level. Constituent parts each level can realize some function of tasks of integrated design, and there is a connection relationship between adjacent levels. Based on the above analysis, level structure of communication system with multiple main bodies of integrated design of infrastructures in large-scale park is shown in figure 4 [10].

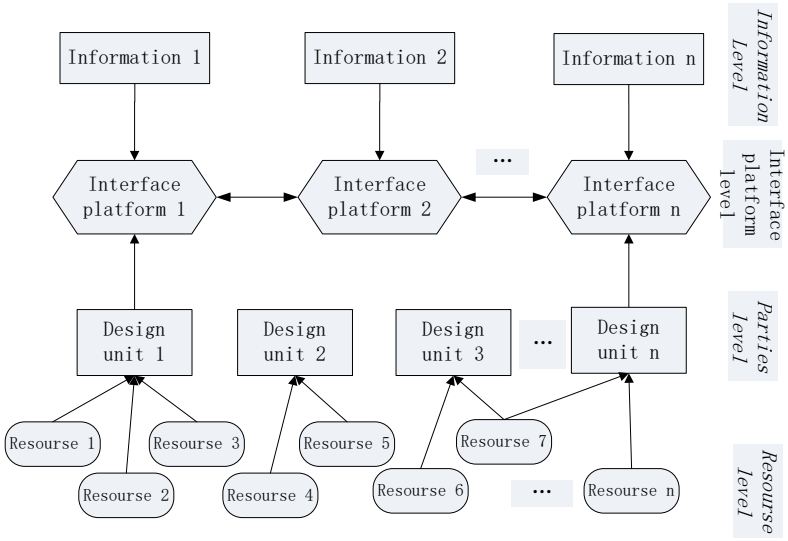

FIGURE 4. The structure of multi-agent communication system of integrated design for large park infrastructure

Information communication system with multiple main bodies of integrated design of infrastructures in large-scale park is divided into four levels:

(1) Resource level. Engineering design needs all kinds of resources, such as various designers, design studio, development software of core technology and the background information required for the relevant design. The resource itself is relatively independent, but belongs to each design unit in the work. Integrated design of infrastructures in large-scale park needs a great deal of resources (different design units, different specialties and different design stages require different resources, so the resources must flow) to carry out the tasks. The complete construction of resource level is the basis for communication with multiple main bodies of integrated design and affects the completion of tasks of integrated design.

(2) Participant level. Participant level is composed of participants in integrated design organization. Participants have their own resources, and then carry out the design work and do the analysis. To finish their own design tasks, the participants will take the initiative to ask other participants to share resources and so on, and accept the request of sharing resource other design participants send.

(3) Communication interface level. Designers needs communication platform to share their resources and information, that is, communication interface level. Communication interface level of participants of integrated design is the mutual communication platform of each business group inside and outside, and is conducive to the cooperative work between various participants. Because each business group and each participant undertake different design tasks, they take different interfaces.

(4) Information level. Information level is composed of information designers communicate. In the process of design, each participant describes the resources he needs to get or provides as information. The information level is the carrier of organizational communication of integrated design of infrastructures in large-scale park.

3. Game theory analysis of integrated design of infrastructures in large-scale park

3.1 POSITIVE GAME

Positive game is also called cooperative game, and means that participants work together, and gain benefits to a certain extent, and undoubtedly the overall benefits also grow, namely, the so-called win-win.

Positive game focuses on the research how organization realizes the maximum overall benefits and how each main body reasonably distribute benefits. The core of positive game is about how to reach a cooperation agreement between participants. Of course, there are undoubtedly some compromises in the process. In the process of positive game, some compromise can increase the overall benefits of alliance and distribution income, which is just a certain amount of residual income that positive game produces.

Two essential factors for positive game are:

(1) For an organization, cooperative benefits of alliance are more than the total amount of the benefits that each main body works alone and produces.

(2) In the internal organization, the benefits that each participant gains are more than the benefits he works alone and produces [11].

3.2 THE ESTABLISHMENT OF POSITIVE GAME MODEL OF INTEGRATED DESIGN OF INFRASTRUCTURES IN LARGE-SCALE PARK

The participants of integrated design organization of infrastructures in large-scale park are numerous and form various design business groups by organizational adhesion. There are interests and conflicts between participants, so there is game relationship between participants in the integrated design alliance. And with the purpose of the completion of design tasks of infrastructures in large-scale park and the maximum benefits of participants of integrated design, game relationship of integrated design alliance is a positive game. Suppose integrated design alliance of infrastructures in large-scale park has m participants (a leader unit and several professional design units), positive game model shall be constructed as follows:

$$F(M,a)=\{P_1,\cdots,P_m;\ g_1,\cdots,g_m;\ a_1,\cdots,a_m\}$$

Notes: M is non void collection of participants, P is M's non void subset, and F can be regarded as an organization; $P_1,\ldots,P_m$ are plan space of participants of integrated design; $g_1,\ldots,g_m$ are agreed conditions of integrated design organization.

$a_j=\{P_1,\cdots,P_m;\ g_1,\cdots,g_m\}$; a_j is characteristic function of no. i design participant, $a(P)$ is the total sum of transferable benefits that the collected P participants gain alone, among them, $a(\varnothing)=0$.

If P and Q are two non void organizations in the integrated design alliance, the benefits that P and Q work together and gain are more than the total sum of the benefits that two groups work alone and gain, that is, $a(P\bigcup Q)>a(P)+a(Q)(P\bigcap Q=\varnothing)$, which is also positive game relationship. [18]

When positive game $F(M,a)$ of m participants is studied, characteristic function a_j is applied, that is, suppose each participant in integrated design organization measures his own benefits with the same standards and benefits $a(P)$ of each organization in integrated design alliance can be distributed to each participant.

Nature 1 for positive game, each j∈M and P∈Q∈M (not including j), and then it shows that:

$$a(Q\bigcup\{j\})-A(Q)>a(P\bigcup\{j\})-A(P) \tag{1}$$

Positive game model is convexity.

In the integrated design alliance of infrastructures in large-scale park, income distribution of each participant affects the implement of design work and success of integrated design work. Take m as vector quantity $C=\{c_1,c_2,\cdots,c_n\}$, which is vector quantity of income distribution of integrated design alliance, for example, c_j is income that no. i participant in the alliance gains.

Nature $2c_j>a\{i\},\ i=1,2,\cdots,m$ (2)

$$\sum\nolimits_{j\in M}X_j=a(M) \tag{3}$$

Formula (2) means that the benefits that each participant in integrated design organization alliance gains are more than the benefits that he gained alone. Formula (3) means that each participant in integrated design organization alliance can maximize his own benefits in the process of cooperation.

3.3 OPERATION MECHANISM OF POSITIVE GAME OF INTEGRATED DESIGN ORGANIZATION OF INFRASTRUCTURES IN LARGE-SCALE PARK

The most important difference between positive game and other games lies in the fact that in positive game, participants have an effective protocol that can solve the interests and conflicts, and the benefits that each participant gains are more than the benefits he works alone and produces. In the integrated design alliance of infrastructures in large-scale park, each participant signs a cooperation agreement through effective negotiation under the leadership to ensure that each participant in integrated design alliance gains fair benefits.

Nature 3 Marginal benefit participants contribute to design organization is $[a(P)-a(P\setminus\{j\}]$, among which, $a(P\setminus\{j\}$ is organization P's benefit value when *j* is not the member of design organization.

It is Shapley value method. Shapley value method is the method to solve the problems of income distribution and the maximum income of each participant in organization alliance. In Shapley value method, income distribution value that alliance members gain is Shapley value, and usually recorded as

$$\Phi(M,a)=\{\Phi_1(\mathrm{a}),\Phi_2(\mathrm{a}),\cdots,\Phi_m(\mathrm{a})\},$$

among which, $\Phi_j(a)$ refers to the benefits No. j participant in the alliance gains:

$$\Phi_j(a)=\sum_{P\in M}\frac{(|P|-1)!(\mathrm{m}-|P|)!}{m!}*[a(P)-a(P\setminus\{j\}](j=1,2,\cdots,m) \quad (4)$$

Notes: $|P|$ is the number of the participants of organization *P*, without considering compensation amount of benefits of participants in the alliance here.

The core of positive game model of integrated design organization of infrastructures in large-scale park is not empty, and the benefits that are distributed to participants in the alliance are knowable in the core of positive game model [12].

4 Case analysis

A city builds a large-scale car park in economic development zone, and infrastructure construction of the car park takes integrated design mode.

$$F(M,a)=\{P_1,\cdots,P_m;\ g_1,\cdots,g_m;\ a_1,\cdots,a_m\} \quad (5)$$

a(*P*) is the total sum of transferable benefits that the collected *P* participants gain alone, among them, $a(\varnothing)=0$.

Integrated design group *M* is composed of *A*, *B* and *C* participant, among which, *A* is the leader unit, top comprehensive Class A design institute at home, *B* and *C* are famous comprehensive Class *A* design units in the region, and *A*, *B* and *C* can all finish design task of infrastructures in the car park alone.

$$a(A)=0.5;a(B)=a(C)=0.25 \quad (6)$$

A and *B* (*B* and *C*, or *A* and *C*) also can finish work together, and Participant A, B and also can finish work together.

$$a(A,B)=a(A,C)=1;a(B,C)=0.75;a(\mathrm{A},\mathrm{B}C)=1.5 \quad (7)$$

For integrated design organization of infrastructures in large-scale park, the total sum of transferable benefits that each subset gains is shown in table 1.

TABLE 1 Efficiency of transferable of each subset of the organization of integrated design

Collection P of each participant	A	B	C	(A,B)	(A,C)	(B,C)	(A,B,C)
a(P)	0.5	0.25	0.25	1	1	0.75	1.5

According to formula (4): in the integrated design group of infrastructures in the car park, the distributed income for member *A*, *B* and *C* can be calculated as $\Phi_A(a)$, $\Phi_B(a)$ and $\Phi_C(a)$.

Among them, *j* = *A*, *B*, *C*; *m* =3.

So

$$\Phi_A(a)=\frac{0!2!}{3!}[a(A)-0]+\frac{1!1!}{3!}[a(A,B)-a(B)]+\frac{0!1!}{3!}[a(A,C)-a(C)]+\frac{2!0!}{3!}[a(A,B,C)-a(B,C)]=\frac{2}{3};$$

$$\Phi_B(a)=\frac{0!2!}{3!}[a(B)-0]+\frac{1!1!}{3!}[a(A,B)-a(A)]+\frac{1!1!}{3!}[a(B,C)-a(C)]+\frac{2!0!}{3!}[a(A,B,C)-a(A,C)]=\frac{5}{12};$$

Similarly, $\Phi_B(a)=\Phi_C(a)=\frac{5}{12}$;

$$\Phi_A(a)+\Phi_B(a)+\Phi_C(a)=a(A,B,C)=1.5$$

We can thus see that in integrated design group of infrastructure construction in the car park, the benefits that members gain are more than the benefits that they gain alone, and the total benefits are also more than the total sum of benefits that they gain respectively.

5 Conclusion

Infrastructures in large-scale park take integrated design model, which is conducive to the cooperative work of design participants. Based on the thought of organizational adhesion, this paper puts forward operation model of integrated design of infrastructures in large-scale park, which mainly has three levels, namely, decision-making level, functional level and business level, and appoints the leader of integrated design unit to lead each design unit to do collaborative design, establishes positive game model of integrated design organization of infrastructures in large-scale park, and solves the problems of income distribution of participants of integrated design organization by Shapley value method.

References

[1] Karlaftis M G, Easa S M, Jha M K, et al. 2012 Design and Construction of Transportation Infrastructure *Artificial Intelligence Applications to Critical Transportation Issues* 121-133
[2] Zerjav V, Hartmann T, Boes H. 2011 The Management of Requirements in Supply Chains of Construction Design: What Causes Uncertainty in Integrated Design Approaches *MISBE2011-Management and Innovation for a Sustainable Built Environment*
[3] BakerW E, Sinkula J M. 1999 The synergistic effect of market orientation and learning orientation on organizational performance *Journal of the Academy of Marketing Science* **27**(4) 411-427
[4] Julian S D, Ofori‐Dankwa J C. 2008 Toward an integrative cartography of two strategic issue diagnosis frameworks *Strategic Management Journal* **29**(1) 93-114
[5] Dorothy Goslett. 1984 The professional practice of design *Batsford*.
[6] Dreyfuss H. 2003 Designing for people *Design* **61**(2) 80-83
[7] Carolynn Black, Akintola Akintoye et al. 2004 An analysis of success factors and benefits of partnering in construction *International Journal of Project Management* (18) 423-434
[8] Colin Gray, 2001 Will Hughes. Building Design Management *Butterworth-Heinemann*
[9] Fewings P. 2013 Construction Project Management: an integrated approach *Routledge*
[10] Hetherington R, Laney R, Peake S, et al. 2011 Integrated building design, information and simulation modelling: the need for a new hierarchy
[11] Maschler M, Peleg B. 1967 The structure of the kernel of a cooperative game *SIAM Journal on Applied Mathematics* **15**(3) 569-604
[12] Klijn F, Slikker M, Zarzuelo J. 1999 Characterizations of a multi-choice value .*International Journal of Game Theory* **28**(4) 521-532
[13] CM Tam. 1999 Use of the Internet to Enhance Construction Communication: Total Information Transfer System *International Journal of Project Management* **17**(2) 107-111

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