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# Central Control of Integrated Innovation in Chinese Complex Project: General Department and Its Effect

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# EQUILIBRIUM AND PERFORMANCE: ORGANIZATIONAL DESIGN OF THE GENERAL DEPARTMENT IN MEGA-PROJECT[1]

[Abstract]: General Department is an innovative organization design pattern adopted by Mega-project for overall scheme design in China. Its philosophy to overall optimize and control some influential subsystems is different to the philosophy of traditional decentralized independent design pattern. This paper proposes the subsystem design models for the General Department pattern and the decentralized design organization in an organizational design framework which considering the complex interdependency among subsystems. The equilibrium solution of the General Department model is a Stackelberg-Nash equilibrium, which is different to the Nash equilibrium in the decentralized independent design pattern. An agent-based simulation is used to compare the two kinds of organizational design patterns from the perspectives of equilibrium and performance. The results show that the General Department could not only prevent the systemic design scheme from sinking into the local optimal solutions of some subsystems, but also improve the performance of the systemic design scheme. And the equilibrium stability and the performance would be improved once the sequential design strategy, firstly to optimize the highly influential subsystems and then to decentralized search the remainder less influential subsystems, is adopted in the General Department. These results verify the efficiency of the General Department for the systemic design scheme in mega-project, which has benefit for the development and application of 'Synthesization and Integration' system engineering method.

**Keyword:** mega-project, the General Department, organizational design, Stackelberg-Nash equilibrium, agent-based simulation

Mega-project technical scheme design is a searching process of multi-agent scheme. In this process, the units which are responsible for designing different subsystems continue to amend their own schemes through competition and compromise in order to achieve final design schemes that can be accepted by all parties. Decentralized organizational design pattern is usually adopted to search and get an relative good systemic scheme. In this pattern, decision-making power is fully authorized, and homogeneous subsystems start to design according to their own goals. However, due to the complexity of the subsystem correlation, the outcome of this organizational pattern in the engineering practice is not desirable. For example, in the process of domestication of the automobile industry in the 80s and 90s in last century, a large amount of vehicle enterprises and component suppliers made their own decisions without overall domestic design resulting in difficulties in the development of independent brand car[3]. In the early stage of research and development of the first Chinese satellite, Dongfanghong 1, the satellite also adopted decentralized organizational design method that caused the indetermination of overall technical scheme and delay of development progress [4].

In the practice process of mega-projects scheme design in China, an innovative organization design pattern, General Department, was occurred. In the case of Dongfanghong 1, a general design department which led by Sun Jiadong was established, and it solved the problem of delay in development progress. After that, the project was carried out smoothly[4]. By gaining the experience from Dongfanghong's case, general department has been becoming a critical organizational department of mega-aerospace-projects in China. For instance, in moon probe project, the general department is called "Center of Moon Exploration and Aerospace Project". Moreover, in manned space project, the general department is called "The Office of Chinese Manned Space Project" . Some space units also have their own general department. These design departments at top is not only responsible for the coordination among subsystems in the project, but also play an important role in general scheme design[5, 6]. For example, in the moon probe project, the Center of Moon Exploration and Aerospace Project should design specific technical schemes for satellite platform and launcher at project scheme stage.

The organizational design pattern of general department assumes that the subsystems are heterogeneous. Under this assumption, some subsystems will own priorities in design and should take global optimization. Then, other subsystems should make their own design decisions relying on the design decisions made by the subsystems mentioned above. However, current organizational design researches mainly assume that the subsystems are homogeneous which ignores the relative importance of some subsystems compared with others. Although some researches take the optimization and control during the whole design process into account, it assumes that the general department only takes charge of management rather than the work of design, and all subsystems are still designed independently. The final technical scheme will be formed after the coordination of general department. The understanding, design process, and assumptions of subsystem in general department organizational design pattern of Chinese mega-project are varying. As a result, it is necessary to start the research of general department organizational design on the basis of the assumption that subsystems are heterogeneous and the general design of some important subsystems.

This paper will study the general department which is a organizational pattern of mega-project with Chinese characteristics and compare the effects of design between general organizational design pattern and decentralized organizational design pattern in two aspects including the equilibrium and performance of design schemes. The paper will be divided into five parts. The first part will be relevant literature review. Then, the second part will introduce the organizational design pattern. Next, in the third part, the simulation model will be established and demonstrated. The fourth part will explain and analyze the results getting from the simulation. Finally, the fifth part will be the conclusion.

# 1. Literature Review

The general technical scheme of a Mega-project is consisted of several subsystems with different functions, and these subsystems are high correlated. The possible choices of final scheme of general technical scheme and subsystem scheme are showing exponential growth trend which presents a system with the characteristic of complexity[7, 8]. Thus, how to deal with this complexity has become a hot issue in mega-project organizational design[9].

The first feasible scheme is to reduce the correlation among subsystems in order to decrease the complexity of systems during the design of subsystem design process.Sanchez and Mahoney（1996）believed that standardized ports were good for the cooperation of product development in the process of disassembling products[10]. Srikanth and Puranam（2014）thought that modularization could support the communication and cooperation during the process of system integration and innovation[11]. The strategy that using modularization to reduce the complexity has become an essential method in the design of complex product[12]. However, this method can limit the choices of systemic design schemes and therefore, has a negative influence on the performance of general design scheme in project[13,14]. Zhou（2013）also held the view that when the decomposability of a system was low, the feasibility and effect of modularization method could be less desirable[15].

The other method is the organizational search which means to find a systemic design scheme with relative high performance through search processing organization without reducing the complexity. This kind of research provides many organizational patterns. The first organizational pattern emphasizes full authorization and believes that it will improve general performance of the system by delegating decision-making power to designers of subsystems[16-18]. The other organizational pattern emphasizes centralization and believes that hierarchy in an organization is helpful in control and cooperation, and can get the searching result quickly[13, 19-21]. Some scholars also start to the research of search strategies such as adaptive search[22-24]. In this kind of researches, subsystems are usually assumed to be homogeneous, and the relative importance among different subsystems is not be considered. The research of hierarchy only adds a CEO who is responsible for decision-making and some middle managers on subsystems. It does not consider about the changes in search methods under different organizational structures of subsystems. The research of search strategies ignores the organizational structure in different search processes.

General department organizational pattern has been adopted in research and development process of Dongfanghong 1, the first Chinese satellite[4]. After that, Qian Xuesen summarized it to the important parts of metasynthesis which was more systematic[25]. Yu Jingyuan and Zhou Xiaoji (2004), Xue Huifeng and Yangjing (2016) pointed out that general department deigned the system by regarding it as a organic combination of several subsystems, and it is the organizational entity to achieve system integration[5,26]. Some scholars also suggest to apply this organizational pattern into more complex system designs[6, 27]. These researches explain the function of general department from the views of system theory and system engineering and have guiding significance to organizational management practice of mega-project, but they are all qualitative explanations or philosophical treatises and lack of quantam of proof.

This paper will discuss the modeling of subsystems correlation of general department organizational design pattern and control and optimization of design process under the organized search framework of complex system. In addition, the paper will also use analogue simulation which is based on agent method to prove the efficiency of general department organizational design pattern by quantitative analysis.

# 2. Organizational Design Pattern

## 2.1 Decentralized Independent Design Pattern

Assuming a mega-project has N subsystems. Each subsystem has one accountability unit responsible for designing, and the decision made by it is $x_i$ （$i=1,\dots,N$）. In order to take the correlation among subsystem design schemes into account, we consider that this design is made under the condition that subsystem's accountability unit $i$ has known other subsystem designs $\overline{x}_i=\left(x_1,\dots,x_{i-1},x_{i+1},\dots,x_N\right)$, and therefore, the performance of subsystem $i$ can be indicated as $f_i\left(x_i\left|\overline{x}_i\right.\right)$. For the entire mega-project, the general performance of the project can be indicated as the linear function of the performances of all subsystems:

$$F(x_1,\ldots,x_N)=\sum_{i=1}^{N}\alpha_i f_i(x_i|\overline{x}_i) \quad (1)$$

In the formula above, $\alpha_i$ is the weighted value of the performance of subsystem $i$. Different subsystems will have different weighted values. The weighted value represents the performance contribution of the subsystem in the whole project. The higher the weighted value, the more important the subsystem.

In decentralized independent design pattern, it usually contains three steps in decision-making process of scheme design for each subsystem:

Step 1: Before determining the technical scheme for a system, this system will first collect information $\overline{x}_i$ about design decisions of related subsystems as much as possible. In the practice of projects, this information collecting process can be both formal-written technical documents or formal technical meeting of exchange and informal private communication[20].

Step 2: The system makes decision about the design scheme $x_i$ in order to achieve the objective of maximizing its performance after considering about design decisions made by other related subsystems. In the situation without general control, each subsystem will pursue its own performance rather than maximizing the performance of entire project. As a result its decision $x_i$ can be indicated as:

$$x_i=\arg\max\ f_i(x_i|\overline{x}_i) \quad (2)$$

Step 3: All subsystems make decisions of their design schemes following the two steps mentioned above until none of them is willing to change its decision. The decision about the scheme of each subsystem will provide new information for other related systems, so decisions made in step 2 will have continuous changes. Finally, all subsystems will be aware of the decision preferences and decision objectives of others related subsystems, and achieve Nash equilibrium which means no subsystem will benefit from changing its decision. The entire system will evolve to a steady state when information is fully exchanged[28, 29].

## 2.2 General Department Design Pattern

Compared with decentralized independent design pattern, the scheme design process under the general department design pattern has a few differences.

Step 1: General department will first determine the design schemes and start design for those important subsystems. $X^*$ represents the important subsystems among $N$ subsystems (In order to be generalized, we assume the first $n$ subsystems are important). $\bar{X}^*$ represents the rest of subsystems ($N-n$ subsystems are left to be general subsystems). All design decisions of the project are $X = X^* \cup \bar{X}^*$. General department will make overall arrangement in according to information about current industry which it has obtained and future industry strategies. Furthermore, it will also consider about the reaction of other unimportant subsystems to determine design schemes of $n$ important subsystems in $X^*$ to pursue performance maximization of the project as a whole. The decision-making process in this section can be indicated as:

$$X^* = \arg\max F\left(X^* \middle| X\right) \qquad (3)$$

Step 2: The rest of the subsystems make their own design decisions based on the design scheme determined by general department. As the objectives under the decentralized independent design pattern, these subsystems also aim to maximize their own performance, so the decision-making process in this section can be indicated as:

$$x_j = \arg\max f_j\left(x_j \middle| X^*\right) \qquad x_j \in \bar{X}^* \qquad (4)$$

Step 3: The two steps above is developing with the continue disclosure of information until all subsystems know others' preferences and objectives and stop to change their own decisions. Under this organizational design framework, the project system will have a constant iteration between two kinds of decisions which are determined by formula (3) and (4), and achieve Stackelberg-Nash equilibrium eventually[30, 31].

It can be seen clearly that the design processes of these two organizational patterns are different. The differences of these organizational design patterns are summarized in Table 1.

**Table 1.** comparison between decentralized independent design pattern and general department organizational design pattern

| No. | Content | decentralized independent design pattern | general department organizational design pattern |
|---|---|---|---|
| 1 | Attributes of subsystems | Homogeneous subsystems | Heterogeneous subsystems |
| 2 | Decision objectives | All subsystems pursue their own performance maximization | General department: pursues performance maximization of the entire project<br>Secondary subsystems: pursue their own performance maximization |
| 3 | Information collection process | All subsystems obtain information of other subsystems by iteration | General department: collects information of important subsystems for one time and collect information of secondary subsystems by iteration<br>Secondary subsystems: collect information of related subsystems by iteration |
| 4 | Iteration process | Once a subsystem changing its decision, related subsystems will also changing their decision until each subsystem knows the decision preferences and objectives of all related subsystems | General department: makes design decision about primary subsystems relying on the information which has obtained and releases relevant information<br>Secondary subsystems: make their own decisions after obtaining the information about primary subsystems design made by general department until each subsystem knows the decision preferences and objectives of all other secondary subsystems |
| 5 | Equilibrium | Nash equilibrium | Stackelberg-Nash equilibrium |

It is hard to get analytic solution for either Nash equilibrium or Stackelberg-Nash equilibrium when the mega-project has a lot of subsystems, so simulation method is taken in this paper to discuss the effects of project design under these two organizational design patterns.

# 3. Simulation Model

In the two organizational design patterns which have mentioned above, the design decision of each subsystem will influence the design of other subsystems, so this paper adopts $NK$ model which has been put forward by Kauffman（1993,1996）to do the simulation[32,33]. This is an agent-based simulation model. It refers to the dynamic process when searching for the highest adaptability during the biological evolution process, and this method has become important in organizational design research[34]. $N$ in $NK$ represents the number of agents existing in a system (each subsystem can be regarded as an agent), $K$ represents how many agents a agent has to be correlated to it. There is also a parameter $A$ in this model describing the number of conditions that an agent will have. According to these three parameters, several types of relevant conditions of each agent in the system will be generated. If each type is given a random performance value, different conditions of system will consist of a fitness landscape which is comprised by many peaks and valleys. The evolution of the system is the highest adaptability searching by this fitness landscape.

For example, a system is comprised by five agent ($N = 5$), each agent has three agents correlated to it ($K = 3$), and each agent has two conditions including 0 and 1 ($A = 2$). Under this situation, to consider about the possible conditions of three correlated agents, the number of possible performance contribution value of each agent is $2^{3+1}$ ($A^{k+1}$). Each performance contribution value is generally selected from (0,1) uniform distribution. As a result, the entire system will have $5 \times 2^{3+1}$ performance contribution values ($N \times A^{k+1}$) which consists of the fitness landscape of this system.

## 3.1 Simulation of Decentralized Independent Design

Different decision-making pattern will has different components and search strategies for fitness landscape. For decentralized independent organizational design pattern, because of the homogeneous subsystems assumption, the fitness landscape is integrated. As a result, the parameter combination $N$, $K$, and $A$ can be indicated as $N \times A^{k+1}$. Its search strategies include sequential optimization and parallel optimization.

In sequential optimization, each agent searches for performance contribution value in sequence. First, the first agent search for the random performance contribution value of a correlated agent when its condition is changing according to the close order. When it finds any performance contribution value is better than the original one, it will changing the original performance contribution value and relevant agent condition. Then, under the new agent composite condition, the second agent start to search according to the close order and determine whether its condition should be renewed. After that, all agents do the search according to the process mentioned above. The search will stop when all agents cannot find a better performance contribution value, and the final condition of all agents at this time is the design decisions of each subsystem.

In parallel optimization, all agents search for the performance contribution values at the same time. Each agent searches in the set of its possible performance contribution values at the same time, and changes the original performance contribution value and relevant agent condition when it finds any performance contribution value under a composite condition is better than the original one. When different agents have different requirements to the same correlated agent, the condition of correlated agent will be determined by agents' weighted values. The process will continue until all agents do not change their conditions.

## 3.2 Simulation of General Department Organizational Design

Under the general department organizational design patter, because of the heterogeneous subsystems assumption, the fitness landscape can be divided into two parts. One is the fitness landscape for important agents focused by general department, and its parameter combination will be $n_1$, $K_1$, and $A$. The other is the fitness landscape for general agents, and its parameter combination will be $n_2$, $K_2$, and $A$. Because there are two parts, a new parameter $C$ will be used to represent the correlation between these two parts. At this time, the $NK$ model will change into $NKC$ model to describe the evolutionary adaptation process of two parts[33]. In addition, because the two parts of agents have different number of agents and correlations, the parameter $C$ will be divided into $C_1$ and $C_2$. The former one represents the correlation between agents in $n_1$ and agents in $n_2$, and the latter one represents the correlation between agents in $n_2$ and agents in $n_1$.

These two parts of agents will adopt different search strategies: the general department will adopt entire optimization strategy, while general subsystems will adopt local optimization strategy.

Under the entire optimization strategy adopted by general department, general department will inspect all searching spaces of each important agent to find out the optimal value. Each important agent who is controlled by general department will find all performance contribution values of correlated agents in $n_1$ when their condition is changing, and calculate the entire project performance under this contribution value. If this value is greater than the original one, then the original value will be changed, and the conditions of correlated agents will change as well. All agents will do the search according to this strategy, and the search will stop when the performance contribution value of the entire project does not change. At this time, the condition in $n_1$ is the condition value of important agents. It can be seen that the criterion of this search process is the performance of the project as a whole rather than the performance contribution values of agents.

Under the local optimization strategy adopted by general subsystems, the agents will do the search in part space to pursue their own performance maximization under the condition that the conditions of important agents have already been determined. At this time, the search strategy of agents is similar to the strategy under decentralized independent decision-making pattern which uses the performance contribution values of agents as the criterion. However, the difference is that the searching part is limited at this time which is in $n_2$ only, and only change the conditions of correlated agents who belong to $n_2$.

These two optimization strategies can also adopt sequential method and parallel method. In parallel search, the entire optimization of general department and partial optimization of general subsystems will be proceeded at the same time while in sequential search, the partial search of general subsystems will be taken after the entire optimization of general department has finished one-iteration. After that, the relevant information will be returned to do the entire optimization for second time, and this process will continue until the system achieves a stable condition.

The search process of two organizational design pattern is described in Table 2.

**Table 2.** comparison between the search processes of decentralized independent organizational design pattern and general department organizational design pattern

| **No.** | **Content** | **decentralized independent design pattern** | **general department organizational design pattern** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1 | Searching space | $N \times A^{k+1}$ | General department space: $n_1 \times A^{k_1+1}$<br>General subsystems space: $n_2 \times A^{k_2+1}$ |
| 2 | Search strategies | sequential optimization or parallel optimization | General department: entire optimization<br>General subsystems: local optimization<br>sequential optimization or parallel optimization |
| 3 | Search objectives | maximize the performance contribution values of each subsystem | General department: maximize the performance of the project as a whole<br>General subsystems: maximize the performance contribution values of each subsystem |

# 4. Results and Analysis of Simulation

In this paper, the simulation has been done using the software called Netlogo5.3.1, and the environment of simulation is a computer with Intel i5 processor with 2.2GHz CPU.

We have completed the simulations for eight systemic scheme designs. The system compositions and parameter structures of these eight designs are described in Diagram 1. All systems are comprised by two parts. The parts on the left side are the important subsystems and the general subsystems are on the right side. The correlations within each part are shown by pink lines, and the correlations between different parts are shown by blue lines.

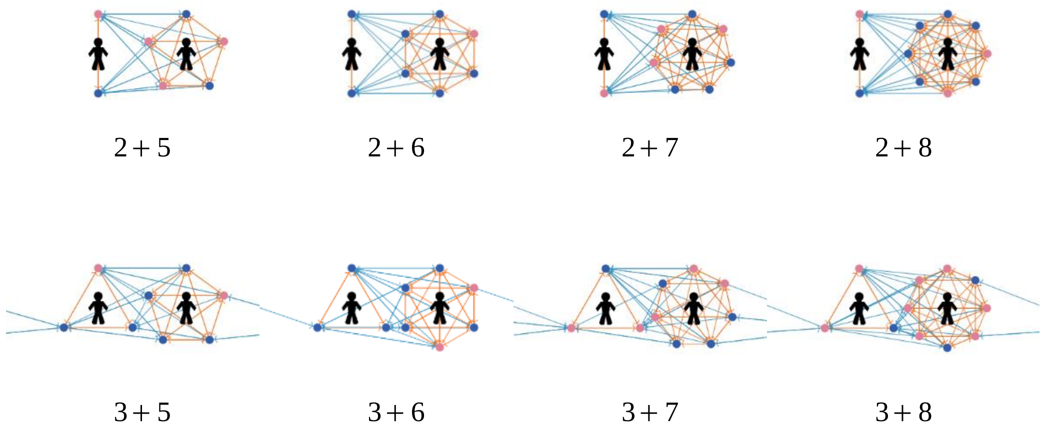



**Diagram 1.** systemic scheme design structure of simulation

## 4.1 Systemic Equilibrium

Table 3 describes the parameters and the number of systemic stable points of the two organizational design patterns and different search strategies, which are based on these eight systemic scheme design structures. Among them, same system compositions and parameter structures have the same searching spaces. In each searching space, each search strategy has done the search with $3\times10^5$ steps. In order to show different importance of the subsystems in these two parts, the performance contribution values of agents in $n_1$ will select averaged randoms between (0,1.2), and for agents in $n_2$, they will select averaged randoms between (0,1).

**Table 3.** equilibrium points under different organizational design patterns

| No. | Number of Agents | | Parameters | | | | Decentralized independent design pattern | | General department organizational design pattern | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $n_1$ | $n_2$ | $K_1$ | $K_2$ | $C_1$ | $C_2$ | **Parallel** | **Sequential** | **Parallel** | **Sequential** |
| 1 | 2 | 5 | 1 | 4 | 4 | 1 | 10 | 10 | 4 | 2 |
| 2 | 2 | 6 | 1 | 5 | 5 | 1 | 12 | 12 | 4 | 2 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 2 | 7 | 1 | 6 | 6 | 1 | 22 | 22 | 4 | 2 |
| 4 | 2 | 8 | 1 | 7 | 7 | 1 | 34 | 34 | 1 | 1 |
| 5 | 3 | 5 | 2 | 4 | 4 | 2 | 11 | 11 | 1 | 1 |
| 6 | 3 | 6 | 2 | 4 | 4 | 2 | 11 | 11 | 3 | 2 |
| 7 | 3 | 7 | 2 | 4 | 4 | 2 | 18 | 18 | 4 | 2 |
| 8 | 3 | 8 | 2 | 4 | 4 | 2 | 24 | 24 | 14 | 5 |

From the table above, we can conclude that:

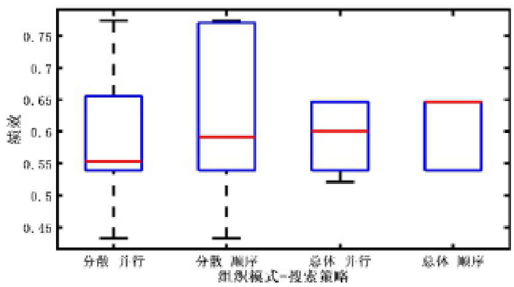
First, the equilibrium points of systemic design will be influenced by systemic complexity, and there is a nonlinear positive correlation between the equilibrium points of systemic design and system size and system correlation. From the first group to the fourth group in the simulation, we compared the equilibrium points of different organizational design patterns and search strategies under the condition that both organizational size (the number of agents) and organizational relation (correlation parameters) are changing at the same time. From the fifth group to the eighth group in the simulation, we compared the equilibrium points of different organizational design patterns and search strategies under the condition with different organizational sizes and same organizational relation. It can be found that the more complex of the system (greater organizational size and higher organizational relation), the more equilibrium points existing in the system, and the growth of them are nonlinear.

Second, systemic stable point of decentralized independent organizational design pattern is much greater than it of general department organizational design pattern. The systemic equilibrium is easy to run into a locally optimal solution. From the first group to the eighth group, the systemic stable points of general department organizational design pattern are always fewer than the number under decentralized independent organizational design pattern. Especially from the third group to the seventh group, the systemic stable points of general department organizational design pattern are much fewer than the number under decentralized independent organizational design pattern. The reason is that all agents under the decentralized independent organizational design pattern consider about pursuing their own benefits maximization, the system will stop to change its condition and achieve a local stabilization when it has searched any local optimal solutions of the fitness landscape. However, in general department organizational design pattern, the objective of general department is to achieve performance maximization of the system as a whole, so it will search for higher adaptive points on winding fitness landscape. As a result, the equilibrium points will be fewer.

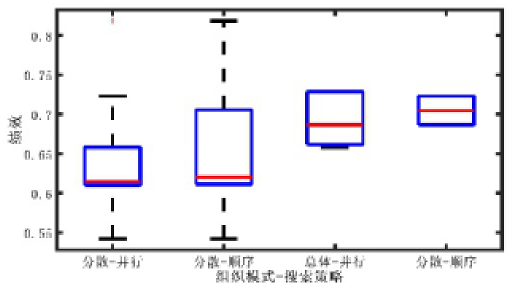
Third, under general department organizational design pattern, the number of stable points using sequential search strategy cannot be greater than it using parallel search strategy, and it is good for the stability of the search if the general department, in the first place, makes the design decision of important subsystems. From the first group to the eighth group, we can see that under the decentralized independent organizational design pattern, both parallel search strategy and sequential search strategy have the same amount of stable points. It can illustrate that if each subsystem only takes its own benefit maximization into account, the stable points of systemic search will be the same, which means either the important subsystems make decisions before others or all subsystems make decisions at the same time, it will finally achieve a systemic local stabilization on the locally optimal solutions. However, under general department organizational design patter, the number of stable points is different between two search strategies. The number of stable points using sequential search strategy will not be greater than it using parallel search strategy (in group 1, 2, 3, 6, 7, and 8, the numbers of stable points using sequential search strategy are fewer than it using parallel search strategy, and in group 4 and 5, the numbers are the same under both strategies). This can illustrate that under the general department organizational design patter, it is helpful to achieve systemic stabilization if the general department makes design decisions of important subsystems at first.

## 4.2 System Performance

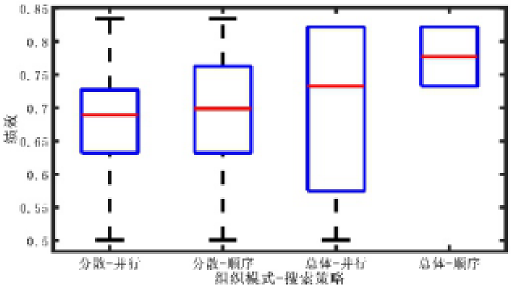
According to the data of simulation above, we use Box-plot to show system performances of two organizational design patterns and two search strategies in Diagram 2. The average of performance contribution values of all agents is adopted to represent the system performance.



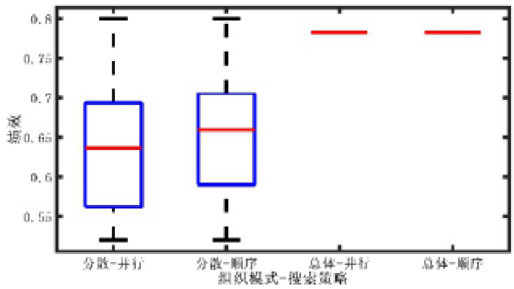

2+5 performance of systemic structure



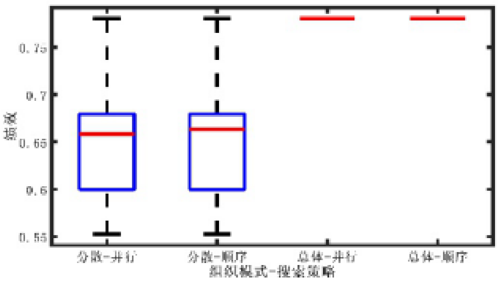

2+6 performance of systemic structure



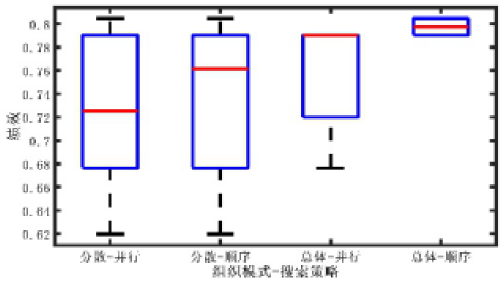

2+7 performance of systemic structure



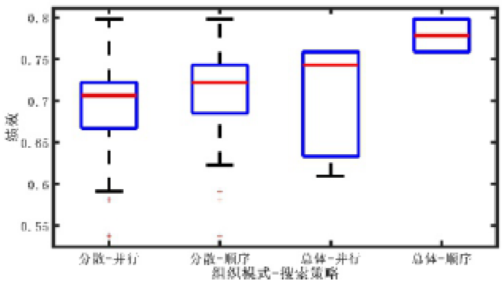

2+8 performance of systemic structure



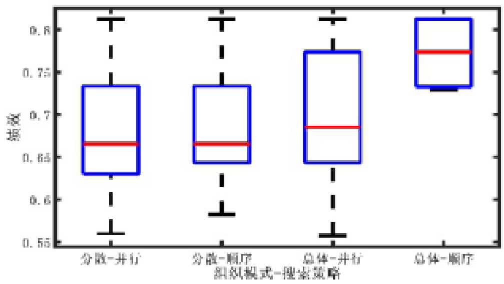

3+5 performance of systemic structure




3+6 performance of systemic structure




3+7 performance of systemic structure




3+8 performance of systemic structure

**Diagram 2.** performance of different systemic structures

According to the diagrams above, it can be concluded that:

First, to compare with decentralized independent organizational design pattern, the general department organizational design pattern can improve the system performance. In the eight groups of simulation, no matter which search strategy is chosen, the medians of system performance under the general organizational design pattern are always greater than those under the decentralized independent organizational design pattern. That illustrates that the former one has higher possibility to find a better stable point on winding fitness landscape which also means that the general department organizational design pattern is better than decentralized independent organizational design pattern at the aspect of performance design.

Second, the system performance of sequential search strategy is no worse than it of parallel search strategy no matter under which organizational design pattern. In the eight groups of simulation, the medians of system performance using sequential search strategy are always greater or equal to those using parallel search strategy under the same organizational design pattern (in group 3 and 4, there is only one equal stable point for both search strategies under the general department organizational design pattern). That means whether the entire optimization of general department exists, the sequential search strategy has higher possibility to search for a better stable point.

According to the stable equilibrium points and the results of the performance in simulation, we can get the comparison between organizational design patterns in Table 4.

**Table 4.** comparison between organizational design patterns

| | | **Organizational design patterns** | |
|---|---|---|---|
| | | **Decentralized independent organizational design pattern** | **General department organizational design pattern** |
| Search strategy | Parallel search | Stable points: greater<br>System performance: low | Stable points: fewer<br>System performance: high |
| | Sequential search | Stable points: greater<br>System performance: higher | Stable points: few<br>System performance: highest |

Therefore, for complex system with high correlation between subsystems, it is efficient to adopt general department organizational design pattern which not only can avoid the entire system to run into many locally optimal solutions, but also improve the performance of the system as a whole. In addition, under the general department organizational design pattern, it is a good design pattern to carry out systemic design work sequentially which means to determine the system schemes of important subsystems on the basis of obtaining the possible selected schemes of subsystems at first, and then, design other subsystems based on design schemes of important subsystems. This strategy can improve the stabilization of systemic design and system performance.

## 5. Conclusion

To sum up, scheme design of mega-project is a complex process in which any changes in design of a subsystem will case the changes of other correlated subsystems even the entire design scheme, which brings big challenge for organization management. An innovative organizational design pattern, general department, has been summarized from mega-project practices in China, and this pattern has achieved good outcomes in the practices of scheme design. There are three contributions of the research in this paper: first, this paper has constructed the decision-making model for general department organizational design of mega-project, and pointed out that the equilibrium solution for this model is Stackelberg-Nash equilibrium. Second, this paper has proved the efficiency of general department organizational design pattern in two aspects including the stabilization of equilibrium and system performance, and pointed out that this organizational design pattern is helpful for the systemic design scheme to avoid to run into locally optimal solutions of some subsystems, and also helpful to improve the performance of system as a whole. Third, this paper has proved that, under the general department organizational design pattern, the stabilization and performance of system scheme will be better if the general department makes decisions about important subsystem deigns at first. The research in this paper is helpful for the promotion and application of this organizational design pattern in mega-project. However, the limitation of this research is that in the practice of project, general department organizational design pattern contains many types of systems which are more complex than the organizational search process in this paper. In the future, we will conduct deeper research for this organizational pattern under the diversified hybrid system framework.

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