



## Using Analytic Network Process to Analyze Influencing Factors of Project Complexity

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**Abstracts:** The management of project complexity has become an important part in the project management, being critical to the success of the large complex project. According to literature review and questionnaire survey, the Analytical Network Process (ANP) method is used to measure the influencing factors of project complexity and Super Decisions (SD) software is used to calculate weights of influencing factors, so as to identify the key influencing factors to manage projects better. Results found that cross-organizational interdependence, multiple stakeholders, number of organizational structure hierarchy, project team's trust and diversity of technology are the five key factors which have the biggest influence on the project complexity. This research provides the scientific support for the practice of project management, which has theory direction significance for mega and complex project management.

**Keywords:** ANP, influencing factors, project complexity, super decisions

### 1 Introduction

In recent years, mega projects are gradually increasing in number and expanding in scale, and the complexity is more and more obvious<sup>[1-2]</sup>. However, compared to small-scale projects, large and complex projects are difficult to predict the results, and the expected value is changed in a large range, while the project manager is obviously incapable of successfully managing the entire project implementation process, all of which result in the phenomenon of investment cost overruns and schedule delays<sup>[3-4]</sup>. Therefore, complexity management of the project has become an important part in the project management, being critical to the success of the large complex project<sup>[5]</sup>.

There have been some researches on the project complexity, which combine the complexity theory and project management<sup>[6]</sup>. A large number of studies have shown that the project complexity is the most important part of the existing project management<sup>[7]</sup>. Even in the 20<sup>th</sup> century, the project complexity had been studied as a

factor in the classification of the construction projects (Shenhar, 1998; Shenhar and Dvir, 1996). But those classification methods still treated the project complexity as a black box. As to the factors affecting the project complexity, further studies are needed. Therefore, combining with the literature review and a questionnaire survey, this paper adopts the Analytic Network Process (ANP) to quantitatively measure the project complexity, in order to identify the key factors affecting the project complexity to manage the project better. The study provides scientific support for the project management practices and is of great theoretical significance on the management of the large and complex project.

### 2 Literature review

#### 2.1 Former research works on project complexity factors

Project complexity is an attribute of the project, resulting from the interaction of a number of different parts<sup>[8-9]</sup>. Traditional research method is usually through the analysis influencing factors of project complexity to identify the root of project complexity, and then achieve the effective control of the whole project through managing these factors. So how to identify the key factors of project complexity and its influencing has become an important direction.

In the past, some scholars had an exploration to the project complexity factors. Based on definition of complexity, Baccarini (1996) summarized the project complexity consisted of organizational complexity and technological complexity<sup>[8]</sup>. Williams (2002) thought that structural complexity and uncertainty are the factors of project complexity<sup>[10]</sup>. Maylor (2003) classifies the project complexity into three categories: organizational complexity (including the number of members, departments, organizations, regions, nations, languages, time zones, etc., level of the organization, and power structure), resources complexity (project scale and size of the budget) and technological complexity (technology, innovation system, uncertainty of the process or demand)<sup>[11]</sup>. And Remington and Pollack's (2007) divided the influencing factors of project complexity into the following four dimensions: experiences and ability of organization members to cope with various types of

Supported by the National Natural Science Foundation of China(70972071,71002019,70902045) and the Humanities and Social Science Found of Ministry of Education(09YJAZH067)

project complexity, project organization structure and its exchange and coordination with other key participants, project culture, and project business process<sup>[12]</sup>. Girmscheid and Brockman (2008) divided the influencing factors of the project complexity into five categories: task complexity, social complexity, cultural complexity, operative complexity and cognitive complexity<sup>[13]</sup>. Ludovic Vidal and Franck Marle (2008) classified the elements of the project complexity into four categories: project scale, differences between the project constituents, interdependence of the project constitutes as well as the interaction between the project and the external environment<sup>[14]</sup>. Harvey Maylor (2008) through investigation found that managerial complexity contained mission, organization, delivery, stakeholder and team<sup>[15]</sup>. Qi Er-shi (2008) classified the complexity of the large-scale project to time complexity and space complexity<sup>[16]</sup>. Li Hui, et al. (2009) thought the elements of the project complexity could be classified into six aspects, i.e., technical complexity, organizational complexity, content complexity, informational complexity, goal complexity and environmental complexity<sup>[17]</sup>. And Marian Bosch-Rekveltda (2010) through literature and empirical methods, summed up 50 influencing factors of project complexity and divided the project complexity into technological complexity (goals, scope, tasks, experience, and risk), organizational complexity (size, resources, project team, trust, and risk) and environmental complexity (stakeholders, location, market conditions and risk)<sup>[7]</sup>. And Bo Xia, Albert P.C. Chan (2012) used Delphi questionnaire survey to identify six key measures of project complexity<sup>[18]</sup>.

## 2.2 Limits of existing measures

From the above studies about the influencing factors of the project complexity, every study has its special angle to analyze the project complexity. Though they have different focuses, they have reached the agreement on items like the technological complexity, organizational complexity, and environmental complexity and so on. In the measure method study on project complexity, although there is a lot of useful exploration based on science system, but the above research still exists the following limitations besides some gained achievements: There is a certain limitation in analyzing influencing factors of project complexity because most of the scholars carry on the research from their engaged fields; Most research on influential factors emphasize the qualitative analysis, and few research adopts quantitative analysis; And existed measures fail to consider the interaction between the various elements, making it difficult to really and effectively reflect the project complexity.

As the combination of the qualitative and quantitative decision-making tool, the ANP combines the subjective initiative and the scientific method to find out the key factors of project complexity, according to measure results, which is beneficial to understand project complexity more clearly, and avoid subjective optional

and blindness in project management. Therefore, in order to overcome the limitations of the existing project factors affecting the measurement methods complexity, this paper adopts the Analytic Network Process to measure the key influence factors of project complexity. This research provides the scientific support for the practice of project management, which has theory direction significance for mega and complex project management.

## 3 Building up influencing factors system of project complexity

From the above literature review of project complexity, each research analyzed the influencing factors of project complexity standing on the different views. And project complexity is the attribute of the project, an interaction result of the different part. Because of the complexity of the whole project system affected and decided by various complexity elements, it's difficult to manage complexity effectively through individual factors identification, management and control isolated for a variety of elements of the system complexity<sup>[19]</sup>.

Using the method of literature review, the paper identified the influencing factors of project complexity and added up the number, studied the influencing factors, and screened the key factors through the expert interview, and then built six first-class indexes including technical complexity, organizational complexity, goal complexity, environmental complexity and cultural complexity, informational complexity and 28 secondary indexes.

### (1) Technological Complexity

The technological complexity includes many properties, such as building type, design and overlapping of the construction, and project dependence of the operation. The technology is unknown and untested, because uncertainty of the results of the many interdependent designs leads to the increase of the complexity.

### (2) Organizational Complexity

The organization is the carrier of project management. Organizational complexity is the most central part of the project complexity, including the organization members, organizational structure and project team, etc. Elements such as members' experience, number of levels and functions of the structure will increase the complexity.

### (3) Goal Complexity

All projects have many goals, for which they must keep a balance, which leads to the increase in the project complexity. In addition, other elements have to be taken into consideration, such as the project tasks, resources and other factors, such as goals, resources, tasks and methods.

### (4) Environmental Complexity

Environmental complexity includes complexity of the natural environment, market economic environment, policy and regulatory environment, etc. In addition, it is necessary to consider the complexity of all stakeholders

within the project, mainly referring to the number and diversity of stakeholders, because their interest and needs are affected by the environment.

#### (5) Cultural Complexity

Culture is considered to be the soft aspect of thinking, including the national culture, industry culture and organizational culture. Complex projects related to multinational participation, which has different cultures and different perspectives. Therefore cultural diversity has led to project complexity.

#### (6) Informational complexity

Information is from multiple stakeholders, and the entire management process, involving a variety of complex contractual relationships. The degree of information dependency and correlation gradually increase between the different parties involved, different processes and flows, leading to increasing complexity of information. The influencing factors of the informational complexity include information system, degree of obtaining information, level of processing and transmission of information, etc. The influencing factors of project complexity are shown in Tab.1.

## 4 Using ANP to analyze project complexity

### 4.1 ANP structure model of project complexity index system

The Analytic Network Process is proposed by Professor T. L. Saaty at the University of Pittsburgh in 1996, is a decision-making method applicable to the

independent feedback system and can solve existing dependence and internal feedback of complex system<sup>[20]</sup>. Based on the Analytic Hierarchy Process (AHP), the ANP method considered feedback and dependence between levels and internal elements, further research on super matrix and ultimate matrix of feedback system and rank weighting. Expands on AHP, ANP allows several indexes coexist which are difficult to quantify, and takes into account feedback, so it can describes the relationship between things in the real world more accurately. Therefore, ANP is more close to reality than AHP to reflect and describe decision-making problems.

The ANP structure consists of two parts: the control layer, including problems target and decision-making rule; and the network layer, which interior is the network structure where the elements interact with each other. The ANP structure model of project complexity index system is shown in Fig.1.

### 4.2 Calculation based on SD

According to the principle of ANP, relationship between the indexes was analyzed combined with Expert Decision to determine its internal dependence and feedback, and determined the relative importance between two indexes to build the ANP judgment matrix, and then the super matrix and the ultimate super matrix were calculated, got weights of the indexes.

During the solving process of ANP, computation is large and complex, so the Super Decisions software was brought in, ANP structure model of project complexity is

**Tab.1 Influencing factors system of project complexity**

The first-class index	The second-class index
Technological complexity(T)	Diversity of technology in project (T1)
	Dependence of technological processes (T2)
	Interaction between the technology system and external environment (T3)
	Risk of highly difficult technology (T4)
Organizational complexity(O)	Number of organizational structure hierarchy (O1)
	Number of the formal organizational units and functional departments (O2)
	Experience and social background of organization member (O3)
	Cross-organizational interdependence (O4)
Goal Complexity(G)	Uncertainty of goals (G1)
	Uncertainty of the project management methods and tools (G2)
	Available ability of resources and skills (G3)
	Diversity of tasks (G4)
Environmental complexity(E)	Dependence of relationship among tasks (G5)
	Dynamics of the task activities (G6)
	Multiple stakeholders (E1)
	Environment of policy and regulation (E2)
Cultural complexity(C)	Environment of changing technology (E3)
	Environment of changing economy (E4)
	Environment of changing nature (E5)
	Multiple participating countries (C1)
Informational complexity(I)	Project team's trust (C2)
	Sense of cooperation (C3)
	Cultural differences (C4)
	Information uncertainty (I1)
	Degree of obtaining information (I2)
	Level of processing information (I3)
	Capacity of transferring information (I4)
	Integration of more than one system or platform (I5)

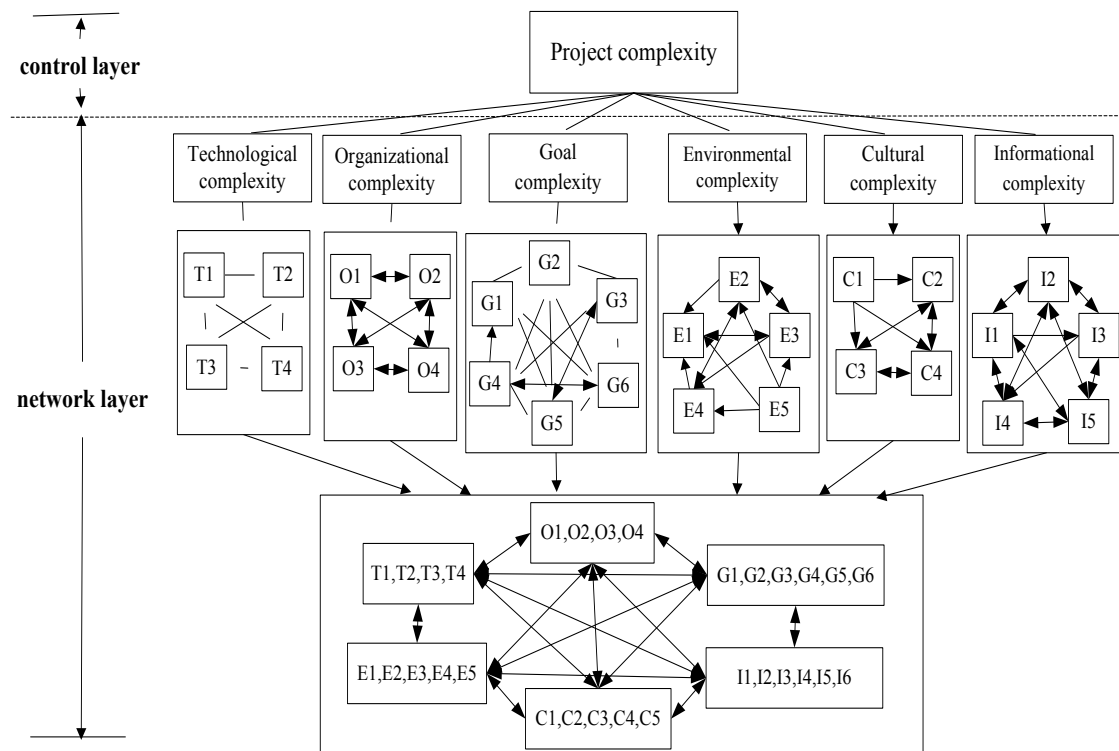


Fig.1 ANP structure model of project complexity index system

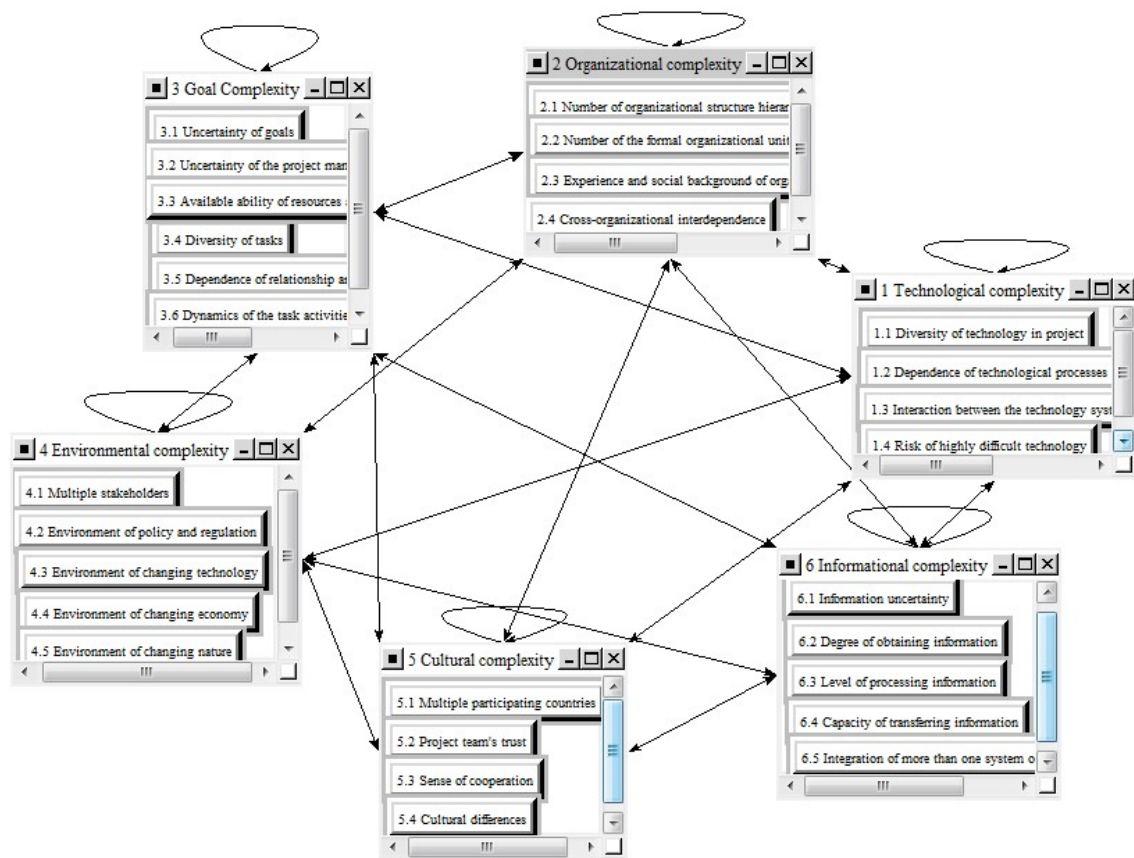
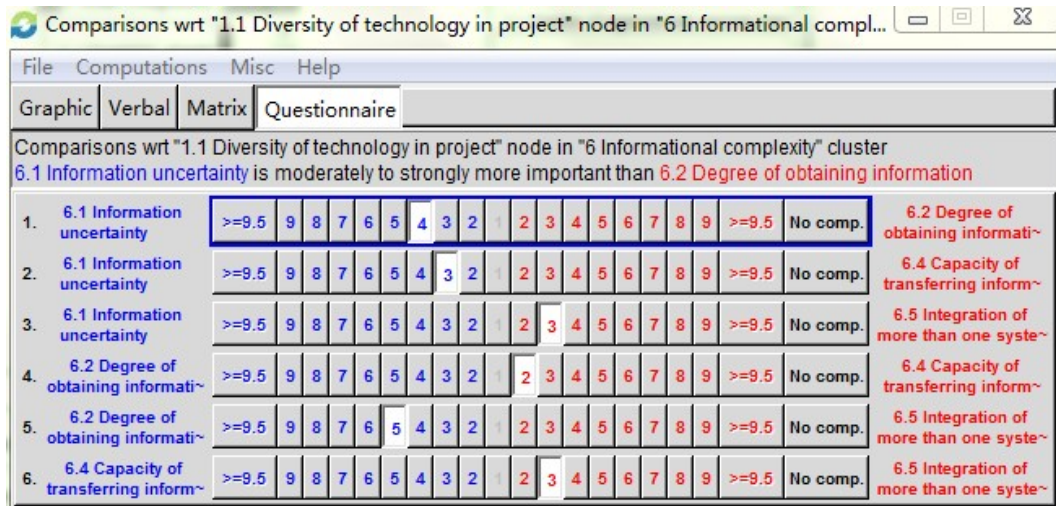


Fig.2 ANP structure model of project complexity



**Fig.3 An example of the evaluation indices judgment matrix interface in Super Decision software**

**Tab.2 Weights of evaluation indices**

Criteria	Criteria weights	Sub-criteria	Sub-criteria weights	Total weights
Technological complexity(T)	0.15846	Diversity of technology in project (T1)	0.34691	0.05497
		Dependence of technological processes (T2)	0.24563	0.03892
		Interaction between the technology system and external environment (T3)	0.19941	0.03160
		Risk of highly difficult technology (T4)	0.20805	0.03297
Organizational complexity(O)	0.24119	Number of organizational structure hierarchy (O1)	0.27870	0.06722
		Number of the formal organizational units and functional departments (O2)	0.14541	0.03507
		Experience and social background of organization member (O3)	0.22584	0.05447
		Cross-organizational interdependence (O4)	0.35005	0.08443
Goal Complexity(G)	0.12084	Uncertainty of goals (G1)	0.23453	0.02834
		Uncertainty of the project management methods and tools (G2)	0.15958	0.01929
		Available ability of resources and skills (G3)	0.12920	0.01561
		Diversity of tasks (G4)	0.15335	0.01853
Environmental complexity(E)	0.13123	Dependence of relationship among tasks (G5)	0.17414	0.02104
		Dynamics of the task activities (G6)	0.14920	0.01803
		Multiple stakeholders (E1)	0.53838	0.07066
		Environment of policy and regulation (E2)	0.07499	0.00984
Cultural complexity(C)	0.15355	Environment of changing technology (E3)	0.22444	0.02945
		Environment of changing economy (E4)	0.08850	0.01161
		Environment of changing nature (E5)	0.07369	0.00967
		Multiple participating countries (C1)	0.21699	0.03332
Informational complexity(I)	0.19470	Project team's trust (C2)	0.39274	0.06030
		Sense of cooperation (C3)	0.25973	0.03988
		Cultural differences (C4)	0.13055	0.02005
		Information uncertainty (I1)	0.26900	0.05237
		Degree of obtaining information (I2)	0.15054	0.02931
		Level of processing information (I3)	0.15848	0.03086
		Capacity of transferring information (I4)	0.20893	0.04068
		Integration of more than one system or platform (I5)	0.21304	0.04148

shown in Fig.2, and the interface of the evaluation indices judgment matrix interface in Super Decision software is shown in Fig.3.

#### 4.3 Results analysis

With the Super Decisions software, the weights of the first-class and the second-class indexes were calculated, and the calculation result is shown in Tab.2.

According to criteria weights, the first-class of influencing factors of project complexity, the relative importance sequence is: Organizational complexity > Informational complexity > Technological complexity > Cultural complexity > Environmental complexity > Goal Complexity. Therefore, the complexity management of the organization, information and technology should be

especially strengthened in the process of project complexity management.

Thereinto, cross-organizational interdependence has the largest weight among the factors of organization complexity; information uncertainty has the largest weight among the factors of informational complexity; diversity of technology in project has larger weight than others among the factors of technological complexity.

According to total weights, the five key factors which have the biggest influence on the project complexity are cross-organizational interdependence, multiple stakeholders, number of organizational structure hierarchy, project team's trust and diversity of technology. Therefore, the five key factors must be intensively investigated and analyzed in order to reduce project risk, so as to formulate corresponding prevention and countermeasures.

## 5 Conclusions

The paper measured the key factors of the project complexity after adopting the Analytical Network Process incorporates both qualitative and quantitative approaches and Super Decisions software, through the literature review and investigation.

The study shows that, organizational complexity, informational complexity and technical complexity are the core parts of the project complexity, and the five key factors which have the biggest influence on the project complexity are cross-organizational interdependence, multiple stakeholders, number of organizational structure hierarchy, project team's trust and diversity of technology. Therefore, during the process of project complexity management, the complexity management of organization, information and technology should be focused. The study provides reference for the project manager to avoid the randomness and blindness, and better manage complex project.

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