Developing the theoretical model of technology innovation collaboration for megaprojects from the perspective of value co-creation

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Abstract

Megaproject is an important platform for technological innovation and value creation. However, the efficiency and effectiveness of collaborative innovation in such projects are disappointing. One of the main reasons is the neglect of the value motivations behind the innovators involved. Therefore, coordinating the value motivations of various innovators to enhance the efficiency and effectiveness of technological innovation collaboration in megaprojects becomes a significant issue. Therefore, this study from the perspective of value co-creation and using grounded theory methodology, develops a three-dimensional theoretical model (encompassing lifecycle, innovators, and collaborative innovation dimensions) for collaborative technological innovation in megaprojects. This model preliminarily reveals the process of collaborative innovation among various innovators throughout the entire lifecycle. It could enhance the mutually beneficial relationships among innovators in the context of megaprojects, and further achieve value co-creation.

Keywords: Megaproject management, Innovation collaboration, Value creation, Theoretical model, Project success

1.INTRODUCTION

Mega-projects typically cover a broad range of areas, such as transportation infrastructure, energy facilities, environmental projects, and high-tech research facilities. Different from general-scale engineering projects, megaprojects are distinguished by their large scale, technical complexity, long duration, and diverse participating entities, leading to multiple uncertainties (Flyvbjerg, 2014). These factors pose significant risks and challenges to technological innovation within megaprojects, and the conventional models of technological innovation are often inadequate for meeting the needs of such projects. Thus, collaborative technological innovation is particularly necessary for these projects to manage various interests and risks through active cooperation, thereby achieving efficient progress and sustainable development.

However, according to the research of Flyvbjerg et al. (2014), large projects often face budget overruns and time delays, which directly affect the efficiency of collaborative innovation. In addition, Xie et al. (2010) analyze the organizational barriers to technological innovation in large-scale projects, and point out that the shortcomings of project managers in technological innovation and the irrationality of the pricing mechanism of innovation results are the main obstacles. These research results show that the current results of collaborative innovation in large-scale projects are not ideal, and further research is needed to solve these problems. Therefore, this paper develop a three-dimensional theoretical model for collaborative technological innovation in megaprojects from the perspective of value co-creation, utilizing grounded theory. The rest of the paper is organized as follows. The second section reviews the literature on the definition, complexity, and collaborative technological innovation of megaprojects. The third section primarily employs grounded theory methodology to code the value motivations of innovators. The fourth section presents the theoretical framework for collaborative technological innovation in megaprojects. The final section concludes with the main findings and limitations of the study.

2.LITERATURE REVIEW ON COLLABORATIVE TECHNOLOGICAL INNOVATION IN MEGAPROJECTS

2.1. Technological Innovation in megaprojects

The earliest studies on technological innovation are rooted in the multi-level economic cycle theories based on "technological innovation" by Schumpeter (Tan, 1988). However, the significant differences between megaprojects and general engineering projects have made technological innovation more challenging (Brockmann, 2016). For example, Xie et al. (2010) have conducted an in-depth analysis of the technological innovation process in megaprojects, identifying the insufficient managerial capabilities of project owners in technology innovation and the irrational pricing mechanisms of innovation outcomes as the primary barriers. Compared to technological innovations in general engineering projects, Wang (2011) highlights the unique characteristics of megaprojects, including their process complexity, systemic innovation, organizational collaboration, and time constraints. Zeng et al. (2019) basing on the innovation ecosystem theory, confirmed the phenomenon of innovation silos in megaprojects.

2.2. Collaborative Innovation in megaprojects

Initially, the concept of collaborative innovation is applied to enterprise research. Swink (2006) has studied the factors influencing collaborative innovation and identified technology, talent, capital, institutions, organizations, information, and knowledge as critical resources in the technological innovation process of major construction projects. With the increasing challenges of innovation in megaprojects, many scholars have begun focusing on collaborative innovation issues in major engineering projects. For instance, Worsnop et al. (2016) point out that innovation in megaprojects should be collaboratively coordinated to avoid organizational conflicts within the project and synchronize individual innovation activities to enhance innovation efficiency. Researchers have summarized and reviewed the literature on domestic and international industry-academia-research collaborative innovation models, hoping to promote the development of such cooperation models (Yu, 2019). Xue et al. (2018) from a social network perspective, analyze the collaborative relationships between major project innovators as well as the impact of these relationships on the innovation performance of megaprojects. Fan et al. (2020) analyze the impact of intra-regional collaborative innovation on regional innovation efficiency by using the Spatial Durbin model. As an example, Zhuang (2021) designs a regional collaborative innovation evaluation model based on the triple helix theory to investigate the regional differences and dynamic evolution of collaborative innovation.

However, current research on technological innovation collaboration is still lacking in the area of megaprojects. Thus, this paper constructs a three-dimensional theoretical model of collaborative technology innovation in megaprojects, which includes three dimensions: project life cycle, innovation subject and collaborative innovation. These three dimensions are intertwined and constitute a comprehensive framework. It aims to focus on the hidden value motivations behind innovation stakeholders and try to address the poor situation of collaborative innovation in megaprojects.

3.RESEARCH METHOD

The Hong Kong-Zhuhai-Macao Bridge, a typical mega infrastructure project worldwide, is selected as the case study to collect data in this study. Besides, the grounded theory method is employed to analyze the data in order to construct a theoretical model for collaborative technological innovation in megaprojects. This method emphasizes "rooting" in rich empirical data through systematic coding, comparison, categorization, and correlation, allowing theories to naturally emerge from empirical materials (Glaser, 1967). What's more, grounded theory allows researchers to follow the data trail, continuously adjusting, correcting, or even overturning original theoretical assumptions to ensure that the generated theory closely aligns with actual situations (Chen, 2015). Specifically, to avoid the biases and fragmentation of data collected from a single source, this paper gathers data from multiple sources to increase coverage. In order to ensure the comprehensiveness and fairness of the data collection process, this study consults a total of 16 academic papers, 6 government reports and supplementary materials from the official website of the Hong Kong-Zhuhai-Macao Bridge, and uses the search engine (such as Baidu) to find 45 related reports, and one government white paper.

Firstly, all collected data undergo manual open coding to tag information related to collaborative technological innovation. Subsequently, these tagged data are logically linked to distill conceptualized codes, forming primary concepts. Then, by examining the logical relationships between these concepts, primary concepts are subjected to axial coding, and iteratively refined into secondary concepts. For example, the primary concepts of "reduced risk of unexpected shutdowns," "legal risk avoidance," and "risk diversification" are distilled into the secondary concept of "risk control." Finally, selective coding is performed on the relatively scattered axial codes. Based on these axial codes, core concepts are refined to identify and construct the theoretical model for collaborative technological innovation in megaprojects.

4.RESEARCH RESULTS AND DISCUSSIONS

4.1. Three-Dimensional Theoretical Model Framework for Collaborative Technological Innovation

Megaproject is a complex giant system, covering complex conflicts and problems. Its technological innovation often involves the collaborative behavior of multiple subjects. However, the project subjects in each stage will change dynamically with the passage of time. Therefore, which subjects should carry out technological innovation? How should the interest motivation of each subject be coordinated, and how should the degree of collaborative innovation be determined? How should collaborative technology innovation be carried out in its life cycle? Generally speaking, from the perspective of project life cycle dimension, technological innovation synergy should cover a long project life cycle, including different stages; From the perspective of stakeholder dimension, technological innovation collaboration involves more innovation subjects (heterogeneous participants and a wide range of stakeholders), and faces very complex conflicts of interest. From the perspective of collaborative innovation, compared with general projects, technological innovation collaboration requires more multi-agent participation. Based on the above content and the open coding, axial coding and selective coding of the collaborative innovation behavior data of the Hong Kong-Zhuhai-Macao Bridge case study, the authors construct a theoretical model for collaborative technological innovation in megaprojects, as shown in Figure 1. This model includes three dimensions, namely the project lifecycle (x-axis), the dimensions of innovating entities (y-axis), and the dimensions of collaborative innovation (z-axis). Specifically, the project life cycle (x-axis) consists of the pre-project period, construction period, and operation and maintenance period. The dimension of innovation entities (y-axis) includes multiple innovation subjects such as government, contractor, supplier, operator, university research institute, and so on. The dimension of collaborative innovation (z-axis) represents the degree of coordination of the value motivation behind the innovation subject. The value motivations are characterized according to these three dimensions, including the dynamism and phase differences of the project lifecycle, the heterogeneity and confrontational uniformity of the innovating entities, and the interactive cooperation of collaborative innovation.

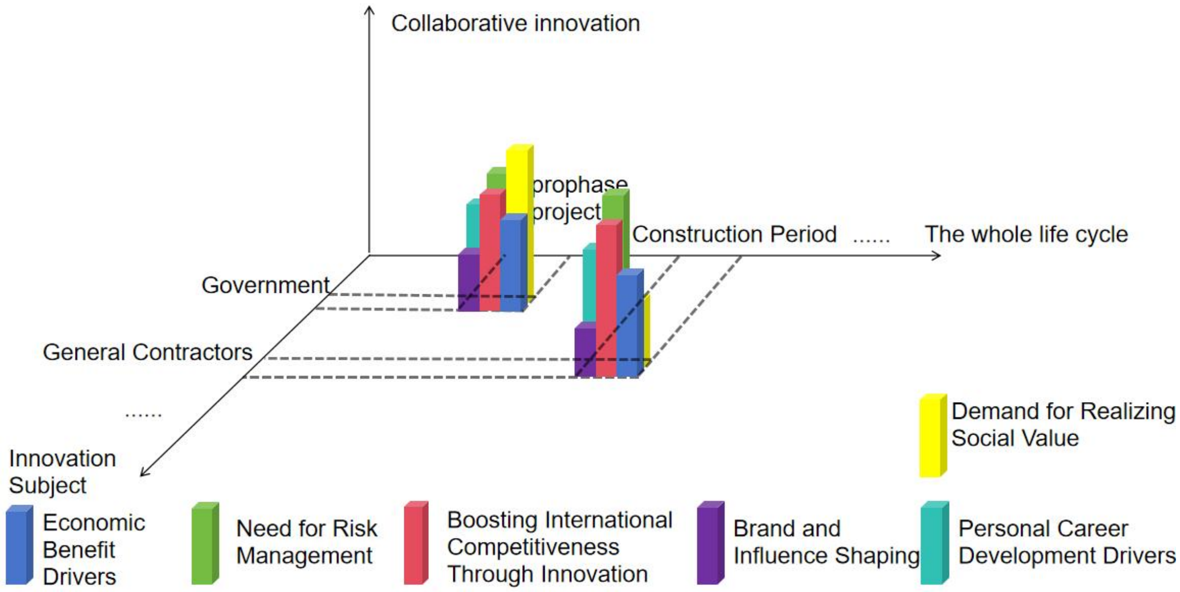

Figure 1. Established Three-Dimensional Theoretical Model of Technological Innovation Collaboration in Megaprojects

4.2. Lifecycle Dimension of Collaborative Technological Innovation in megaprojects

Technological innovation collaboration spans the entire lifecycle of a project, including the initiation, construction, and operation phases, leading to the following characteristics in the value motivations of the innovators:

(1) Phase Differences: On one hand, each phase of the project has specific tasks and goals, resulting in different interest demands from the innovators at each stage of the project lifecycle. For example, the early stage of the project may focus on market research, technology selection, and feasibility analysis, where companies might pay more attention to market potential, technological leadership, and policy orientation. The execution phase, however, focuses on technology research and development, prototype manufacturing, and market testing, where the interests of companies, universities, and users might include cost control, performance optimization, and user experience. These interests show distinct phase-based differences.

(2) Dynamism: On the other hand, as the project lifecycle spans a long period, external factors such as market environment, technological trends, policy regulations, and societal needs constantly change, directly impacting the value motivations of the innovators. For instance, the emergence of new technologies may lead companies to adjust their research and development directions to maintain technological leadership. Changes in policy subsidies might prompt companies to adjust their business models to gain more support. The evolution of user demands requires companies to continually optimize products to meet market needs. Therefore, the motivations need to adapt dynamically to environmental changes, which reflects the dynamic nature of the stakeholders' motivations.

4.3. Innovator Dimension in Collaborative Technological Innovation of megaprojects

Innovators in megaprojects refer to the key roles and entities that participate in innovation activities and drive the technological innovation process in large, complex projects with significant socio-economic implications. Various participants are involved in these activities, including leading companies, specialized contractors and suppliers, universities and research institutions, government agencies, industry associations, alliances, and intermediary organizations. Each party can influence the success and efficiency of collaborative technological innovation, so the importance is to balance the values of all parties and meet their demands.

(1) Heterogeneity (Diverse Value Motivations): Due to the high complexity of megaprojects, there are many entities involved in innovation, including businesses, universities, governments, and users. Each innovator develops diverse value motivations based on their value orientation and functional positioning. For example, businesses pursue economic benefits, market share, and competitive advantages; universities focus on the transformation of scientific research results, academic reputation, and talent cultivation; governments aim to promote industrial development and enhance national scientific strength and social welfare; users expect high-quality, convenient, personalized products or services.

(2) Confrontational Uniformity (Interdependence and Gaming): Since technological innovation involves collaborative benefits, the value motivations of innovators are not isolated but are interrelated and influence each other. On one hand, there are cooperative relationships among entities, such as technological cooperation between businesses and universities and policy support from governments to businesses, which reflect the sharing and complementarity of interests. On the other hand, there may also be competitive relationships, such as businesses competing for market share and universities competing for research resources, reflecting conflicts and gaming of interests. This special relationship requires innovators to consider how to balance relationships with other entities while pursuing their own interests, aiming for a win-win situation.

4.4. Dimension of Collaborative Innovation in Megaproject Technological Innovation

Interactive Collaboration: Projects often face various uncertainties and challenges throughout their entire lifecycle, requiring innovators to timely adjust their value motivations and engage in collaborative innovation to respond to changes. If the value motivations of innovators can effectively collaborate, significant synergistic effects can be produced, that is, through cooperation to achieve value co-creation. For example, constructors, designers, and university research institutes innovate offshore rapid island construction and composite foundation combination technologies, promoting the iterative upgrade of marine engineering technology. A company receives funding from the Zhuhai Science and Technology Enterprise Innovation Fund to build an environmental monitoring unmanned vessel in two and a half years. This synergistic effect emphasizes the importance of cooperation among innovators, which is an indispensable factor for the success of project innovation.

5.CONCLUSION

This paper primarily constructs a three-dimensional theoretical model of collaborative technological innovation in megaprojects, including the entire lifecycle, innovating entities, and collaborative innovation dimensions. The results show that the value motivations of the innovators exhibit characteristics in three stages, namely the dynamism and phase differences of the project lifecycle, the heterogeneity and interconnectedness of the innovating entities, and the interactivity of collaborative innovation, which effectively reveals the collaborative innovation process throughout the entire lifecycle of mega-size projects. This study can enhance the level of mutually beneficial cooperation among innovators, enabling them to jointly drive technological innovation, thereby forming a synergistic effect during the project lifecycle. It also further contributes to overall innovation capability and efficiency and achieving value co-creation. However, this research still has one main limitation, as grounded theory involves some subjectivity in data analysis. In future research, empirical studies could be conducted to validate the identified theoretical model.

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