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COMMENTS

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From systematicness to complexity: Fundamental thinking of mega-project management

Mega-projects are characterized by their large-scale investments, long life-cycle, and extraordinary levels of organizational, technological, and environmental complexity (Flyvbjerg, 2017). They are naturally regarded as large, coupled human, and physical systems consisting of coupled sub-systems linked through flows of human, information, and matter; these systems evolve through time (Bakhshi et al., 2016; Kiridena and Sense, 2016). Not about let systems be, engineering refers to “making things happen” with convergence, optimum design, and operation consistency (Mihm et al., 2003; Ottino, 2004). Specially, mega-projects, which are regarded as typically artificial complex systems, are composed of elements with different properties; connections among those elements change invariably. Mega-project management is proposed to analyze and deal with complexity (Sheng, 2018). However, the traditional reductionist focuses on the isolated components of a system and frequently overlooks critical interactions across individual components. System theory emphasizes the integration of individual systems to achieve a common system goal (Davies and Mackenzie, 2014; Philbin, 2015). General methods of construction management cannot be simply applied to mega-projects. Progression toward successful mega-project management requires a new fundamental thinking to integrate various individual, socioeconomic, and environmental factors that interact across organizational level, space, and time (Lin et al., 2016; Lin et al., 2017; Liu et al., 2015; Niemeier et al., 2014). The core is the evolution from systematicness to complexity, which could bring about a series of significant differences in the thinking, principles, and methodologies (Sheng, 2018).

Adaption from systematicness to complexity is profoundly rooted in the establishment of three subsystems, namely, recognition, coordination, and conduction. First, a recognition system should be established to analyze complex management problems. This subsystem is supposed to uncover and analyze the construction and systematic complexities of mega-projects; the analysis is an iteration process of synthesizing-analyzing - integrating-decomposing (Sheng and You, 2007). Second, a coordination system should be set up to operate and oversee management activities. This subsystem is supposed to design and degrade the complexity of management problems through the operation mechanism and process of management organization. It also conducts a series of unique management strategies of adaptability and multi-scale management (Sheng, 2018). Third, a conduction system should be set up to provide comprehensive controls in real time. This subsystem is supposed to conduct multi-subject coordination at every stage and level of management according to the management objectives and the strategies of mega-projects (Xu et al., 2008). The evolution from systematicness to complexity encompasses the non-superposition of integrity in complex systems and is referred as complex integrity.

As a holistic conception, complex integrity is critical to understanding interdependency and complexity and creating solutions beyond conventional disciplinary, reductionist, and systematist. By combing complex hard (management target) and complex soft (management subject) systems, complex integrity involves not only elements at the direct, noticeable, and physical levels, but

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also those at the indirect, unnoticeable, and socio-economic levels. The management of mega-projects could blend and distill ideas, concepts, methods, tools, and theories from various disciplines, including engineering, management, and social science, to deliver the overarching functionality and ensure the integrity of the project as one system throughout the entire life cycle (Davies and Mackenzie, 2014; Pikaar et al., 2014). This administration approach also allows for clarification and reassignment of stakeholders' responsibilities (e.g., among governments, contractors, suppliers, and operators), reduction of conflicts, and enhancement of synergies.

In practice, the Hong Kong-Zhuhai-Macao Bridge (HZMB) is a fairly typical case of a successful solution to complex integrity in mega-project management. HZMB is a world-class sea-crossing project, which consists of a series of three cable-stayed bridges and one undersea tunnel spanning the Lingdingyang channel linking the Hong Kong Special Administrative Region, Zhuhai city of Guangdong province, and Macao Special Administrative Region. Confronted with extreme institutional, technological, organizational, and environmental complexity, HZMB employs a comprehensive system to address the complex integrity of the project. Recognition, coordination, and conduction systems are built to analyze, judge, and solve the complex management problems of HZMB, including jurisdiction, politics, society, economy, management, and technology. First, to analyze the complexity, a series of investigations on relevant issues are conducted before the approval of HZMB. These issues were classified into macro, meso, and micro scales. Based on the findings, a comprehensive decision-making system and a multi-scale concept were established regarding the importance of management targets. In general, HZMB should not only meet quality standards, but also satisfy frequent typhoons, crisscross navigation, airport height restrictions, high environmental standards, and biological conservation requirements. This goal is expected to minimize its impacts on river flow, navigation, and hydrology. The design process has undergone a rigorous period with rounds of repetition. Numerous substantive revisions were conducted to integrate subsystems function together as a system, such as civil and structural works, environmental mitigation, drainage, electrical and mechanical, traffic control, and surveillance system. Second, to coordinate the management activities, four principles (i.e., up-scaling, industrializing, standardizing, and assembling) are applied to establish internally consistent rules. The standardization of design, construction, quality, and operation ensures that all actions taken by one part or different phase of the project life-cycle are consistent with others. Auxiliary stable routines and processes, such as 6S management, HSE management system, and closed or quasi-closed working environment, are also employed to facilitate coordination. Third, to advance construction, a series of umbrella executive organizations are formed to deal with financial, logistical, and legal issues. These organizations handle contracts and control. Systems integrators make tradeoffs in the interest of system-wide goals rather than the interests of individual organizations. During the construction process, independent teams gather new information, engage collaboratively, and respond to emergent, unforeseen problems in real time. Planning ahead of time plays a critical role in preventing known problems from happening, managing changes, identifying contingency measures necessary for unexpected emergencies. Carefully defined schedules are created to govern the actions of sequential processes of the project and match the activities of multiple parties in advance. Formal and flexible risk-sharing contractual agreements, shared goals, planning, and persuasion are utilized to encourage close cooperation between project teams and delivery partner organizations. New tools or approaches, such as generalized information management system, robot-based plate production line, and prefabrication factory, are implemented to push the plan ahead and accomplish project-wide goals.

Despite significant advances, further efforts are required to incorporate simultaneously more human and natural components, develop new tools, and translate experiences and achievements into policy and practice. It is an opportune time for academic researchers, engineers, project managers, and policy-makers to join forces to develop tools from systematic to complex thinking for mega-project management (Battiston et al., 2016; Davies and Mackenzie, 2014).

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