Risk Analysis of Construction Project Life Cycle Information Management Based on System Dynamics

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Abstract. Information is the chain in which the project management system operates. When assessing project risks, traditional methods often have difficulty balancing the integrity of the project. This paper analyses the risk elements of information management in the whole life cycle of construction projects, attempts to use the system dynamics method to establish the causal diagram of each stage, and describes the impact of information risk elements on project schedule, quality, cost and safety. The results show that the negative feedback loops of the whole system is mostly. Besides, the influence between the targets can be transformed, and the system itself can achieve a relatively stable state through self-regulation.

1. Introduction
Information management is one of the core tasks of project management. Due to the special nature of construction products, information management has always been the weakest link in construction project management. Identifying the information risk elements throughout the lifecycle of an engineering project and studying their possible impacts on the overall project are important and urgent.

2. Information management and system dynamics of construction projects
Construction project management is a complex and dynamic system engineering. The system dynamics specializes in complex dynamic system problems and assisting managers in decision making. The project risk management process involves many subjective and dynamic factors which cannot be effectively processed by traditional tools, while system dynamics can work well.

Many scholars have tried to apply system dynamics in project risk management. Wang Qifan [1] expounded the absolute advantages of system dynamics in the dynamic complexity of project risk management. Feng Lei [2] qualitatively analyzed the performance problems of engineering projects under the Partnering mode by constructing a causal diagram. Li Cunbin [3] analyzed the impact transmission of risk factors of engineering projects and carried out simulation. Jiang Li [4] constructed the project risk system model by using system dynamics, and considered the optimal strategy of risks control from the perspective of the whole and system.

This paper attempts to analyze the information management risks existing in the engineering project by means of system dynamics from the perspective of real estate developers, observing the role of potential information risk elements on the project management system and their impact on project management objectives, in order to lay the foundation for the later quantitative assessment of the impact of information management risks on project objectives and the formulation of strategies.

3. System dynamics model of information management risks in construction project life cycle
This paper adopts a three-stage pattern of construction project life cycle: decision stage,
implementation stage and operation and maintenance stage. Therefore, the construction project management system is divided into three corresponding subsystems. The objectives of the project are schedule, quality, cost and safety. The assignment is to analyze the subsystems of each stage separately, find potential information risk elements, explore their relationship with various elements in the system and project objectives, and draw causal diagrams, which can provide a reference for the later quantitative assessment and make proper control strategies.

3.1. Decision stage

One of the main tasks in the project decision-making phase is to conduct a feasibility plan to fully identify the potential risks. The relevant risks of information in this stage mainly include information of market, resource, environment, policy and law [5].

Market information risks. It includes competitive information, demand information and price information. The operational efficiency of construction projects depends to a large extent on the popularity of products in the market. Whether you can fully understand competitors and reasonably predict product market share, consumer demand, sales price, etc., is very important to have a competitive advantage.

Resource and environmental information risks. The source information includes construction project materials, labor situation, water, electricity and other infrastructure resources information, which are crucial to the smooth development of construction projects, especially the financing of project funds. Environmental information such as natural climate factors, hydrogeological information, road transport conditions, construction waste disposal, etc. If the preliminary information preparation is not completed, the project may be interrupted and the project schedule will be affected.

Policy information risks. In the social and economic operation, the government often regulates market development through macro-policies, such as adjusting deposit and loan interest, modifying the function of planning land, canceling or adding certain projects, enacting new policies, or banning old regulations, which may bring investors different degrees of loss. Investors can't control policy risks, but they can carefully study the policy regulations and analyze the policy intentions by reasonably analyzing the information, so as to predict their trends and appropriately avoid risks.

Legal information risks. At present, the domestic construction investment laws system is still not perfect, and the phenomena of "relationship engineering" and "fake guarantee project" are prominent, which disrupts the market order and increases the risk of investment. In addition, especially when it comes to international engineering investment, it is necessary to thoroughly understand the local construction laws, regulations and contract terms, so as to avoid various engineering disputes in the later implementation process.

The causal diagram in the decision stage is shown in Figure 1. In the graph, "B" means the negative feedback loops, "R" means the positive feedback loops; "+" means elements next to "+" have the same trend, "+" means elements next to "-" have the opposite trend, and this is the same in the back.

The feedback loops involving the targets are as follows:

(B1) Cost + Price - Purchasing Power + Profit + Interest Rate + Cost;
(B2) Cost + Quality + Purchasing Power + Profit + Interest Rate + Cost;
(R1) Quality + Purchasing Power + Profit + Construction in Progress + Quality;
(B3) Quality + Purchasing Power + Profit + Interest Rate + Cost – Quality.

3.2. Implementation stage

The implementation stage includes design, bidding, construction and completion acceptance, which is the most complex and difficult phase to control in the life cycle. There are a large number of risks in this stage. Among them, the risks related to information management mainly include information asymmetry, poor information sharing, lag in information exchange, difficulty in integration of various types of information, loss of information, and factors related to human behaviors.

Information asymmetry. Information asymmetry is easy to trigger adverse selections and moral hazard behaviors [6]. In the bidding stage, if the tenderers and the bidders are not familiar with each
other, it is easy to cause adverse selections. It is a good way to choose information consulting firms to understand each other's corporate reputation, technical management capabilities and financial status to achieve the best choice. In the implementation stage, the contractor may use the information advantage unethically, inducing speculative behavior, and claiming engineering claims, etc., which would damage the interests of the owners. Establishing a reasonable incentive and restraint mechanism by signing a contract can promote the goal consistency and mitigate the impact of moral hazard.

The amount of information is large and the types are complicated, which makes information difficult to integrate. Due to the long period of implementation stage of the construction project as well as involving multiple majors and links, the information refers to multimedia data like various engineering documents, sound images, and language information like verbal instructions, reports, negotiations and so forth. Large amount of information and diverse forms could result in the inability to integrate information effectively. At present, construction projects mostly adopt unified information classification and coding, and use computer information management system to classify, storage and dynamically manage information, which has a certain effect.

Information exchange is lagging and sharing is poor [7]. The traditional information exchange is mainly based on the peer-to-peer approach, with many communication channels and poor transmission efficiency, which often leads to the lag of information exchange and fail to obtain accurate information in time, causing construction errors and affecting the schedule of the project. In addition, each party has its own management information system that has a large degree of incompatibility, which affects information sharing. At present, flat communication method is more and more accepted, especially the application of BIM can effectively coordinate the work of all parties as well as improve the efficiency and sharing of information transmission [8].

Loss of information. At present, most of the project materials are transmitted in paper form. The design-to-construction stage and the completion-to-usage stage are two important over-stages, during which the loss of information is particularly serious, affecting the effective process of operation and management in the later period [7].

Human factors. The information that people have and display, such as the responsibility of managers, business level, moral quality, enthusiasm of workers, customers’ satisfaction, is crucial but also easy to be ignored. Closely tracking the work status of employees, timely discovering the emotion of workers, and fully understanding the evaluation and attitudes of customers can to some extent avoid making mistakes as well as having the negative effects on quality of projects.

The causal diagram of information risks in the implementation phase is shown in Figure 2.
The feedback loops involving the “Cost” target are as follows:

(B4) Cost - Quality + Customers’ Satisfaction - Managerial Quality - Information Loss + Cost;
(B5) Cost - Quality + Customers’ Satisfaction - Managerial Quality - Information Asymmetry + Reverse Selection + Ethical Risk + Engineering Claim + Cost;
(B6) Cost - Quality + Customers’ Satisfaction - Managerial Quality - Information Loss + Construction Error + Project Needs Rework + Project Rework - Schedule - Schedule Pressure + Hiring New Labor - Overall Labor Level - Training + Cost;
(B7) Cost - Quality + Customers’ Satisfaction - Managerial Quality - Information Communication Lag + Construction Errors + Project Needs Rework + Project Rework - Schedule - Schedule Pressure + Hiring New Labor - Overall Labor Level - Training + Cost;

3.3 Operation and maintenance stage
The operation and maintenance of the building is crucial, which is the most easily overlooked phase in project management. If the enterprise's management information system is of a high level and the files are relatively complete, then it will be much more convenient if there are any repair needed in the later use process, since it is more convenient to quickly and accurately check the drawings to find out the certain problem. If it is necessary to replace the materials or Components, technicians can quickly view the properties and models of the materials in the archives for easy procurement, which can effectively save time and manpower, reduce resource consumption and save costs. This savings can be used to further improve management information. The causal diagram is shown in Figure 3.
Figure 2. Causal diagram of information risks in decision stage

Figure 3. Causal diagram of information risks in operation and maintenance stage

Figure 4. Causal diagram of information risks in the whole life cycle

The feedback loops involving the target is:

(R2) Management Information System Level + File Integrity - Resource Cost + Cost - Management Information System Level.

The causal diagrams of each stage subsystem are integrated to obtain the causal relationship of the information risks in the whole life cycle of the project, as shown in Figure 4.

In the whole life cycle, there are total 23 feedback loops involving the project objectives, including 3 positive feedback loops and 20 negative feedback loops. A positive feedback loop means that if a
factor in the loop increases (decreases), the variable itself increases (decreases) after a closed loop, namely the solid feedback has a reinforcing effect. On the contrary, for a negative feedback loop, it can self-adjust and maintain dynamic balance. In the process of project development, each risk element has different degrees of influence on the four objectives, and the impacts on one objective will also be transformed into another. However, finally the overall balance can be maintained.

4. Conclusion
An engineering project is a complex system. System dynamics takes the system as the research objects and provides a good way for the identification of information risk elements and their impacts on project objectives. This paper attempts to establish causal diagrams in the construction project, and qualitatively describes the impacts of information risk elements on objectives of cost, quality, schedule and safety. The result shows that the whole system has a large proportion of negative feedback loops, and the system itself can reach a relatively stable state by self-regulation.

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