Modelling Construction Project Management Based on System Dynamics

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Abstract
Affected by many factors, the execution process of construction project is highly dynamic, uncertain and always not what we plan to be. Traditional project management approaches, such as WBS, CPM and PERT fail to take the factors and project process as a whole. It is considered as their main weakness on improving project performance. To address this, this paper developed a construction project management model based on System Dynamics which captured affecting factors such as quality supervision and rework during its execution, schedule delay, project control actions, project goal adjustment, and more importantly, their interactions. In this way, SD model is more realistic than traditional model and thus it can assist project managers in better understanding and controlling construction project.
Keywords: PROJECT MANAGEMENT, SYSTEM DYNAMICS (SD), SIMULATION

1. Introduction

Along with the development of society and economy and the rapid change of science and technology, there are more and more complex construction projects in construction industry. Complex construction projects are affected by so many factors that construction processes are highly dynamic and uncertain, which bring severe challenges to construction project management.

Traditional approaches of construction project management, such as WBS, CPM and PERT, are conceptually rooted in reductive thinking[1] where it is hypothesized that the complexity of a project can be reduced by dividing the project into manageable and controllable activities[2]. Consequently, the general principle of these approaches is in deconstructing a construction project further into even smaller fragments and searching for explanations at the lowest possible level [3].

However, the traditional project management approaches have two disadvantages. Firstly, the project is considered to be simple sum of each work, and the relationships of these works are neglected. Secondly, these approaches cannot describe the relationships between project work and key factors affecting project execution process, such as resource, control policy, time delay and project goal. Therefore, traditional project methods couldn't model the complexity and dynamic nature which are inherently in construction project. Hence a new approach to assist construction project management is needed.

As a cross discipline based on control theory, decision theory, simulation technology and computer applied technology, System Dynamics (SD) has advantages on dealing with dynamic and complex problems in complex system [4]. It has been widely used in macroscopic areas such as economic, social, and ecological and biological systems [5-6]. In recent years, researchers introduce SD to project management field, such as product development project management, risk management of project and project estimation [7-9]. However, SD has received relatively little attention in construction project. In order to fully explore the applicability of SD and develop a new approach for construction project management, this article introduces SD to this field and focuses on how to model construction project based on SD, which is the most important step to improve performance of construction project.

2. Research Methodology

2.1. System Dynamics Approach

System dynamics (SD) introduced by Forrester, is an objective-oriented simulation methodology enabling us to model complex systems considering all the influencing factors[10]. SD considered that the system function is determined by its structure, and the system behavior pattern depends on the dynamic structure and the internal feedback mechanisms of the system [11]. System dynamics provides a rigorous approach for description, analysis and exploration of complex systems. Much of the art of SD modeling is to discover and represent the feedback process which along with stock and flow structures, time delays and nonlinearities, which determine the dynamics of system [4].

The method of System Dynamics, which is used to deal with complex systems problems, is a combined method of qualitative and quantitative analysis, and based on system thinking and general reasoning. With computer simulation, the System Dynamics model can solve various problems in complex system.

2.2. Steps of System Dynamics Modelling

A flowchart representing different steps of System Dynamics modelling process is shown as Fig. 1. Steps from 1 to 4 are repeated until the SD model is refined. Through repetition the model developer could get a better understanding the dynamics of real system and thus the model becomes more approaching real system.

With computer simulation, the impact of alternative policies to improve construction performance could be assessed, which is shown as step 5.

3. Overview of Construction Project SD Model

The first step of System Dynamics modelling is to define model boundary which shows that which

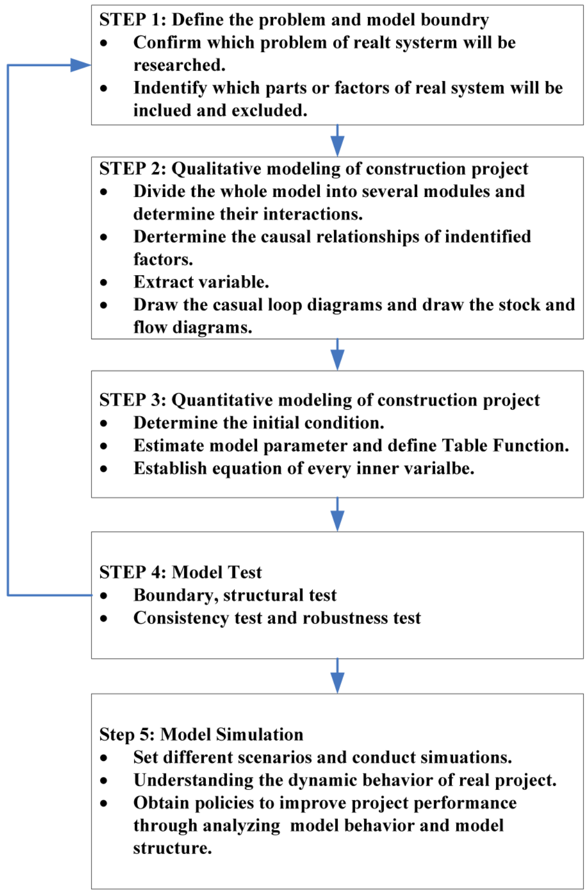

Figure 1. Steps of construction project modelling by System Dynamics approach

parts of the project system will be considered in SD model and which will not. Construction project SD model aims at describing the real processes of construction project operation so main influencing factors and main steps of project management should be considered. In the macroscopic view, construction project is the end product of material flow and information flow. Human, money and material are combined to form material flow of which the direct product is building entity. Information flow formed by main steps of project management such as making plan, checking project status, analyzing deviation between plan value and actual value, making control policy, adjusting deviation and adjusting project goal according to project environment. Project management aiming to realize the goals of construction project is adjusting the direction and rate of material flow by information flow.

The control loop in Fig.2 describes dynamic changing process of construction project. It consists of material flow process in which design work and construction work are executed, and information flow process in which project management work are executed. Both of them form a closed-loop feedback system which System Dynamics model of construc-

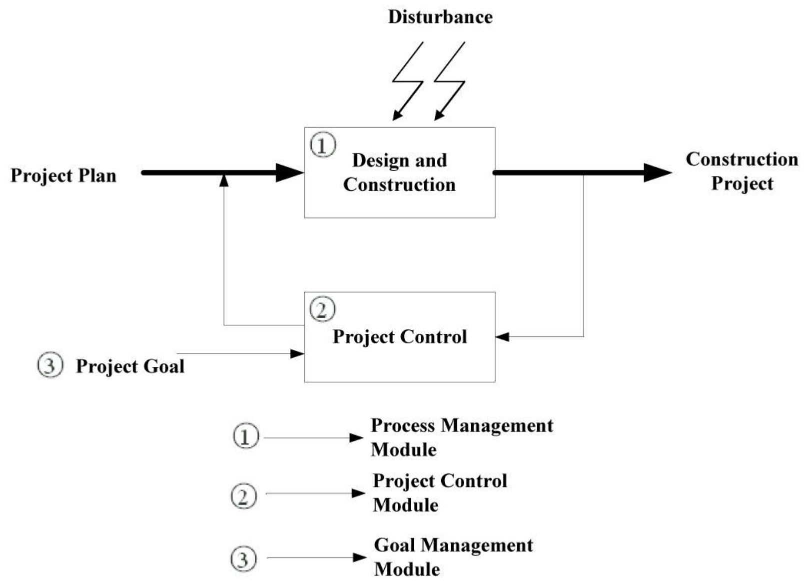

Figure 2. Overview of construction project SD model structure

tion project just captures. Information flow within the model boundary is the biggest feature of SD model different from CPM model and Discrete Event Simulation model of construction project.

4. Modelling

4.1. Process Management Module

As a core component of SD model, the process management module captures the dynamics of work execution within a project, shown in Fig. 3. It is evolved from the model of product project proposed by Ford [12], and Rodrigues et al. [13]. Their original model, however, has been further developed to simulate the construction project processes, such as Sangwon et al. [14].

There are four possible states of any work item, titled Work To Do (WTO), Work Awaiting Supervision (WAS), Quality Problem Awaiting Management Decision (QPAMD) and Work Done (WD), which are represented by stock in System Dynamic Model. At beginning, the WD stock is empty and when the project is finished it is full of work items. Available work items are introduced to the WTD through Work Introduction Rate, which is determined by relationships with related activities (e.g., Start-to-Start or Finish-to-Start). Work items in WTD are executed and then moved to WAI through Work Rate (WR), which is regulated by the level of resources assigned and actual productivity. All work items in WAS are need to be supervised. If quality requirements are met, the work is then moved from WAI to WD through the Work Completion Rate (WCR). The failed work, however, is moved to QPAMD stock through Rejection Rate

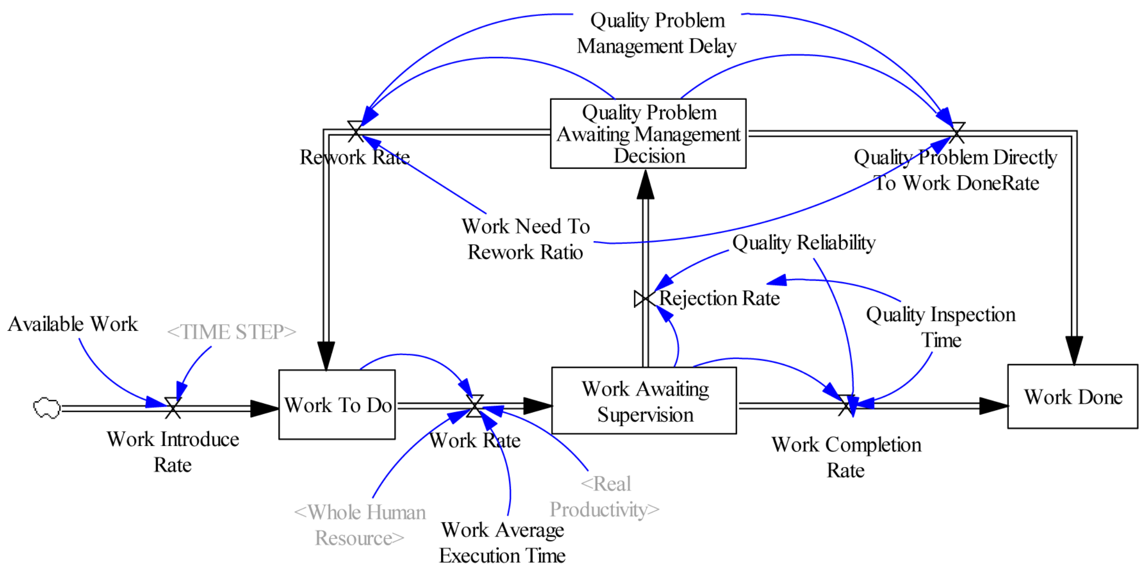

Figure 3. Process management module

(RR) flow. Work items with quality problems in QPAMD stock are returned to WTD through Rework Rate (ReR) if they need to be reworked. And they are moved to WD through Quality Problem Directly To Work Done (QPDTWD) if they are confirmed by designer that they don't need to be reworked for some reason, for example, the next step could remedy the problem.

Equations of stock variables and rate variables in process management module are shown as equation (1) to equation (9).

$$WTD[i] = WTD[i]_0 + \int_0^t (WIR[i] - WR[i] + ReR[i])dt \quad (1)$$

$$WAS[i] = WAS[i]_0 + \int_0^t (WR[i] - RR[i] - WCR[i])dt \quad (2)$$

$$QPAMD[i] = QPAMD[i]_0 + \int_0^t (RR[i] - ReR[i] - QPDTWDR[i])dt \quad (3)$$

$$WD[i] = WD[i]_0 + \int_0^t (WCR[i] + QPDTWDR[i])dt \quad (4)$$

$$WR[i] = \min(WTD[i]/WAET[i], WHR[i]*RPro[i]) \quad (5)$$

$$WCR[i] = WAS[i]/QIT[i]*QRe[i]) \quad (6)$$

$$RR[i] = WAS[i]/QIT[i]*(1-QRe[i]) \quad (7)$$

$$ReR[i] = QPAMD[i]/QPMD[i]*WNTRR[i] \quad (8)$$

$$QPDTWDR[i] = QPAMD[i]/QPMD[i]*(1-WNTRR[i]) \quad (9)$$

Where i=current activity, and $i \in \{1, 2, ...n\}$. It is supposed that the construction project is composed of n activities.

4.2. Project Control Module

Project control is the main task of project management. It aims to produce the desired outcome of a project, and its main mechanism is feedback control. When construction project suffers from schedule delay, project managers usually takes control actions to accelerate the work rate in order to keep the real progress the same pace with project plan. The SD model developed in this paper just incorporates project control actions while the traditional project management models such as CPM and PERT always exclude.

Project control module is shown as Fig. 4. The number of completed work in stock WD in Fig. 3 reflects the real progress. When it is behind, managers usually apply increasing human resources policy or overtime policy. The required human resource and the required work time are determined by the required work rate which is calculated by remaining work items and the rest of time. Human resource and work time need to be increased is according to the present number and required number. Accompanying overtime work, fatigue effect may be trigged and it will decrease the real productivity due to weariness. The real productivity affects Work Rate in return. project Which control policy manager would takes and to which extend the policy will be used are represented by two variables namely Willingness to Adjust Human Resource and Willingness to Overtime Work.

4.3. Goal Management Module

Goal management module captures adjustment of project goal during work execution, shown in Fig. 5. Sometimes construction project suffers from big disturbances such as substantive change orders or longtime bad weathers, control actions described above are also difficult to achieve the planned schedule. Another kind of management policy could used in practice is to adjust the goal according to required time and the time which has been taken. Similarly, whether manager would like to adjust goal or not and to which extend adjustment will be taken are captured by the variable namely Willingness to Adjust Goal.

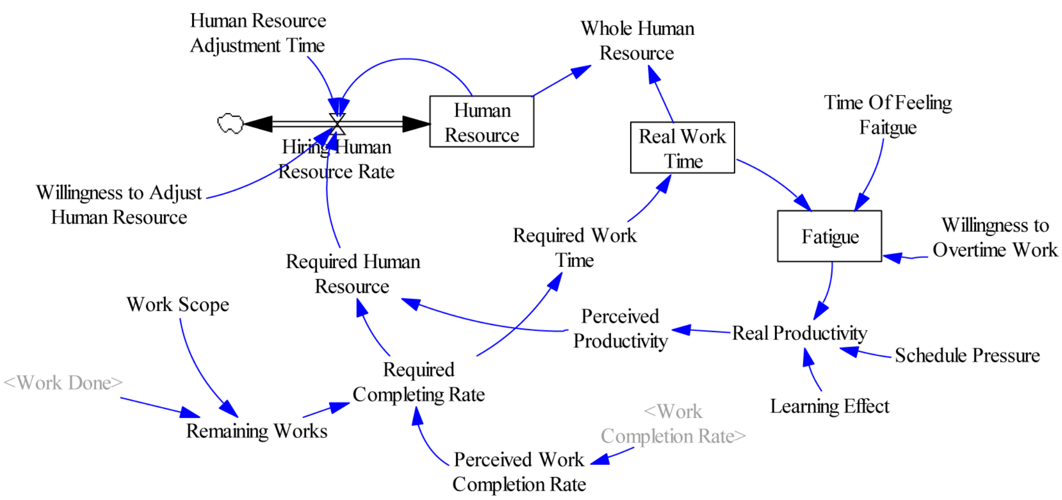

Figure 4. Process management module project control module

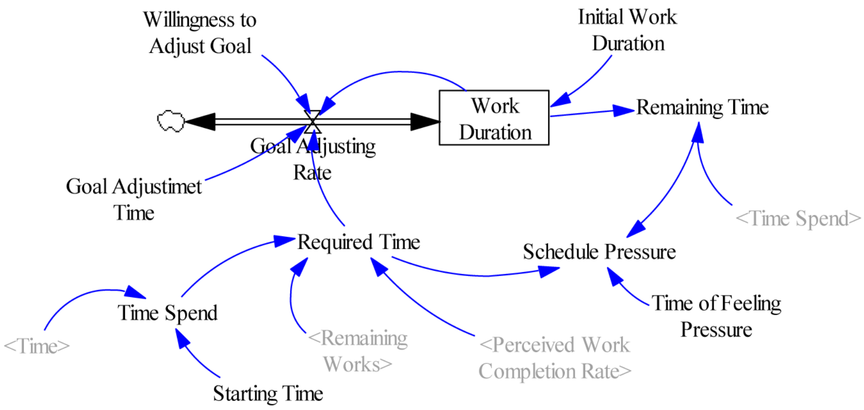

Figure 5. Goal management module

5. Conclusion

Construction projects are affected by so many factors that construction processes are highly dynamic and uncertain. To increase similarity of simulation model with real system, the model developed in this paper based on System Dynamics takes into account quality supervision and rework during project execution, schedule delay, project control actions, project goal adjustment, and more importantly, their interaction. In this way, the dynamics of the project can be better understood and controlled. Further research on assessing impacts of alternative policies to improve project performance through simulation on SD model, shown as step 5 in Fig.1, is required.

Acknowledgements

This work is supported by sub project of National Natural Science Foundation significant project of China (No.71390523), National Natural Science Fund of China (No.71471136) and Ministry of Education Humanities and Social Sciences Youth Fund (No.13YJC790034).

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Fuzzy Assessment of Quakeproof Property in Stadium Buildings

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Abstract
Stadium buildings are important population-intensive buildings where various social activities are held frequently. The quakeproof property of stadium buildings directly concerns safety and image of social people and the cities. This research takes sports stadium buildings for example, combines architectural characteristics and quakeproof requirements of sports stadium and introduces fuzzy assessment theory. Deep analysis is carried out from the site environment, foundation, major structure, building materials and components which influence quakeproof property. On this basis, this paper proposes a set of scientific comprehensive assessment index system, and applies fuzzy comprehensive assessment to construct quakeproof property assessment model of sports stadium. Meanwhile, based on case study of Wukesong Stadium, this paper verifies feasibility of this assessment system. The research shows that this method has certain reference significance for quakeproof property assessment of similar stadiums.
Keywords: STADIUM BUILDINGS, QUAKEPROOF, FUZZY COMPREHENSIVE ASSESSMENT

1. Introduction

Compared with other natural hazards, earthquake imposes the most serious destructive effect on human society and it is most sudden [1]. At present, early warning technique is still not developed. Human beings can only depend on passive prevention methods such as enhancing quakeproof property of buildings. For some important buildings such as sports stadium and station, there is corresponding quakeproof design which can resist certain intensity of earthwork. To visually reflect quakeproof property of buildings, architectural engineering standard also sets corresponding quake-proof grade, and specifies corresponding specifications. Due to functional attribute