World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:5, No:10, 2011

Payment Problems, Cash Flow and Profitability of Construction Project: A System Dynamics Model

Wenhua Hou*, Xing Liu, Deqiang Chen

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***Abstract*—**The ubiquitous payment problems within construction industry of China are notoriously hard to be resolved, thus lead to a series of impacts to the industry chain. Among of them, the most direct result is affecting the normal operation of contractors negatively. A wealth of research has already discussed reasons of the payment problems by introducing a number of possible improvement strategies. But the causalities of these problems are still far from harsh reality. In this paper, the authors propose a model for cash flow system of construction projects by introducing System Dynamics techniques to explore causal facets of the payment problem. The effects of payment arrears on both cash flow and profitability of project are simulated into four scenarios by using data from real projects. Simulating results show visible clues to help contractors quantitatively determining the consequences for the construction project that arise from payment delay.

***Keywords*—**payment problems, cash flow, profitability, system dynamics.

I. Introduction

CONSTRUCTION Payment Problems (PP) have attracted wide concerns in the industry for many years in both developing and developed countries. These problems are especially serious and widespread in Mainland China. According to the official data from the National Bureau of Statistics of China (NBSC), the Chinese construction industry kept developing, but burdens of payment problems are increasingly heavy from 1996 to 2003. By the end of 2003, accumulated payments with problems in the Chinese construction industry reached to 367 billion RMB [1] including 186 billion RMB payment arrears, that the amounts agreed by both parties [2]. Though administrative intervention from the central government mitigated the payment problem [3], it is a difficult problem to be resolved in the construction industry of mainland China. Payment Problems seriously affect the normal operation of contractors and hinder the healthy and sustainable development of the construction industry, in some cases, their negative impacts even extend to other aspects of the society.

On the other hand, most construction companies have suffered from inadequate cash resources for a long time. It is likely to be the final causes of failing for many companies, since cash flow is the most important power of running construction companies. Lack of cash brings extra expenses to construction companies and decreases profitability of them. Cash flow and profitability are interactive, even though they are different issues. Chinese construction companies experienced a low rate of profitability compared with the average level in the world and there are more than 15% construction companies running under deficit in 2003 and 2004 [1]. Undoubtedly, the PP is one of factors resulting in the poor performance of Chinese companies [4]. As far, most studies on PP in Chinese construction industry focus on the causes and solutions [4], [5], [6], [7], [8], but few of them address causes and consequences of payment problem with a systematic view. This paper focuses on the consequences caused by PP to construction companies. Specifically, with a systematic perspective, the paper performs quantitative analysis for the impacts of payment arrears on cash flow and profitability of construction project in the context of construction industries in Mainland China. Being acutely aware of these effects is helpful to contractors for their decision making.

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II. System Dynamic Approach

The System Dynamics (SD) approach, being used for fifty years, is based on a comprehensive view of the project and focuses on the feedback processes that take place within the project system. It offers a rigorous method for the description, exploration, and analysis of complex project systems comprised of organizational elements, the project work packages and the environmental influences [9].

The construction project cash flow system has three major characteristics: (1) the system is fairly complex and consists of multiple interdependent components involving cash inflow and cash outflow, which are highly dynamic over time; (2) structure of the system Involves multiple feedback processes; (3) there is time delay between some causes and results within the system. Therefore, SD is more suited to describe a project cash flow system than other modeling tools. The SD approach attributes

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the source of problem to the structure of system, and based on the description of dynamic structure of project cash flow system by using system dynamic techniques. This paper explores the behavior of project cash flow system affected by payment arrears under different conditions.

III. Formulation Of System Dynamics Model

There are five principal steps to establish a SD model, described as follows.

Step (1): Definite the objective of a SD model. The objective of this model is to analyze the corresponding cash balance and cumulative profit under different payment conditions by simulating cash flow system, and then determine the effects of payment problems on project cash flow and profitability because they are related. Thereby the contractor can choose the optimum condition within the possible range.

Step (2): Identify the model boundary. To explore the behavior mode of project cash flow system under the influence of PP. All of the key factors which have impact on cash inflow and outflow are included within the model like revenue, cost and expenses. Other factors, such as banks, owners and competitors, are excluded from the model as model environment. The straight line on Figure 2 shows the boundary of model.

Step (3): Screen out the variables. The model variables are selected based on literature review, the information gathered from the real system, and the interviews conducted with project managers. The principal variables can be seen as in Fig. 1.

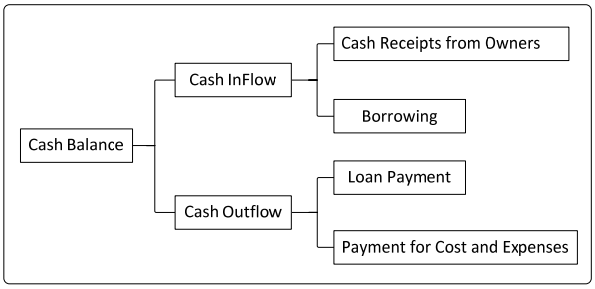


Fig. 1 The Principal Variables of proposed SD Model

Step (4): Identify the causal relationship. Fig. 2 shows the feedback loop of project cash flow system which will be explained in following paragraph.

The system consists of several reinforcing and balancing loops. During the construction process of project, the payment for labor and material cause cash outflow. With the cost occurring, the project is completed gradually, and then the contractor bill to the owner for construction revenue which include cost, overhead and profit. Payments received from the owner constitute project cash inflow. The contractor does not receive the payment from the owner in time, which is the payment delay. When payment delay happened, the contractor either could not provide timely payment for labor and material correspondingly. The dynamic process is defined as an operation loop in cash flow (R1).

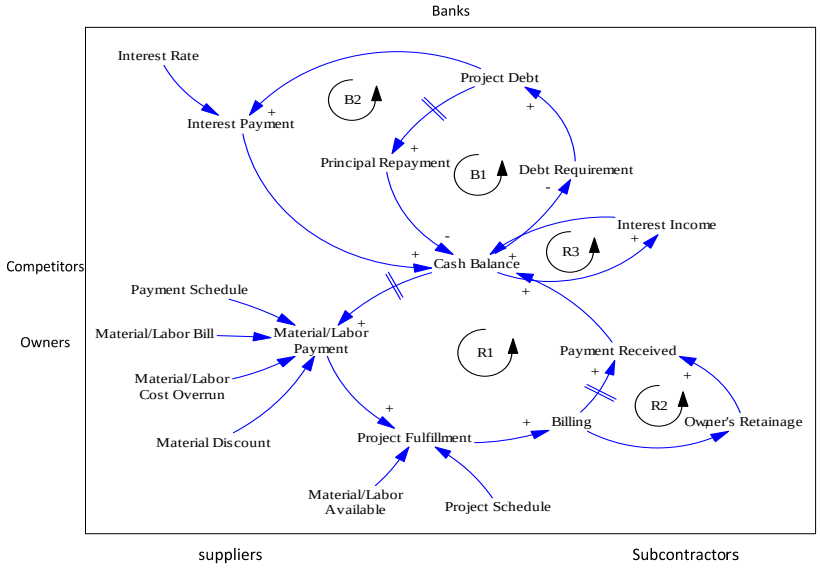


Fig. 2 Casual Loop of Project Cash Flow

The retention loop (R2) shows the owner retains 10% of the completed work from each payment until the withheld amount reaches 5% of the contract amount. The retention will be later paid to the contractor if the project is finally accepted by the owner or guarantee expired. So there is a delay before the contractor receives the retention money.

When the cash balance is not enough for payments and other use, the contractor needs to borrow money from banks which constitutes one of cash inflow. Then both of the interest payment and the principal repayment cause project cash outflow. These are the financing loop (B1 and B2).

Step (5): Form the SD model. This paper builds the project cash flow model, which includes 70 system equations, with software Vensim PLE.

From a system view, the project cash flow model includes not only the financial unit but also project management unit and

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purchase unit, these units are all linked together. For example, inadequate cash resources may result in payment delay for material and labor. When payable to suppliers and workers reach to certain amount, the contractor cannot get material in time and the construction workers lack motivation to work. This will make the construction delay and corresponding material and labor cost overrun which conversely increase cash outflow. So the financial unit and project management unit are interactive with each other. In addition, the cash flow system can also illustrate the profitability by cost saving which consists of interest payment, interest income, material discount, material and labor cost overrun. Profitability is represented by the variable of cumulative profit which is cumulative cost saving. Only building the project cash flow model with system thinking, effects on cash flow and profitability caused by payment problem can be confirmed more accurately.

IV. Simulation Results and Analysis

A. Model Validation

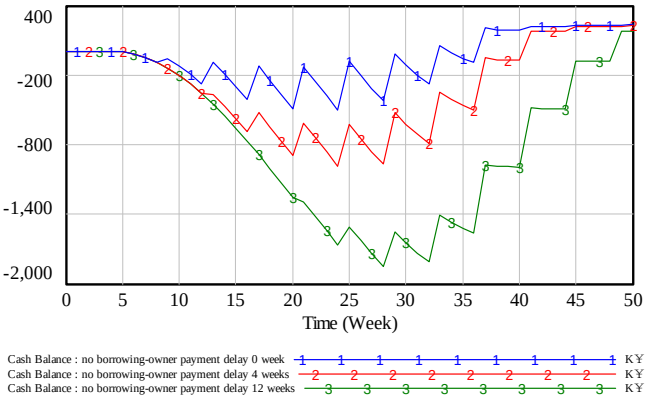
Model validation is a crucial process for the confidence in the soundness and usefulness of a model. Both structural and behavioral validation tests were performed in the model. The useful time period of the model simulation was fixed as 50 weeks from September in 2009 to August in 2010.

The example construction project in this paper is an 11-story, framed structure residential building located in Chongqing City of China. The construction period is eight months (32 weeks).

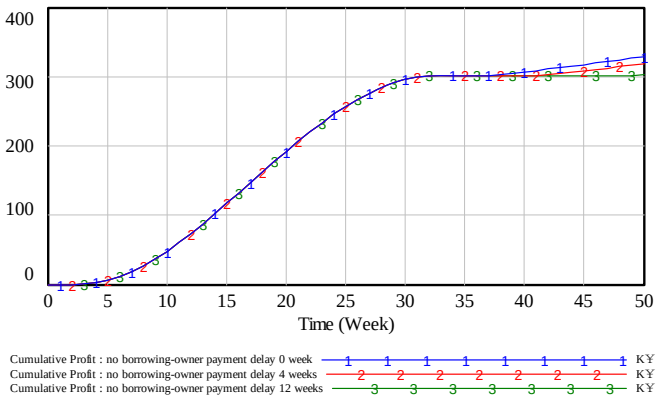
B. Results and Analysis

1) Scenario I

Fig. 3 (a) and (b) demonstrate the impact payment delay from owner has on project cash flow and profitability when contractor cannot get any loan, where curve 1 represents a base run with no payment delay from owner. Curve 2 and 3 represent the behaviors of the cash system with 4 and 12 weeks payment delay respectively. As seen in Fig. 3(a) that payment delay decreases the cash balance, and the delay time is longer the cash balance curve drop more quickly. The lowest point of curve 3 reach to nearly negative 2 million RMB compared with negative 0.5 million RMB of the lowest point on curve 1. So payment delay made the contractor sank into a dangerous situation with large cash gap. However, when it came to the profitability, it seems that payment delay from owner did not affect the cumulative profit of project because of accrual accounting.



(a) Cash Balance in Scenario I

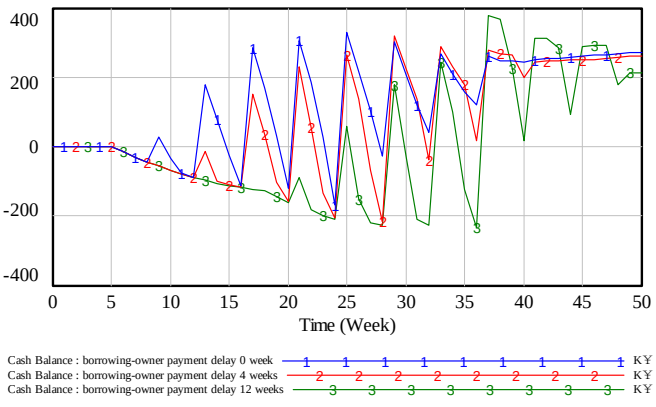


(b) Cumulative Profit in Scenario I

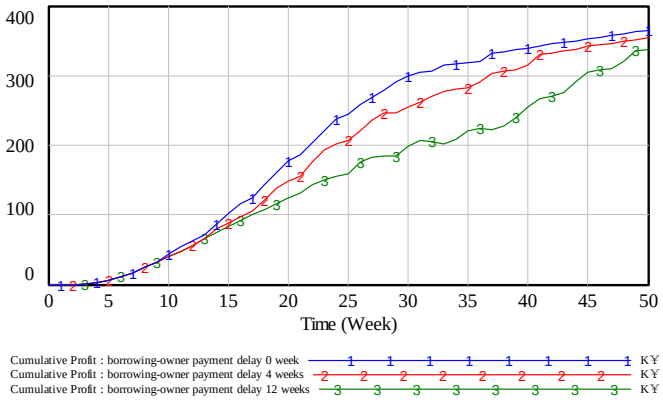
Fig. 3 Simulation Results for Scenario I

2) Scenario 2

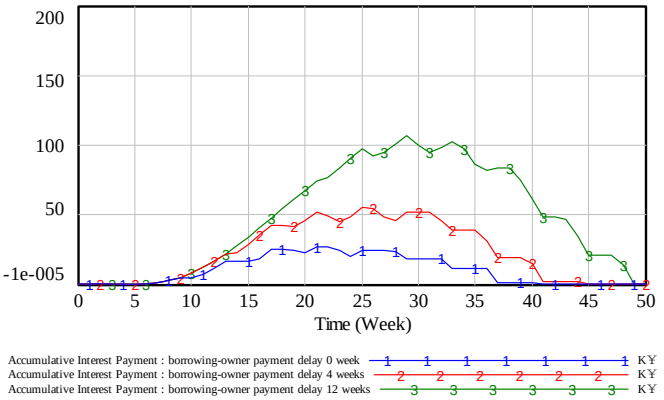
When cash is inadequate, contractors generally apply to banks for a loan. The example project is simulated with borrowing once the cash balance became negative assuming that the contractor can get loans when he needs it and the debt repayment period is 12 weeks. The curves 1, 2 and 3 on Fig. 4(a), 4(b) and 4(c) represent no payment delay, 4 and 12 weeks payment delay from owner respectively with borrowing. As we can see, when the delay time is longer, the cash balance is lower, and project is more often in the cash lacking state in most time. Fig. 4(b) reflects that longer payment delay time decreases the profitability of project obviously. It can be explained as more debts and corresponding more interest expenses, in Fig. 4(c).



(a) Cash Balance in Scenario II



(b) Cumulative Profit in Scenario II

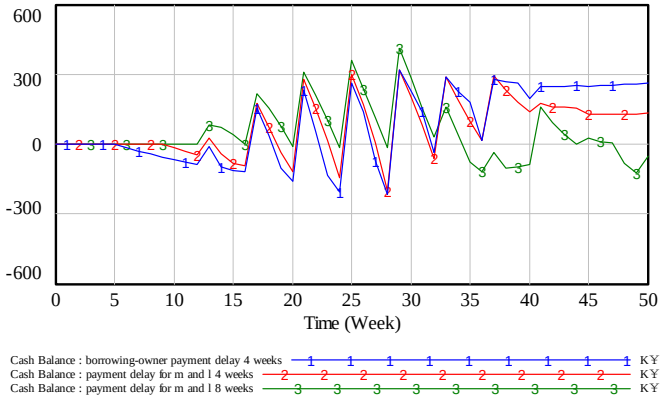


(c) Accumulate Interest Payment in Scenario II

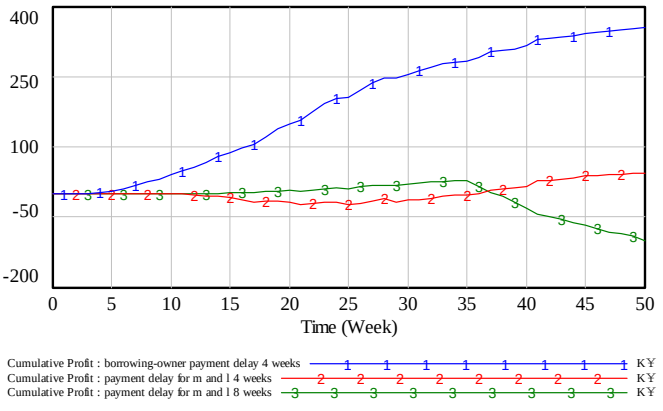
Fig. 4 Simulation Results for Scenario II

3) Scenario III

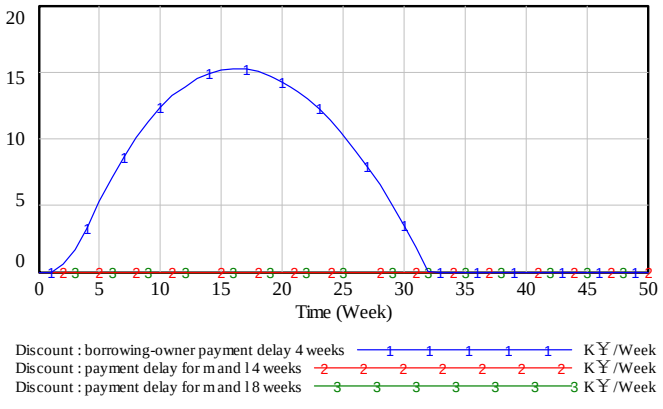
In practice when contractors can not get payment from the owner in time, he generally put off payment for material and labor. The value of this variable of payment delay for material and labor is assumed zero on above two scenarios. In Figures 5(a to e), curves 1, 2 and 3 represent no payment delay for material and labor, 4 and 8 weeks delay respectively caused by 4 weeks payment delay from the owner. The behavior of cash system was illustrated in Fig. 5(a). As we can see, curve 3 is above curve 1 and 2 from the ninth to thirty-fist week, the period of intensive construction activities. It indicates that longer delay time for material and labor brings more cash balance for contractors during construction period. But the cost for this situation is that the contractor cannot get material discount and material and labor cost overrun, in Fig. 5(c),(d) and (e). Curve 1 means better performance on profitability which indicates the contractor has to trade off between advantage and disadvantage of payment delay for material and labor.



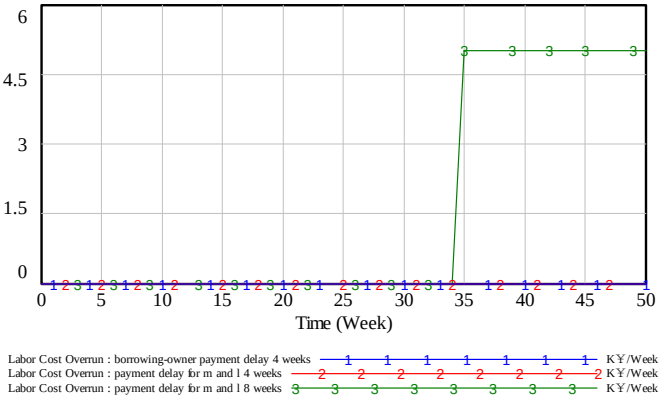
(a) Cash Balance in Scenario III



(b) Cumulative Profit in Scenario III



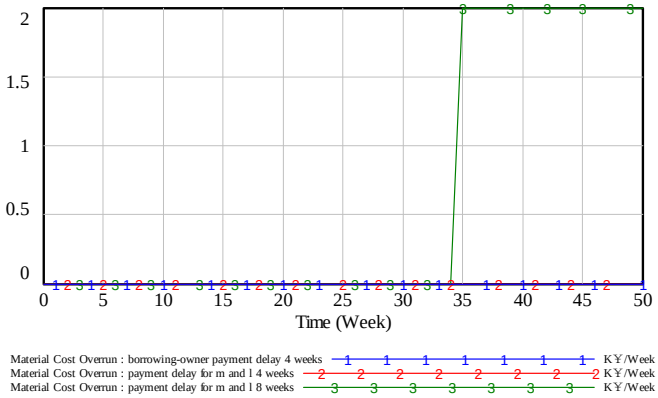
(c) Discount in Scenario III



(d) Labor Cost Overrun in Scenario III

Fig. 5 Simulation Results for Scenario III

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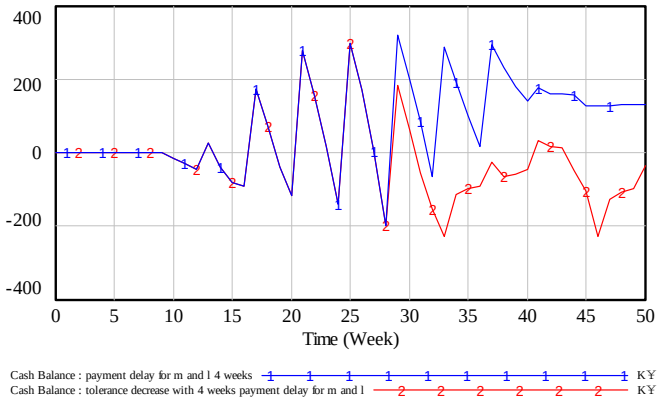
(e) Material Cost Overrun in Scenario III
Fig. 5 Simulation Results for Scenario III (cont.)

4) Scenario IV

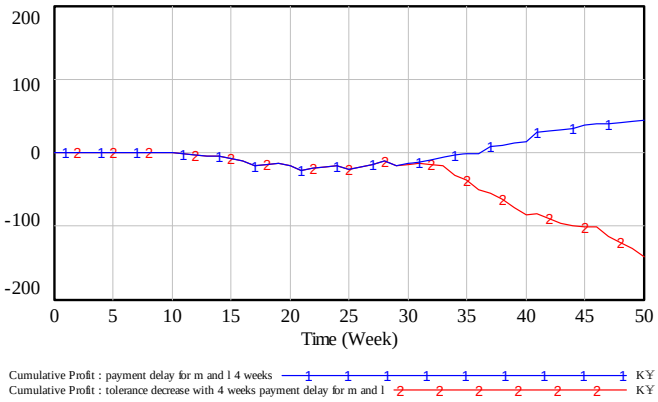
When payable to supplier and labor accumulate to certain amount (we call this amount as tolerance), material could not timely arrives in construction site and the incentive of construction workers decrease even they refuse to work, which will cause construction delay and material and labor cost overrun.

In Fig. 6(a) to 6(d), with 4 weeks payment delay for material and labor, curve 1 represents the tolerance of material suppliers and construction workers is 1.2 and 0.3 million RMB respectively, about half of total project material and labor costs. Curve 2 represents the tolerance decrease to 0.8 and 0.2 million RMB respectively, nearly one third of total project material and labor costs. Material and labor are more often unavailable with lower tolerance so less work is finished during the same period. Thus the contractor receives less payment from the owner which leads to less cash balance. On the other hand, slow construction process causes project delay and further the cost of material and labor overrun which results in cash outflow increase and profit decrease, in Fig. 6(a), 6(b), 6(c) and 6(d). Therefore, both of cash balance and profitability decrease with lower tolerance.

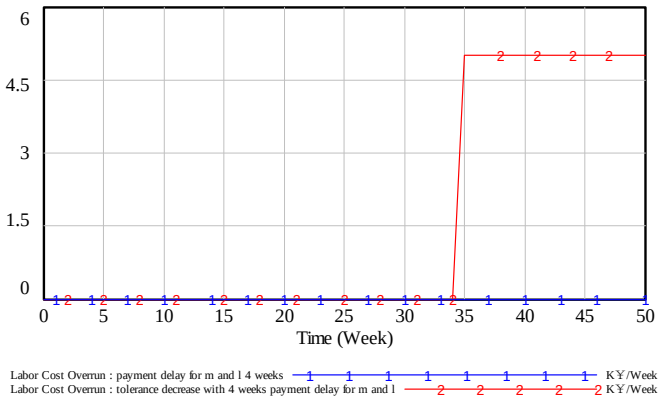
Curves 1 and 2 have similar meaning in Fig. 6(e) to 6(h) as curves 1 and 2 in Fig. 6(a) to 6(d) except the payment delay for material and labor changed into 8 weeks. The decrease of tolerance also reduces cash balance and profitability but the beginning time point of this state is earlier which is unfavorable to contractors. However, the cause of profitability decrease is not the material and labor cost overrun, since they have the same cost overrun. More interest income and less interest payment brought by more cash balance owning to more finished work account for the decrease of profitability, seen in Fig. 6(g) and 6(h).



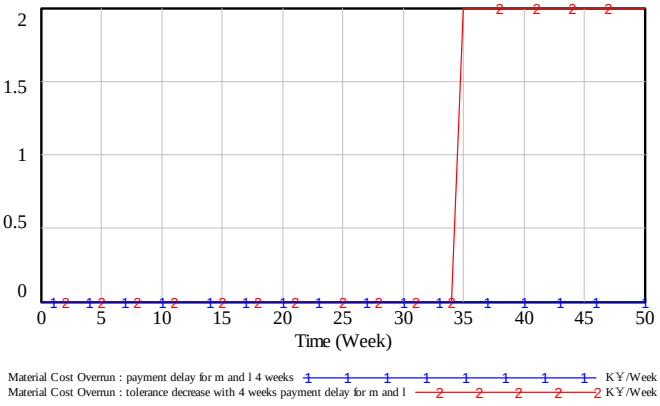
(a) Cash Balance in Scenario IV



(b) Cumulative Profit in Scenario IV



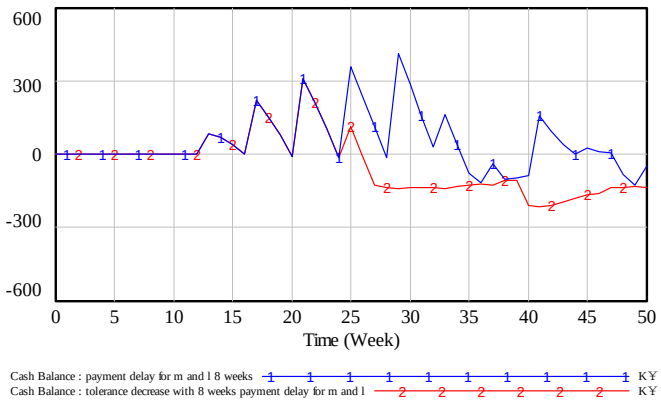
(c) Labor Cost Overrun in Scenario IV



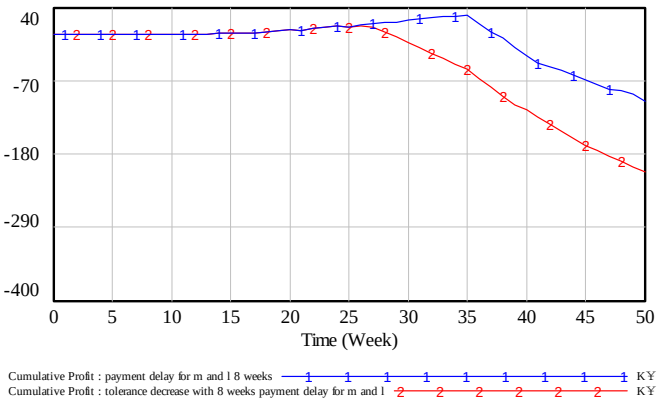
(d) Material Cost Overrun in Scenario IV
Fig. 6 Simulation Results for Scenario IV

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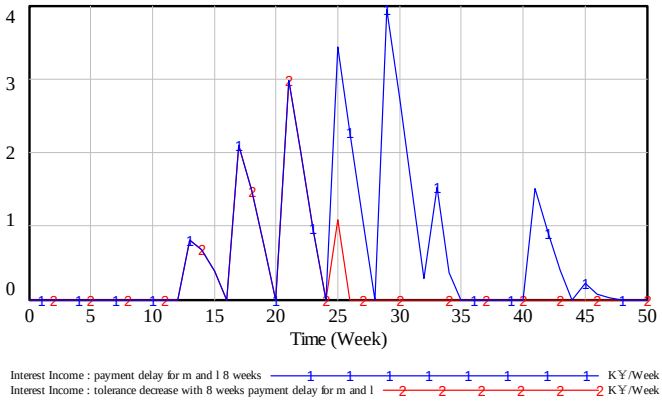
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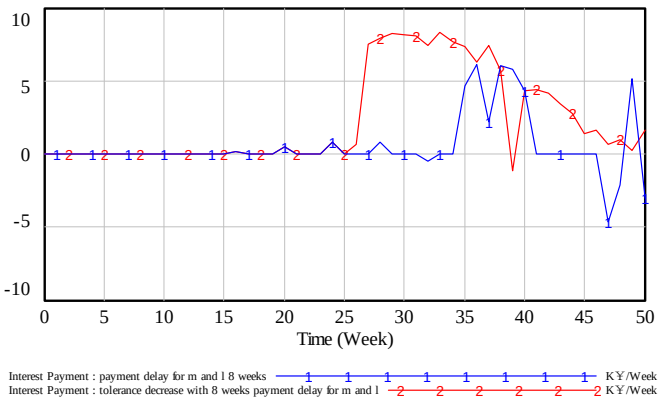
(e) Cash Balance in Scenario IV



(f) Cumulative Profit in Scenario IV



(f) Interest Income in Scenario IV



(g) Interest Payment in Scenario IV

Fig. 6 Simulation Results for Scenario IV (cont.)

V. Conclusion

In this paper the author proposed a SD model to simulate project cash flow system. The analysis of the impact of payment arrears which is pervasive in Mainland China on cash flow and profitability of construction project with real project data indicates that, generally, the longer the payment delay from owner, the more cash balance and profitability decline. The profitability suffers decrease with payment delay for material and labor though cash balance could be higher temporally. The decrease of tolerance of material suppliers and construction workers also reduces cash flow and profitability. The establishment of model and results are helpful for contractors' financial decision making when they try to maximize benefit of construction companies.

Acknowledgment

The work is supported by the Fundamental Research Funds for Central Universities in China under Grant No. CDJSK10-01 -59.

We gratefully acknowledge members of the Centre for Information Science & Technology of Chongqing, and the Laboratory of Intelligent Computing & Smart Services of Chongqing University, for their insights that make the paper into shape. In particular, we want to give thanks to Dr. Bin Cai for his support and Ms. Xueqin Shan for her comments.

Thanks also should be given to Dr. Yongbai and Dr. Jiahu Xu with the Kansas University for all support and inspiration, and Mr. Lin Ma for discussing topics on System Dynamics.

Many thanks also to the anonymous referees to comment our work.

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