

System Dynamics Approach to Progress Payment Regulations

JeongHoon Lee¹, Moonseo Park², Hyun-Soo Lee³, Sungjoo Hwang⁴

¹ Ph.D Course student, Seoul National University, 39, Daehak-dong, Gwanaak-gu, Seoul, Korea

² Professor, Seoul National University, Seoul, Korea

³ Professor, Seoul National University, Seoul, Korea

⁴ Ph.D Course student, Seoul National University, Seoul, Korea

Correspond to di5555@snu.ac.kr

ABSTRACT: The construction market condition is getting worse because of global constructions slow down, low profit, market contraction and so on. For these reason, most construction companies depend on public construction projects which possible to protect construction fee, known as progress payment, by laws. Despite this law, problems of progress payment are constantly occurring and it has been main factors that hinder the construction cost's cash-flow in construction project. To solve this problem, many researchers suggested various solutions but most of solutions were focused on specific target as owner, general contractor, and subcontractor. So, most of solutions were insufficient consider about interaction between contractors. Because of these reasons, it was hard to reflected policy. This research aimed to use system dynamics to develop the model for the application and payment based on the regulations and papers. Also, performed a developed model's verification based on progress payment regulation's basic objectives.

Keywords: Application and Payment Problem, Progress Payment, System Dynamics

1. INTRODUCTION

The recent construction conditions slowdown leads contractors to face fierce competition for winning contracts and profit decrease. Especially, 「Prospective of Construction in 2011」 says that the size and amount of the investment in construction is estimated to be decreased significantly compared to last year, accelerating financial difficulties of construction businesses in Korea. To solve this problem, many constructors are required to procure costs necessary to carry out projects on time by using the minimum financial costs [1].

If such costs necessary for executing projects are not available when needed, based on the business characteristics where only few contractors' conduct project with their own capital, businesses will have to secure costs by paying interests to the primary or private financial banking. In extreme cases, they may become bankrupt when their funding capacity is weak with cash flow problem. Following the results from survey on the status of professional constructors, conducted in December 2010 by the KOSCA (Korea Specialty Contractors Association), the deterioration of liquidity such as less order placement happened and payments problems increased bankruptcy and closure of businesses by 169% and 166% each from the previous year, respectively.

Therefore, smooth construction costs such as progress payment flow is an important factor for successful project and prevention of bankruptcy and closure caused by slow cost. The impact of such project performance based on

the construction costs flow will be greater for public construction involving large-scale projects.

Thus, the government stated regulation regarding public construction's progress payment on 「the State Contract Act in Korea」 to prevent conflicts in terms of payment and receipt. Therefore, ordering entities are required to follow guidelines based on the relevant regulation.

However, the statistics in Precedents in 「Construction Arbitrations in Korea, Vol. 3」 [2] shows that in despite of these regulations, disputes related to payment for public construction constantly occur every year and the amount is higher than that of private construction. The reason of current situation could be considered that public construction owner's major interest is to reach the expectable target without less damage such as payment frauds and industrial accident. So there has been not enough chance for construction contractors to consider cash-flow [3].

Also the priority of general contractors, subcontractors, and providers of materials and manpower is to make smooth cash flow and does not pay much attention to the impact of construction cost flow based on the contractual relation structure.

So, most studies have focused on specific subjects such as ordering entities, contractors, and subcontractors, which most concern about improvement from un-linear perspective. These approaches were effective to find partial answers to related subjects selected for problem identification survey on current progress payment.

However, in terms that application for and provision of current progress payment take place in nonlinear structure

with circulatory but diverse interests, Approach from dynamic perspectives is needed.

So, in this paper performed that based on the progress payment regulations on the application and payment. And the knowledge on interrelatedness uses system dynamics model that enables phenomenal analyses to generate modeling of the application and payment structure of progress payment.

After that, related to contracts variables will be quantitatively identified in terms of delayed application and payment in Korea. Finally, based on the simulation results, suggested solutions for application and payment problems.

2. RESEARCH OBJECTIVE AND SCOPE

The scope of this research is limited to laws related to the application and payment period that arises during a public construction projects. Because as for private construction projects, an implementation of laws related to progress payment cannot be concretely identified [4] and the impact of provision of current progress payment based on business sizes is greater, the matter pertaining to private construction projects was not considered.

As for regulations related to each contractor's relationships will occur based on various ways of order placement. However, the most general pattern, at the stage Owner, General contractors, subcontractors, and materials and manpower providers (M/M providers) were established [5]. Also, other systems such as direct payment to subcontractors are applied only to some particular situations so these were not considered in this research. The research process is as follows Figure 1.

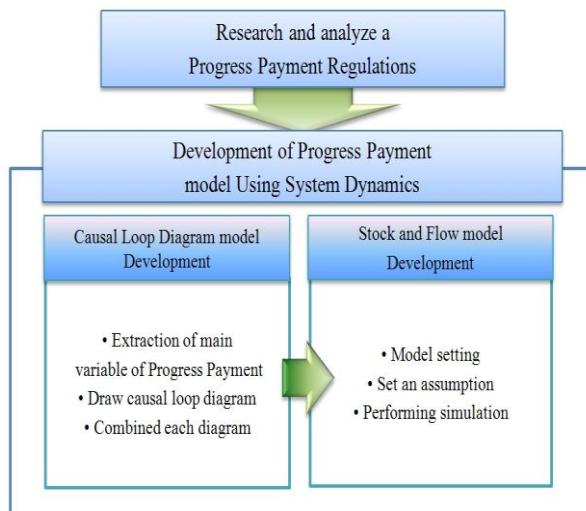


Figure. 1 Research Process

1) Based on a literature review, the current problems related to application and payment of current progress payment is identified.

2) Based on the analysis of construction stats and status surveys, the laws and problems related to application for

and provision of the current Korean public construction projects are analyzed

3) Based on the literature review conducted previously and existing laws, performing developed stock and flow model verification.

3. PRELIMINARY RESEARCH

3.1 Definition of Progress Payment

As most of public construction projects have larger scale than private one, ordering entities provide a certain amount of the contract price, as an advance payment, for smooth construction. After receiving, constructors use the money for the costs necessary at the beginning stage. And they ask for construction costs based on the current progress, which is called current progress payment [6].

Thus, progress payment can reduce financial burden and risk of constructors since they request for more expenses when necessary if it is carried out with its primary intent [4]. However, in order for constructors to receive current progress payment, the application for the completed part must first. Then, it requires certain time for evaluation before the final payment decision which leads to delayed payment.

3.2 Literature Review

Several studies have been researched payment problems and define main reasons. Wu et al [7] emphasized impact of construction payment problems, investigated legal issues related to payment in mainland China and compared with other nations' contract law. After that, try to explain how to prevent and address payment default in the construction industry through regulative measures using geometric models. Wibowo [8] performed surveys, researched how the money invested in construction flows through the economy and developed interactions between main factors by contractors' expenditure model using soft system model. William [9] reviews a several court cases relating to concurrent delay between general contractor and subcontractor. Also, try to confirm the impact of concurrent schedule delays to general contractor and subcontractor using a warehouse project as a case study. Ardit and Chotibhongs [10] performed a questionnaire surveys related to subcontracting issues and administered to subcontractors, general contractors, and owners to determine the difference in perceptions between the parties. Keane et al [11] represents an analysis of the most likely causes and effects of variations on construction projects and emphasis on delay in payment can lead to an increase in project cost due to interest rates.

In Korea, the following studies were conducted to solve problems related to the application for and provision of current progress payment.

Shim [3] based on interviews with practitioners and a literature review, suggested ways to improve multi-level subcontracting structure that takes place publicly and emphasized the importance of payment through improvement of the multi-level subcontracting structure.

Kim [12] identified eight problems on the construction sites of Korea based on interviews and surveys, suggested ways to improve, and stressed the reasonable construction cost estimation and payment. Ku [13] analyzed the operation status based on interviews with people related to constructions with the lowest winning price and found that the biggest problem was the financial liquidity among ordering entities, contractors, and subcontractors. He suggested measures that can be applied by ordering entities, contractors, and subcontractors. Lee [14] interviewed with people on construction sites to derive problems with the estimation and methods of provision of current progress payment and to provide short and mid-term ways for improvement. Park [15] derived major elements necessary for win-win cooperation between general contractors and subcontractors and stressed that the importance of compliance with time limit for current progress payment was very important. Lee [16] analyzed major issues and judicial precedents related to direct payment to subcontractors by ordering entities in order to minimize damages done to subcontractors arising from bankruptcy of contractors, etc. and to suggest matters for the protection of subcontractors.

In summary, the common problem identified in most of the studies is that the laws does not properly support current progress payment in relation to the application for and provision of current progress payment. Also, various problems of regarding current progress payments are identified as major factors. And deteriorating financial structures of companies engaged in construction and suggestions to solve these problems were provided.

However, most of the studies were based on surveys and literature reviews, resulting in insufficient grounds for structural system analyses where the application for and provision of current progress payment takes place. Also it was difficult to identify the mutual impacts between and among construction contractors based on quantified numbers and the suggested solutions was limited to specific subjects.

3.2 Progress Payment Problem of Korea

Based on 「the State Contract Act in Korea」, the progress payment must take place at least every 30 days but constructors have to ask *higher-level* –which is defined as the contract position is directly high-companies or ordering entities for the relevant documents. Hence, necessary period for the application for such documents is not separately provided by laws and differs by time of preparation and workload of constructors applying for it. So, this workload is relating a simplification for the application process. For this reason, there are two types of documents submitted by constructors to public construction ordering entities, which are regular payment documents and simplified payment documents.

General Conditions for Constructions based on 「the State Contract Act」(Established Accounting Rules 2200.04-104-19) says that every third application should be prepared with full documents for payment but the first and second applications are allowed with simplified

payment document in order to save time for both contractors for document preparation ordering entities for efficient reviewing. However, this regulation is not condignly performed in the field. Actually, based on studies on methods of progress payment not only some central government agencies as ordering entities but also most of the local governments as ordering entities are not aware of simplified payment method so the current institution is not taken advantages. [14]

Relating payments regulation mentioned about ‘due date for payment to under contractor’. Due date means that the date when payment is actually made; it is the date that contractor start counting the days to the ‘final date for payment’ which is when contractor actually get contractors’ hands on the money [17]. So, if high level contractor passed the due date for payment, under contractor could be occurred financial crisis. Nevertheless, recent survey shows that overdue the payment problems continually happened and it considered main reason for subcontractors’ bankruptcy [18].

3.2 System Dynamics

System dynamics, after the development by Professor Forrester, MIT, has become one of the most widely used analytic methods for industrial, economic, social, and environmental systems. One of the strong characteristics of system dynamics is the provision of dynamic methodologies to analyze complex nonlinear systems [19].

Methods of system dynamics modeling expressions are to use arrows to indicate the impact levels between and among variables and they make mutual feedback loops as Table 1.

Table 1. System Dynamics Diagram [20]

Diagram	Description
	Variable A's increase (decrease) will increase (decrease) variable B. When all other conditions are identical
	Variable A's increase (decrease) will increase (decrease) variable B.
	Critical time delay is to be included to satisfy the causal relationships between variable A and variable B.
	Defined as rates or flow that change stock in system
	Defined as stock or level as a variable saved as a system result

After that, the impact level between and among stakeholders will be simulated based on the control of major variables. Stock & Flow means a quantity

saved and flow works as a valve to adjust entrance into and exit out of the stock. Variables mean those of human relationships that can control the increase or decrease of flow [20].

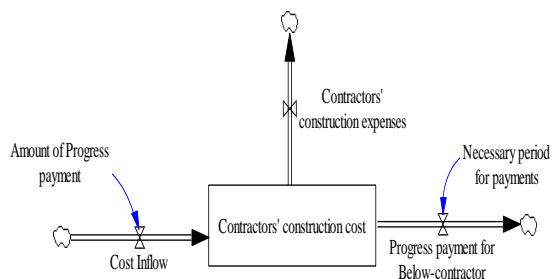


Figure 2. Examples of Stock and Flow

Previous studies related to system dynamics analyzed for the analysis of the above modeling are as follows. Park [21] provided an example of Singaporean government that strengthened construction productivity with the model and suggested the direction for policy establishment process through simulation. Pena-Mora [22] suggested a hybrid model to solve the problem of mismatch between strategic analysis and operational analysis. This model is combines system dynamics and discrete event simulation. Also, application example a earthmoving process is selected and simulated. Hwang [23] suggested for a feasibility assessment of housing demand adjustment policies, used system dynamics to simulate the housing market changes according to governmental policies.

The dynamic and structural perspective of system dynamics to solve problems with policies and industry provides big advantages to identify the impact of specific factors in construction on the overall system.

Accordingly, this research used the comprehensive and structural approach of system dynamics while placing the basic model for simulation and modeling as the basis of the current laws. As for the period for application and payment, an independent variable, the estimates derived through the legal grounds and literature reviews were used for the analysis of stock, a dependent variable, through the inflow and expense adjustment.

4. MODEL DEVELOPMENT

4.1 Causal Loop Diagrams (CLD) Development

Considering a general condition of progress payment process, relationship between owners and general contractors has the highest contract priority [24]. Fig.3 shows that basic model of general contractors' progress payment application process. *General contractors' progress payment application* – which is defined as the general contractors' application documents and it contains requesting amount of payment – affects *amount of owner's payment* – which is defined as that owner accepted all of the general contractors' requested amount of payments but actual payment is not yet– and depending

on whether it done in initial contract period or not, *general contractors' construction cost liquidity* affected (B1).

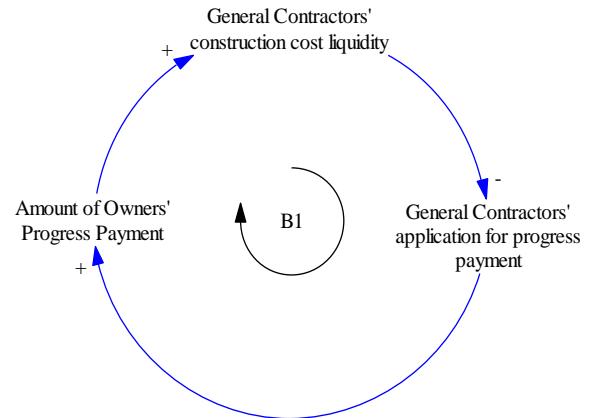


Figure 3. General Contractors' Progress Payment Application

However, general contractors needed a preparation of documents as *General contractors' applied workload*. Therefore, most regulation and laws were set the applications of progress payment process performed at particular period, likely the end of each month or at monthly intervals. In this paper, however, set the applications of progress payment period depending on each contractor's holding amount of construction cost and limited not exceed a month. It is because progress payment applications worked based on actually performed in place, and these actual performing are continuing occur during the prior application period. So contractors suffer from lack of construction cost before secure the payment of prior application, and it can cause contractors' unwanted bankruptcy.

Following with these assumptions, this study develops relationship between owners and general contractors causal loop diagram.

Fig.4 shows that *General contractors' application for progress payment* affects *Owners' burden to review documents* because most application forms consists of paper and it contains lots of specialized information. *Owners' burden to review documents* decides whether *Owners' progress payment delay* happens or not. And if *Owners' progress payment delay* happened, it affects directly *General contractors' construction cost liquidity* (R1). Also, regardless of *General contractors' application for progress payment*, this variable affects *General contractors' applied workload* and it decided *General contractors' delay in application level* (R1-a).

Of course, the roles of both loops, once the application and review are over, become insignificant. The counter effects of these two loops are continued as the frequency of application increases along with temporary decreases of the construction costs liquidity coming from delayed payment of ordering entities

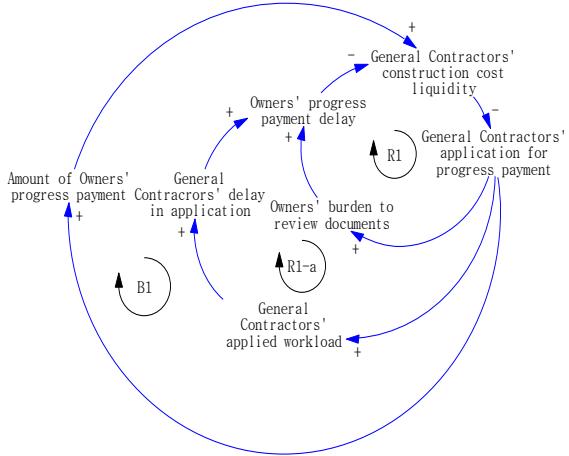


Figure 4. Progress Payment Process Between Owner and General Contractor

As illustrated by Figure 4 shows that payment relationship of between general contractors and subcontractors. According to the *General contractors' construction cost liquidity* determines *General contractors' payment delay* and affecting *Subcontractors' construction cost liquidity*. *General contractors' construction cost liquidity* decides *subcontractors' application for progress payment* the ordering entity's progress payment amount, result a virtuous cycle loop that maintains liquidity at a certain level (B2).

However, the *subcontractors' application for progress payment* is made toward a general contractor, resulting in a loop (R2) that affects *General contractors' construction costs liquidity*. Also *Subcontractors' applied workload* leading to *Subcontractors' delay in application*, it caused by *General contractors' payment delay* (R2-a).

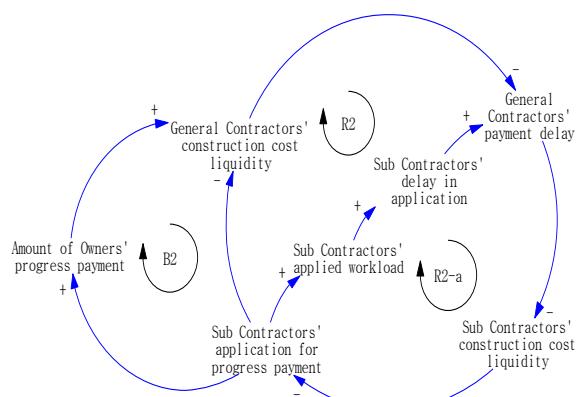


Figure 5. Progress Payment Process between General Contractors and Subcontractors

Fig 5. shows that like the relationship between general contractors and sub-contractors, *Subcontractors' construction costs liquidity* affects *subcontractors' payment delay*, determining *m/m provider's construction cost liquidity*. The *m/m provider's application for progress payment* based on costs liquidity affects *Amount of Owner's progress payment* (Loop B3: *m/m provider's application for progress payment* → *Amount of Owner's progress payment* → *General contractors' construction cost liquidity* → *General contractors' payment delay* →

Subcontractors' construction cost liquidity → *Subcontractors' payment delay* → *m/m Provider's construction cost liquidity* → *m/m Provider's application for progress payment*) adjusts the construction costs liquidity.

However, *m/m provider's application for progress payment* target is a subcontractor, so it affects the *Subcontractors' construction cost liquidity* (Loop R3: *m/m Provider's application for progress payment* → *Subcontractors' construction cost liquidity* → *Subcontractors' payment delay* → *m/m Provider's construction cost liquidity* → *m/m Provider's application for progress payment*). Also, increase in *m/m Provider's application for progress payment* occurs *m/m Provider's delay in application* Loop (R3-a).

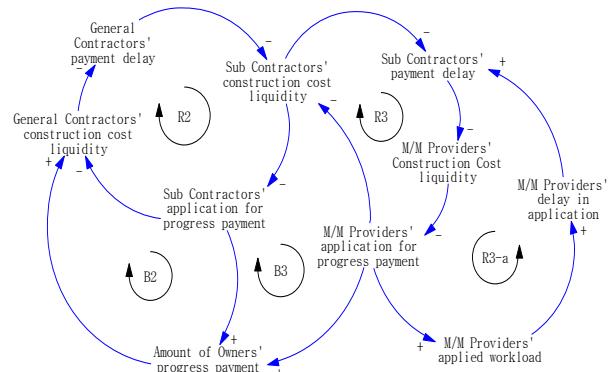


Figure 6. Progress Payment Process Between General Contractors and Sub Contractors

4.2 Stock and Flow Model Development

For quantitative analysis, Figure 7 Stock and Flow model for progress payment developed based on from Figure 1 to Figure 6 models. In this stage, each contractor's amount of progress payment set as Flow. Also, the flow of each contractor's payment goes into set as Stock, named a Capital of each contractor.

Basically, each contractor has two outflows; contractors' expenses and progress payment for below contractor. Contractors' expenses including an Amount of contractors' wages paid and Amount of contractors' construction cost. These variables result are constant and not effected by regulations or other construction circumstance.

5. VERIFICATION OF THE MODEL FEASIBILITY

In this stage, performed a more objectives to obtain accurate main simulation results, perform a base case simulation for verification of model feasibility. The conditions of base case results that each contractor's minimum amount of capital more than zero during the total construction period and each contractor's cash flow have to show a regular pattern. Also, each contractor's initial value – which is defined as advance payment– set by general conditions and it is calculated each contractor's total construction cost * 30%.

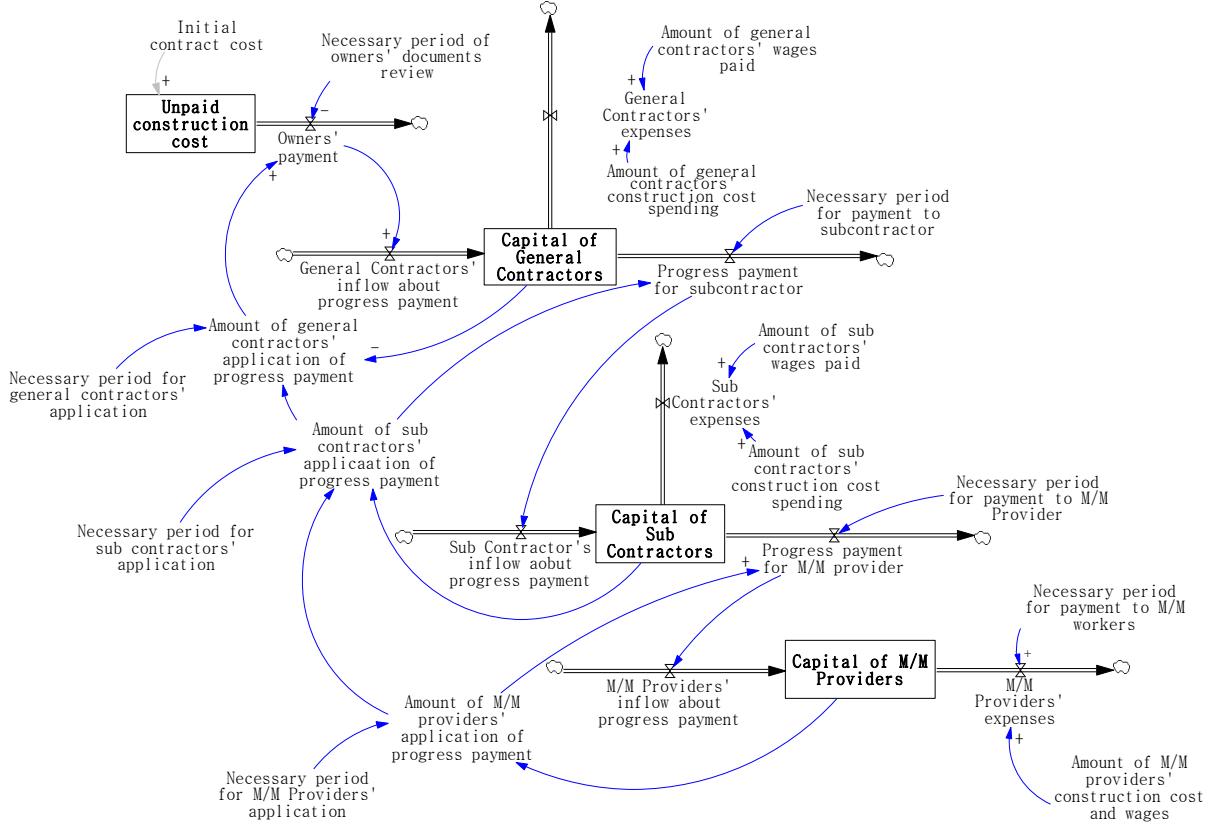
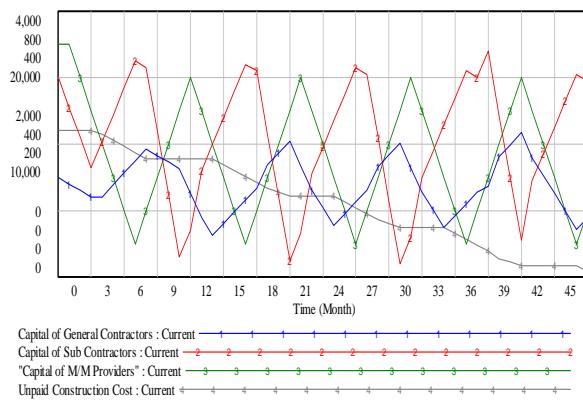


Figure 7. Progress Payment Stock and Flow Model

Each contractor's total construction cost is set a rate of between each contracts based on 'Value of Construction works completed by Ordering Agency and Scope of Work (General contract, Subcontract) 2006, Statistics Korea'. So, total construction cost is 11000, general contractors 5500, subcontractors 3300, m/m providers 2200 (units: million).



* The Y-axis is each of the three groups of figures from the circle at the top of the figure general contractor, subcontractor, M/M Provider, total construction cost reserves the construction financing (million).

Figure 8. Base Case: Smooth Application and Payment of Progress Payment

As a result, it is found that the overall costs flow of contractors satisfies the purpose of current progress payment, 'The minimum construction costs secured > 0' ;

indicates that the minimum value of each contractor's construction costs graph is over '0' as shown Fig 8.

6. CONCLUSION

This research developed a progress payment regulation model based on the current laws, application and payment problems. After that, we performed a developed model's validation to application of progress payment delay duration based on basic assumption.

Developed model will be applicable to how much affect each participant's cash flow as a progress payment duration changes. However, this research was conducted based on the current legal standards, limited information and a comprehensive analysis in consideration of more diverse variables constituting the current application for and provision of current progress payment has not taken place, which is a limit.

In the future, based on this research, major factors leading to delayed application for and provision of current progress payment shall be identified based on questionnaire surveys and literature reviews so that a causal loop can be generated. The quantification of this shall be attempted while its results shall lead to further studies on solutions to each major factor related to the application for and provision of current progress payment.

REFERENCES

- [1] Smith-Daniels, Dwight E., Padman, Rema., Smith-Daniels, Vicki L, "Heuristic scheduling of capital

- constrained projects", *Journal of Operations Management*, Volume 14, Issue3, pp.241~254, 1996.
- [2] Park, Sam-kyu, "Precedents in Construction Arbitrations, Vol. 3 Construction Arbitration", *The Korean Commercial Arbitration Board*, pp.3~9, 2006.
- [3] Shim, Gyu-buhm, "Ways to Improve the Multi-level Subcontracting System", *The Construction & Economy Research Institute of Korea*, 2006.
- [4] Lee, Sang-buhm, "A Way to Adjust Construction Cost based on the Introduction of Payment Regulations for Construction Projects", *The Korea Institute of Building Construction, Collection of Papers*, Vol. 10, Issue 1, pp.175~181, 2010.
- [5] Albert Bates Jr., L. Tyrone Holt, "Large, Complex Construction Disputes: Dynamics of Multiparty Mediation", *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, pp.58~62, 2011.
- [6] The Ministry of Science-Technology, "Engineering Business Contract and Claim Management Techniques", pp.228~229, 1995.
- [7] Wu, Jin., Kumaraswamy, Mohan., and Soo, Gary , "Regulatory measures addressing payment problems in the construction industry: A calculate understanding of their potential outcomes based on Gametric Models", *Journal of construction engineering and management*, pp. 566~573, 2011.
- [8] Wu, Jin., Kumaraswamy, Mohan., and Soo, Gary , "Regulatory measures addressing payment problems in the construction industry: A calculate understanding of their potential outcomes based on Gametric Models", *Journal of construction engineering and management*, pp. 566~573, 2011.
- [9] Lbbs, William., Nguyen, Long D and Simonian, lonny, "Concurrent delays and apportionment of damages", *Journal of construction engineering and management*, pp. 119~126, 2011.
- [10] Ardit, David ., Chotibhongs, Rannon, "Issues in Subcontracting Practice", *Journal of construction engineering and management*, ASCE, pp.886~876, 2005.
- [11] Keane, Patrick., Sertyesilisik, Begum and Ross, Andrew David, "Variations and change orders on construction projects", *Journal of legal affairs and dispute resolution in engineering and construction*, pp. 89~96, 2010.
- [12] Kim, Woo-young., Lee, Boak Nam., Lee, Young Hwan and Sung, You Kyong, "The diagnosis of eight problems on Korea's construction sites and ways for improvement", *The Construction & Economy Research Institute of Korea*, 2007.
- [13] Ku, Bon-sang., Jang, Hyeon-seung, "Analyses of the Status of Construction Sites Applying the Lowest Bidding Price with Slow Construction Economy and Ways for Improvement", *The Korea Institute of Construction Engineering and Management, Collection of Papers*, Vol. 10, Issue 6, pp.146~154, 2009.
- [14] Lee, Young-hwan., Choi, Seok-in,"A Way for the Improvement in Handling and Procedure of Progress Payment on Construction Sits", *Construction Issue Focus, Construction Economy Research Institute of Korea*, 2009.
- [15] Park, No-sung., Kim, Han-soo, "An Analysis on the awareness of commensally cooperation between contractors and subcontractors in Korean construction", *The Korea Institute of Construction Engineering and Management, Collection of Papers*, Vol. 10, Issue 5, pp.28~37, 2009.
- [16] Lee, Dong-hoon et. al, "An Analysis of Important Judicial Precedents related to the Direct Payment to Subcontractors", *The Korea Institute of Building Construction, Paper Collection*, Vol. 10, Issue 1, pp.111~121, 2010.
- [17] National Specialist Contractors Council (NSCC), "Taking control of the payment process – Guidance on the construction Act for specialist contractors, 2011.
- [18] The KOSCA, "A report for analyses of the status of professional constructors", *The Korea Research Institute for Construction Policy*, 2011.
- [19] Kwak, S, "Policy analysis of Hanford tank farm operations with system dynamics approach." Ph.D Dissertation, The Massachusetts Institute of Technology, 1995.
- [20] Sterman, J.D, "Business Dynamics, Boston: Irwin" McGraw-Hill, pp.191~232, 2000.
- [21] Park, Moon-seo et al, "An Analysis of Construction Policies via System Dynamics", *The Agricultural Institute of Korea (Structural System)* Vol. 21, Issue 5, pp.123~135, 2005.
- [22] Feniosky Pena-Mora, Sangwon Han, SangHyun Lee and Moonseo Park, "Strategic-Operational Construction Management: Hybrid System Dynamics and Discrete Event Apporach", *Journal of Construction Engineering and Management*, 2008.
- [23] Hwang, Seong-ju, Park,Moon-Seo., Lee,Hyun Soo, Kim, Hyun Soo. "A feasibility study on the policies to adjust the housing demand based on system dynamics simulations", *The Korea Institute of Construction Engineering and Management, Collection of Papers*, Vol. 11, Issue 5, pp.32~41, 2010.
- [24] Curtis R.Reitz, "Construction Ledears' Liability to Contractors, Subcontractors, and Materilmens", *The University of Pennsylvania Law Review*, pp 416-459, 1981.