RAPID RETURN ON INVESTMENT BY INNOVATIVE METHODS IN CONSTRUCTION VISUALIZED BY CASH FLOW MODEL

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Abstract

The introduction of innovative methods such as automation and robotics in construction improves productivity, quality and safety of construction. Due to economic downturn and lack of economic feasibility, the development of new machinery based on construction systems during the 1990s stopped prior to achieving the necessary Return On Investment (ROI). Therefore, the authors identified that it is necessary for innovative construction methods, that the owners or clients should demand an individual profit regarding to the building construction process. In the past, the manufacturing companies harvested the benefits of productivity improvement by innovative construction methods for cost reduction. The companies did not emphasize on the profit for the owners. In this paper, the authors analyze and visualize how previous applications of innovative construction methods on relatively large-scale construction sites, changed the cash flow of the project life. A simulation, analysis, and comparison of the trade-off of various effects to cash flow, by shortening the construction period despite an increase in cost by innovative construction methods, are proposed. An analysis is developed on how big the amount of the profit benefits has to be, in order to not just benefit to owners, but also cover the expenses for research, development and management operations required to develop and implement innovative construction methods. Techniques and methods from the financial engineering field are introduced in order to evaluate profit and expense margins. The authors are also aware of the risks involved in such an evaluation, by considering the fluctuations of the rent income to be provided from the finished building using the Monte Carlo technique. The aim of the proposed cash flow approach to innovative construction methods is to set up an economic framework in which technological development can exist. The outcome of the approach shall complement technological driven approaches to innovative on-site construction methods and later serve as a basis for future technically oriented research.

Keywords: discounted cash flow, Monte Carlo Technique, Net Present Value and Return on Investment.

1. OVERVIEW OF THE STUDY

1.1. Background and Objectives

The introduction of innovative methods such as automation and robotics in construction improves productivity, quality and safety. Due to economic downturn and lack of economic feasibility the development of new machinery based on construction systems during the 1990s stopped prior to achieving the necessary Return On Investment (ROI). Therefore, the authors identified as a major research question that for the expansion of market and individual profit, it is necessary for buildings owners to demand innovative construction methods. In the earlier years, the manufacturing companies harvested the benefits of productivity improvement by innovative construction methods for the purposes of cost reduction, without emphasizing owner related profit.

In this paper, the authors analyze and visualize how previous applications of innovative construction methods to relatively large-scale building construction site changed the cash flow of the project life. Additionally, a simulation, analysis, and comparison of the trade-off of various effects to cash flow by shortening the construction period despite an increase in cost by innovative construction methods, are proposed. An analysis on how big the amount of profit benefits have to be, in order to not just benefit to owners but also cover the expense for research, development and management operations necessary to develop and implement innovative construction methods.

1.2. Methods

Project worksheets are considered as well as calculations of the cash-in and the cash-out at each point during the project life. Furthermore, techniques from the financial engineering field, in order to evaluate profit and expense margins are utilized. The authors are aware of incurred risks in this evaluation, by considering the fluctuations of the rent income to be provided from the completed building using the Monte Carlo technique. The aim of the proposed cash flow approach in innovative construction methods is to set up an economic framework in which technological development can take place.

2. OUTLINE OF MODELING

2.1. Building typology

Initially, the building typology is defined, which is later analyzed in this paper. A new high or middle-rise apartment building with standard quality grade is considered for this analysis. This apartment is intended for renting and they will be located in Tokyo, Japan.

It is assumed that the building is completed by a standard construction method in a time frame of 20 months. The information about the term of work is quoted from the ``Council of Japan construction industry employees' unions´´ (2012).

The total sum of construction costs is defined at 250,000 yen/m^2. This yields approximately 2,000 euro/m^2 at an exchange rate in January 2013. This construction cost is taken from the database of the ``Japan Building Cost Information´´ (JBCI) 2012 published by the Construction Research Institute. JBCI comprises cost information announced for the feasibility study, planning and basic design stage of the building project by Construction Research Institute. This was compiled and analyzed statistically in real construction contracted prices, which were collected from construction companies and architectural design offices.

The authors define the rent income of this building from related information for customers on the website of properties for rent located in Tokyo, Japan. The rent is 250,000 yen / month for an area of approximately 70 m^2. It is 2,000 euros /m^2 at an exchange rate in January 2013.

In addition, all financial values in this paper make the total sum of the construction cost an index, i.e. 100. The cost of construction fixes it to the equivalence and observes the change of other variables even if using any method in this paper shortens the construction time frame.

2.2. Innovative construction methods Applied to Model

The construction period is reduced from a standard construction method (20 months) down to 15 months, 10 months and 5 months, by utilizing innovative construction methods. No specific construction methods are suggested for application to this model. The purpose is to quantify the influence the cash flow has on the whole project life. In other words, the purpose is to clarify the change of the Net Present Value (NPV) of the project by the proposed construction methods. On the basis of the above, the followings can be depicted regarding new construction methods proposed in this paper:

Initially, Ando et al. (1983) suggested multi-site scheduling presented in Figure 1. Using this approach the construction time was reduced by carrying out parallel activities into divide sites. This method has already been adapted to many actual projects in Japan.

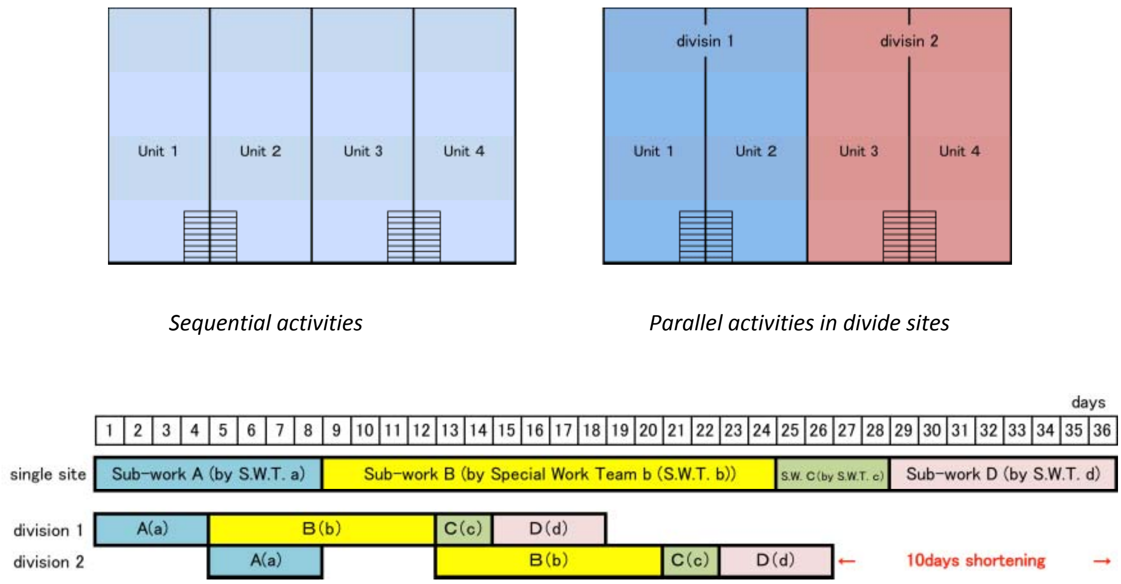

Figure 1: Effect of construction time reduction by parallel activities in divide sites

Figure 2 depicts such an example. Furthermore, the construction time can be dramatically shortened if all sub-works can be implemented on the same time reference. This construction method requires an increase in costs due to the higher management of the supply chain of materials and components, enhanced crane activity and the adjustment of the contract contents between some sub-contractors.

Figure 2: Example of parallel activities in divide sites

Secondly, Kanisawa et al. (2003) suggested the introduction of multi-skilled workers in real building construction sites. The skills of the construction workers were specialized to the scope of specific tasks, and this lead to the rigid Union shops in Germany, U.S.A. and Japan. The introduction of new methods to the building construction lowers their rate of operation and tends to disturb improvement of the productivity. Introduction of multi-skilled workers improves the productivity of fragmented works. It disturbs the spread to entail special costs for their upbringing.

Another construction method developed recently is the super-high-speed construction that Chinese company "Broad Group". According to the movie shown on their website (http://www.broad.com), they built a 30-storey hotel by a system which incorporated most of its facilities in the slab components beforehand, in only 15 days. In a big market such as China where economic development is remarkable, such a method of construction may spread to enable rapid ROI.

2.3. Model of the Cash Flow

Assuming the building models and applied techniques mentioned above, the authors describe the summary of the cash flow in the whole project life consisting of the design stage, construction stage, rental stage, and remaining value evaluations showed (Figure 3).

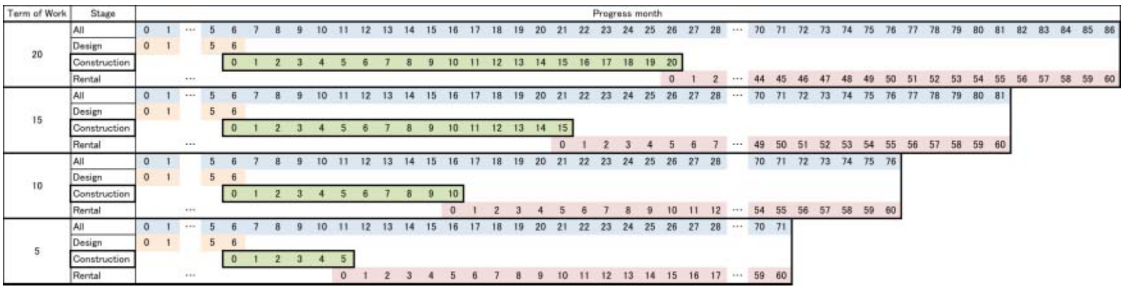

Figure 3: Model of project life

The discount rate for the monthly cash flow it is assumed at 1/12 of the annual discount rate. The standing point of the present value of the cash flow sets it at the time of the project start, i.e. month 0.

Design stage: It is supposed that this building is designed within 6 months and the involved designed costs comprise 10% of the construction costs. The authors contacted a contractor and a design office to make this model simple in the analysis of the cash flow. But this does not mean the design and build contract.

The design progresses every month during the design stage and the owner pays the design fee to the design office periodically every month. The sales amount gross profit rate of a design office sets it with 6.5%. If the discount rate is 0% on all project stages, this means that the design office's NPV would be 0.65. When the design office completes the design, this eventually costs 10. The design office pays the expense equally every month.

Construction stage: The sales amount gross profit rate of a contractor sets it with 6.5%. If the discount rate is 0% in the whole project life, this means that the contractor's NPV is 6.5. When the contractor completes the construction, it costs 100. Three during the term of work divides the payment for the works. This payment condition is based on some real contracts of apartment construction in Japan. The contractor pays the expense equally every month to sub-contractors, Material suppliers, etc.

– The owner pays 30% of the construction cost to the contractor at the beginning phase.

– The owner pays 30% of the construction cost to the contractor after 2/3 of the term of work.

– The owner pays 40% of the construction cost to the contractor at the completion of work stage.

Rental stage: This building is a configured apartment for rental purposes. The length of the rental stage is 60 months. The series of the rent incomes, change setting by simulations are mentioned in section 3. The details of the setting will be also explained in section 3.

Remaining value evaluations: The residual value of this building becomes zero after 20 years with the introduced discount on the fixed amount, on every month during the rental stage.

2.4. Matter to simulate

In this paper, the authors examine the following three points. These points are the consequences of shortening the term of work. In other words, it is confirmed how NPV of the project is thereby changed.

– The contractor can get the money for construction work earlier.

– The owner can start the rental stage earlier.

– The occurring fluctuations of owner's income in the rental stage due to the widely varying rates of vacancy over time.

In Japan, the shortness of pay back period of the project often becomes the important condition when banks provide a loan to an owner. The economical and the social environment of the construction projects significantly changed in the past time. Therefore the real profit to be provided from the project by time progress tends to considerably vary from the basic business plan. On a high-risk project, the shortness of the payback period may have priority over the maximization of the profit from it.

3. RESULT OF SIMULATION

3.1. Present Value of the Cash Flow

The cash flow during an assumed 5-months term of work project life based on the proposed method is given below (Table 1 and Figure 4). The cash in of the owner begins after entering the rental stage, once the building is completed. The contractor's NPV is 7.15 (=110*6.5%), as explained later. In this setting, the owner's NPV is 50.71. NPV are the same even if they shorten the term of work using any technique on this condition in defiance of the discount rate.

All		0	1	2	3	4	5	6	7	8	9	10	11	12	13	···	69	70	71
Design		0	1	2	3	4	5	6											
Construction								0	1	2	3	4	5						
Rental													0	1	2	···	58	59	60
Owner	Cache In	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.43	1.43	···	1.43	1.43	76.43
	Cache Out	0.00	0.00	0.00	0.00	0.00	0.00	-40.00	0.00	0.00	-30.00	0.00	-40.00	0.00	0.00	···	0.00	0.00	0.00
	Cache Flow	0.00	0.00	0.00	0.00	0.00	0.00	-40.00	0.00	0.00	-30.00	0.00	-40.00	1.43	1.43	···	1.43	1.43	76.43
	Present Value	0.00	0.00	0.00	0.00	0.00	0.00	-40.00	0.00	0.00	-30.00	0.00	-40.00	1.43	1.43	···	1.43	1.43	76.43
	Net Present Value	0.00	0.00	0.00	0.00	0.00	0.00	-40.00	-40.00	-40.00	-70.00	-70.00	-110.00	-108.57	-107.14	···	-27.14	-25.71	50.71
Contractor	Cache In	0.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	0.00	30.00	0.00	40.00						
	Cache Out	0.00	-1.56	-1.56	-1.56	-1.56	-1.56	-1.56	-18.70	-18.70	-18.70	-18.70	-18.70						
	Cache Flow	0.00	-1.56	-1.56	-1.56	-1.56	-1.56	38.44	-18.70	-18.70	11.30	-18.70	21.30						
	Present Value	0.00	-1.56	-1.56	-1.56	-1.56	-1.56	38.44	-18.70	-18.70	11.30	-18.70	21.30						
	Net Present Value	0.00	-1.56	-3.12	-4.68	-6.23	-7.79	30.65	11.95	-6.75	4.55	-14.15	7.15						

Table 1: Worksheet of cash flow calculation (5-months term of work project)

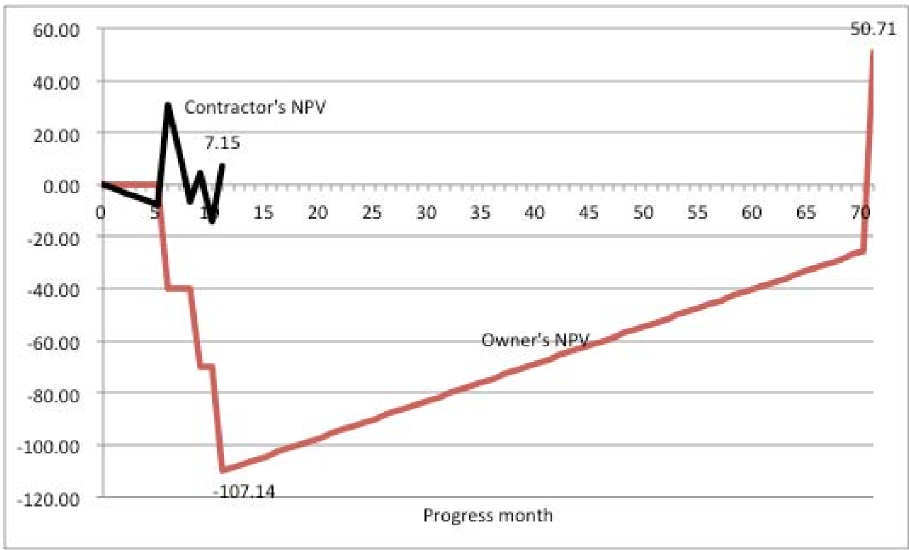

Figure 4: Change of NPV (5-months term of work project)

3.2. Present Value of the Discounted Cash Flow

DCF analysis yields the overall value of a business, including both cash out and cash in. DCF analysis is a technique determining what a business is worth today in light of its cash yields in the future.

Table 2 shows NPV discounted at 10% with all other conditions the same as Table 1. As for NPV of the contractor it falls from 7.15 to 6.55 and the owner one falls from 50.71 to 0.57. The influence of the discount rate strongly appears to the owner having a long rental stage.

All		0	1	2	3	4	5	6	7	8	9	10	11	12	13	···	69	70	71
Design		0	1	2	3	4	5	6											
Construction								0	1	2	3	4	5						
Rental													0	1	2	···	58	59	60
Owner	Cache In	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.43	1.43	1.43	1.43	1.43	76.43
	Cache Out	0.00	0.00	0.00	0.00	0.00	0.00	-40.00	0.00	0.00	-30.00	0.00	-40.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cache Flow	0.00	0.00	0.00	0.00	0.00	0.00	-40.00	0.00	0.00	-30.00	0.00	-40.00	1.43	1.43	1.43	1.43	1.43	76.43
	Present Value	0.00	0.00	0.00	0.00	0.00	0.00	-38.06	0.00	0.00	-27.84	0.00	-36.51	1.29	1.28	0.81	0.81	0.80	42.40
	Net Present Value	0.00	0.00	0.00	0.00	0.00	0.00	-38.06	-38.06	-38.06	-65.90	-65.90	-102.41	-101.12	-99.83	-43.44	-42.63	-41.83	0.57
Contractor	Cache In	0.00	0.00	0.00	0.00	0.00	0.00	40.00	0.00	0.00	30.00	0.00	40.00						
	Cache Out	0.00	-1.56	-1.56	-1.56	-1.56	-1.56	-1.56	-18.70	-18.70	-18.70	-18.70	-18.70						
	Cache Flow	0.00	-1.56	-1.56	-1.56	-1.56	-1.56	38.44	-18.70	-18.70	11.30	-18.70	21.30						
	Present Value	0.00	-1.55	-1.53	-1.52	-1.51	-1.49	36.57	-17.64	-17.50	10.49	-17.21	19.44						
	Net Present Value	0.00	-1.55	-3.08	-4.60	-6.11	-7.60	28.97	11.33	-6.17	4.32	-12.89	6.55						

Table 2: Worksheet of discount cash flow calculation

Figure 6 shows the influence that the change of the discount rate of the cross axle given in NPV. The discount rate increases; NPV is shown to drop. The discount rate when net present value becomes zero comprises the Internal Rate of Return (IRR) of the project. In this setting, the success of a 20-months term of work project becomes severe or uncertain, because the IRR of the 20-months term of work project is bigger by 1.8% than that of the 5-months term of work project.

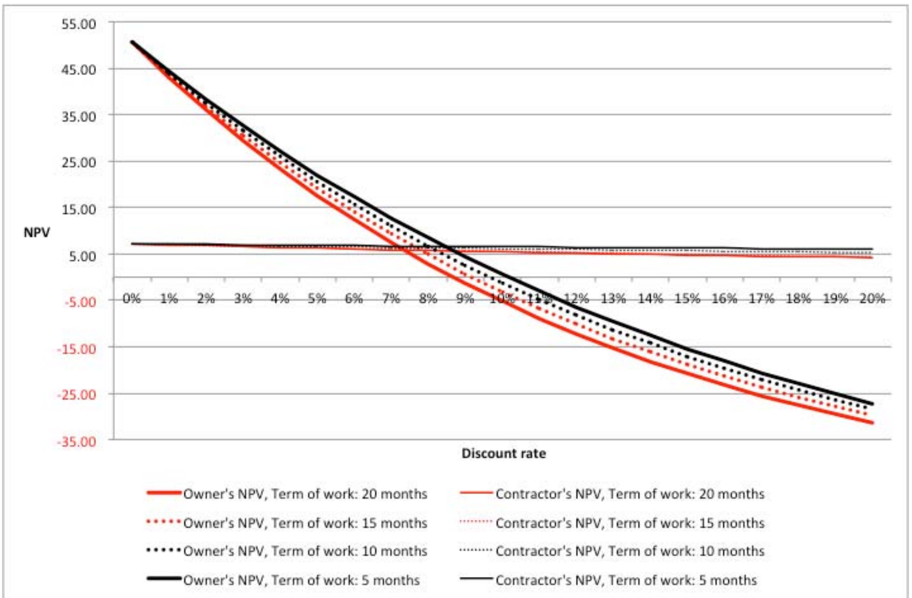

Figure 6: Change of NPV and IRR

Figure 7 shows that change of NPV when the term of work is assumed 5-months and 20-months and discount rate is 5% and 10% respectively. In the latter half of the project and the remaining value evaluation, cash in reduces under the influence of the discount rate, and NPV decreases, too.

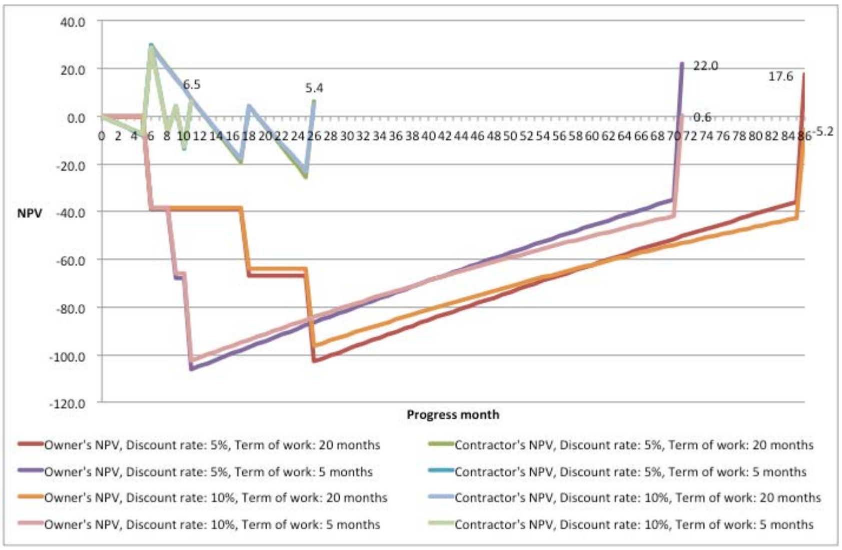

Figure 7: Change of NPV (5-months term of work and 20-months term of work and discount rate: 5% and 10%)

3.3. NPV of the DCF in Consideration of Ratio of Vacancy

In the simulations presented in sections 3.1 and 3.2, the occupancy rate of the apartment at 100 % is calculated in order to simplify the models. The occupancy rate is introduced in order to retrieve the risk of the project over the progress of the time. The authors use "Oracle Crystal Ball" which is the Excel-based application for the Monte Carlo model based simulation. The unevenness of the occupancy rate of this project is expressed in normal distribution (average: 95%, standard deviation: 15-30%). The standard deviation increases equally every month until the 86-months, from 15% to 30%. This setting expresses the actual situation in which the occupancy rate decreases by the progress of time. When the occupancy rate became higher than 100% in this simulation, it was regarded that both inhabitants and the rent rose.

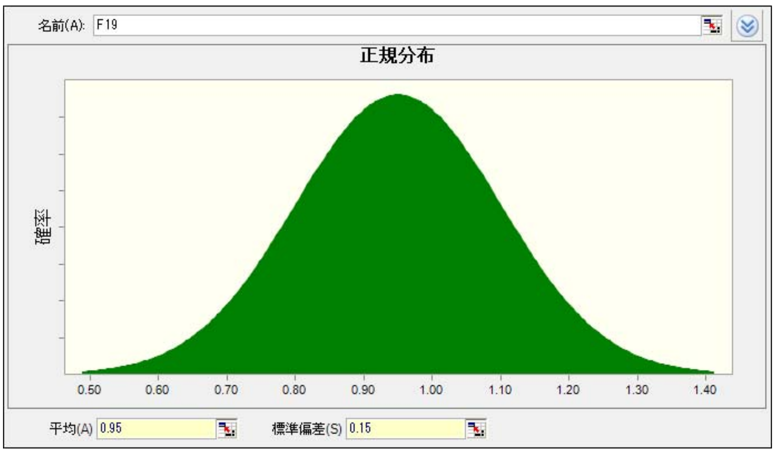

Figure 8: Example of the probability distribution of the occupancy rate (average of occupancy rate: 95% and standard deviation: 15%)

Figure 9 and 10 shows that owner's minimum and average NPV simulation results. It comprises a comparison of an extreme condition, i.e. the NPV of the 5-months term of work project exceeded the NPV of 20-months term of work project. In the case of 8% of discount cash flow, which are realistic in economic developing countries, NPV of 5-months term of work project can ignore the possibility to become smaller than 0 whereas 20-months term of work project has nearly 50% of possibility that NPV becomes smaller than 0.

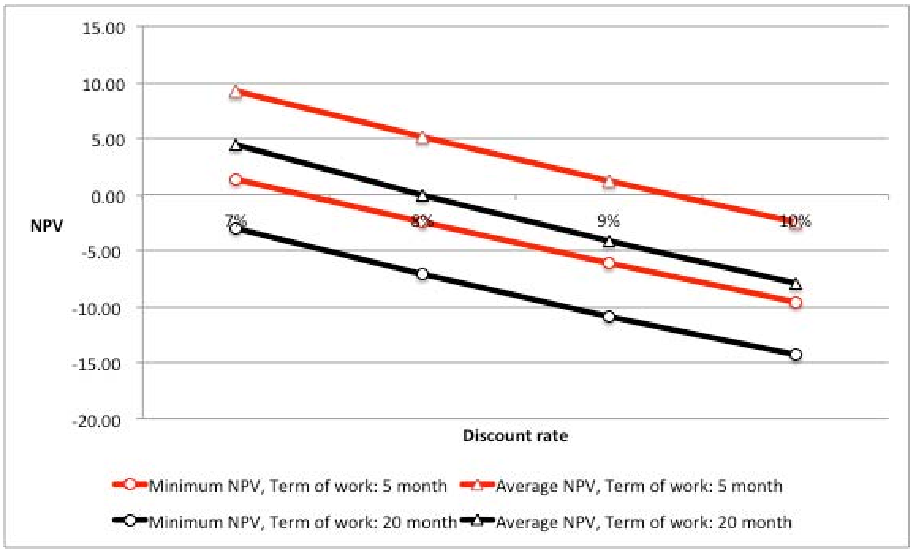

Figure9: Change of minimum and average owner's NPV

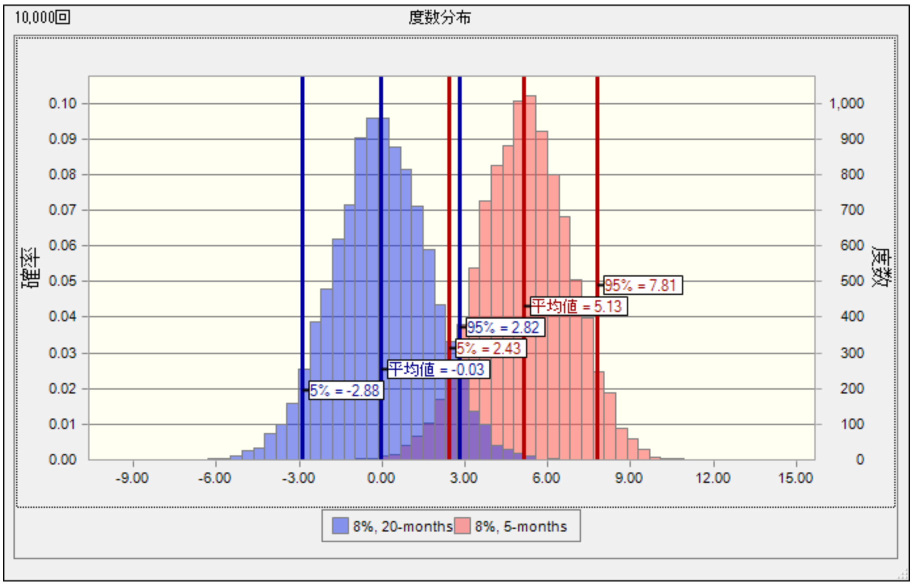

Figure10: Comparison of the prediction distribution of the owner's NPV (8%, 5-months term of work project and 8%, 20-months term of work project)

4. CONCLUSIONS

In this paper, we clarified the consequence that shortening the term of work by the introduction of innovative construction methods like automation and robotics increases the NPV of the project. Similarly, if the proposed cash flow model is introduced, which incorporates quality and safety improvement, the upper limit of the additional investment such as R&D costs for the realization can be extracted from the increase of NPV. It is not realistic to collect costs from single projects. The total investment for R&D should be decided assuming the total number of similar projects provided. Contractors should inform owners that involved innovative construction methods could eventually efficiently increase the NPV of a building. This leads to releasing contractors from price competition. The proposed study is important not only for contractors but also for owners.

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