A STUDY ON DURATION ESTIMATE METHOD USING STOCHASTIC MODEL IN THE BIM ENVIRONMENT

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ABSTRACT: Recently, Construction Projects are being much bigger and more complex. So the importance of Construction Planning and Management is increasing and increasing because of the Construction Projects is involved in a variety of construction-related subjects. Competitive of the Construction Industry decided Cost, Construction Duration and Productivity. But they were just focused on Cost Saving instead of Construction Duration and Productivity. However, they have to finish construction projects using minimum cost and duration with quality and function of required level for successful Construction projects. Thus, current high exchange rate and high period, it is clear to decrease construction cost and to do economic construction in huge Construction Projects and it means more advanced Construction Schedule Management needs for economic construction. But Construction Scheduling Planning, basic of Construction Schedule Management, adjusted contract period without Pre-Planning, just depending on experience and ability of Construction Engineer. Because of that, this study suggests new Duration Estimate Method using Stochastic Model in BIM Environment for advanced Construction Schedule Management. Existing Duration Estimate Methods are just modified wrong points of them or analyzed effective factors of construction schedule. However, New Duration Estimate Method is just consists of Stochastic Model and BIM Environment without existing Duration Estimate Methods. So, new method has creativity and specialty. After this research, it would be a great model in construction industry field.

Keywords: BIM; Stochastic Model; Construction Duration; Duration Estimate Method

1. INTRODUCTION

In today's Construction Market is much bigger than before. Because of that, most of construction companies need to find methods which could be increased their competitive edge. For strengthen their competitiveness, a lot of main contractors have spent their budget to research knowledge of Construction Management.

Schedule Management is one of main parts in Construction Management. Nowadays, many construction companies established their own Schedule Management Standard Manual which derived from previous experience. But manuals in each companies are different each other and are not reflected uncertain factors such as weather conditions, increasing material cost and delivery situation.

Thus, planned schedule which deduced from standard manual in each construction company is different from actual schedule. So it is not useful to reduce cost and work time. It means, if planned schedule was to close actual schedule, it could be effective because of reduce cost and work time.

Main problem of current duration estimation method is Deterministic Approach. It is not sensitive than Probabilistic Approach. It means current duration estimation method is hard to reflect change factors. But Stochastic Approach is possible to reflect uncertain factors, because of this approach based on Probabilistic Approach. So for advanced duration estimation method, using Stochastic Approach is needs to consider.

However, the ultimate purpose of this study is not only establishment of advanced duration estimation method but also application in BIM (Building Information Modeling) Environment. Current, BIM is also used one of methods for increasing competitiveness in construction companies. Of course, making duration estimation method has a huge value; because of it could be brought efficiency in construction work environment. But the main purpose of using BIM is also reduction of work time and increment of efficiency. So if they used together, it could be occurred synergy effect.

Thus, main purpose of this study is establishment of Duration Estimation Method in BIM Environment. For this goal, first of all research of current scheduling status of construction company in Korea is progressed.

And then, basic factors of Monte Carlo Simulation to make estimation method are determined. Duration Estimation Method is limited floor unit of Reinforced Concrete structure.

Last, application method of BIM Environment is derived. Application has restrictive scope focused on 4D Simulation which is one of the most effective process in BIM Environment.

2. THEORETICAL REVIEW

2.1 Previous Studies

Prior Literature on Duration Estimation includes probabilistic approach. Fente, J. et al. (2000) and Maio, C. et al. (2000) analyzed and defined probability distribution for Construction Simulation. Their studies are not related duration estimation directly. But, defining probability distribution in their studies has relations for make duration estimation method.

And Lee (2005) had trials to reduce duration and presented a practicality from Stochastic Project Scheduling Simulation Program. This Program provides probability which can finish construction works on completion date.

However, those studies are not use Stochastic Approach for Duration Estimation directly.

2.2 Construction Scheduling Status in Korea Construction Industry

Current main contractors in Korea use their own scheduling standardization and manual which derived from previous construction experience. But most scheduling works in construction companies progressed from total duration which determined in Contract Agreement. Because of that Master schedules which made by main contractors have gaps if they compared with As-Built schedule.

1) Work Calendar Establishment
2) Presentation Working Day and Calendar Day in each process using Scheduling Manual
3) Calculation each duration using Scheduling Manual
4) Modify duration followed Construction Scale and Construction Detail Level

Even though scheduling approach methods are quite similar between main contractors in Korea, duration calculation methods of each company are totally different. Table 1 is shown duration calculation methods of each construction company. [1]

Table 1. Probability Distribution Calculation Result

Firm	Calculation Equation
A	a + b × Floors
B	a × Floors + c
C	a + b × Floors
D	a + b × Floors
E	a + b× √Gross Floor Area + c
F	a × Area / b
G	a × Floors + c

*a, b, c : Constant

The cases of A, B, C, D, G companies calculated duration only using number of floors. F Company considers Area and E Company consider Floors and Gross Floor Area.

Especially, F Company thinks other various variables such as Construction Scale, Structure and Ability. But gaps between planned duration and actual duration are huge.

Of course, these days Scheduling Method is not useless. But it is based on previous experience and it is not reflected other exogenous variable like uncertain factors during construction period. Because of that, current method has a problem that planned duration is not correct actual duration. It means waste labor and time in real construction work. So if this method could be improved, construction work would be more effective.

Further, estimated duration which is similar to Actual Duration could be occurred reduce construction period and construction cost.

3. RESEARCH METHODOLOGY

3.1 Duration Estimation from Stochastic Approach

Stochastic Approach is based on Probabilistic Approach. Probabilistic Approach is able to provide many and various information instead of Deterministic Approach which has limited change because of only one input value and is insensitive about change. Figure 1 is an expression about comparison between Deterministic Approach and Probabilistic Approach.

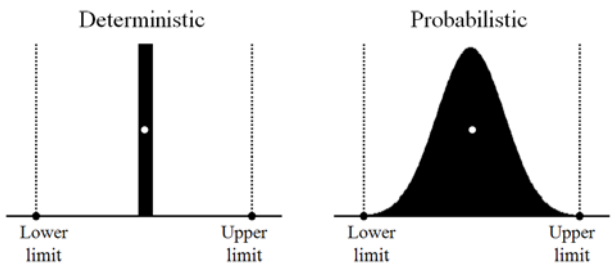


Figure 1. Comparison between Deterministic Approach and Probabilistic Approach

Thus, using Stochastic Approach can get not only statistic information like mean and standard deviation but also analyze variations from each confidence level. Of course, probability distribution of each variation need for analysis and collecting each distribution is really hard. But if it was possible, it could execute simulation of real world.

3.2 Monte Carlo Simulation Method

Monte Carlo Simulation Methods are a class of computational algorithms that rely on repeated random sampling to compute their results.

Monte Carlo Simulation Methods are often used when simulating physical and mathematical systems. Because of their reliance on repeated computation and random or pseudo-random numbers, Monte Carlo Simulation Methods are most suited to calculation by a computer.

Monte Carlo Simulation Methods tend to be used when it is infeasible or impossible to compute an exact result with a deterministic algorithm. [2]

Monte Carlo Simulation Methods are especially useful in studying systems with a large number of coupled degrees of freedom, such as fluids, disordered materials, strongly coupled solids, and cellular.

More broadly, Monte Carlo Simulation Methods are useful for modeling phenomena with significant uncertainty in inputs.

In this study, use 'Crystal Ball' program for execution Monte Carlo Simulation Method.

4. DURATION ESTIMATION METHOD USING STOCHASTIC MODEL

4.1 Duration Estimation Method Basic Formula

In this section assuming Basic Formula to make Duration Estimation Method. Basic Formula is consists of 'Estimation Value', 'Standard Duration' and 'Prediction Value'. First of all, 'Estimation Value' is a dependent value calculated from 'Standard Duration' and 'Prediction Value'. 'Standard Duration' is an independent value. It is deduced from Master Construction Duration planed in each Construction Company using own 'Scheduling Manual'. Last, 'Prediction Value' is also an independent value calculated from gaps between 'Master Schedule' and 'As-Built Schedule'. Equation 1 is a Basic Formula of Duration Estimation Method.

$$EV = SD + PV \quad \text{(eq.1)}$$

*EV = Estimation Value
*SD = Standard Duration (Constant)
*PV = Prediction Value (Normal Distribution)

4.2 Floor Division for Analysis

Each floor has each different property. Floor Division based on floor properties had to progress for this study. In this study, floors divided 8types. Each type is Foundation, Basement Floor, Basement Floor adjacent Foundation, 1st Floor, 2nd floor, Repeated Floor, Top Floor and P/H Floor.

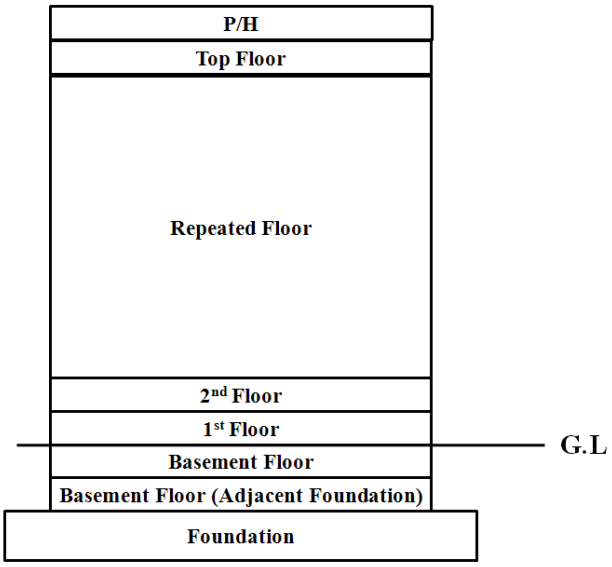


Figure 2. Floor Division for analysis

In this classification, Basement Floor and Basement Floor adjacent Foundation is quite similar but it is totally different. Because of generally Basement Floor Construction isn't related to Foundation Structure Construction. But Basement Floor adjacent Foundation has to construct carefully with consideration about Foundation Structure.

Between 1st Floor and 2nd Floor are also different. When 1st Floor is constructed, it needs to think about connection between Basement Floor and 2nd Floor. But 2nd Floor needs to think about 1st floor and Repeated Floor. Figure 2 is made up above explanation.

4.3 Probability Distribution Calculation from between Master Schedule and As-Built Schedule

In Section 4.1, Basic Formula of Duration Estimation Method is assumed. In that Formula 'Prediction Value' is exogenous variable which occurs from uncertain facts such as weather condition, labor and delivery situation and Increasing cost of materials.

Thus, Selection of Prediction Value is possible to calculate gaps between real schedule and planned schedule. Real schedule is an 'As-Built Schedule' and planned schedule is 'Master Schedule'.

Calculation progressed using Schedule of Apartment Complex which has 6 buildings and similar stories. Table 2 is a result of probability distribution calculation in each division.

Table 2. Probability Distribution Calculation Result

Division	Gap	
	Mean	Standard Deviation
Foundation	5.67	3.83
Basement Floor (Adjacent Foundation)	-17.50	8.55
Basement Floor	0.17	5.64
1st Floor	8.33	11.27
2nd Floor	5.83	14.52
Repeated Floor	0.74	2.67
Top Floor	2.67	4.72
P/H	10.33	8.94

4.4 Duration Estimation Using Monte Carlo Simulation

In former Section 4.3, calculation 'Prediction Value' of eq.1 is completed from gap between Master Schedule and As-Built Schedule. After then, Input variables for Monte Carlo Simulation using Crystal Ball. Monte Carlo Simulation progressed under 1,000 Trials and 95% Confidence Level. Next Table 3 is shown variable of each Floor Division.

Table 3. Probability Distribution for Monte Carlo Simulation and Standard Prediction Value

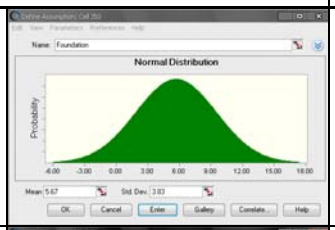
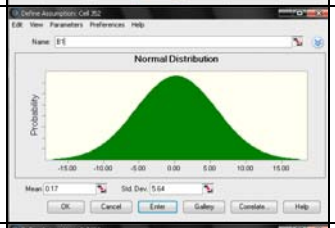
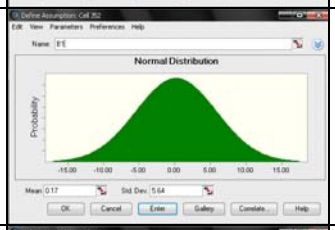
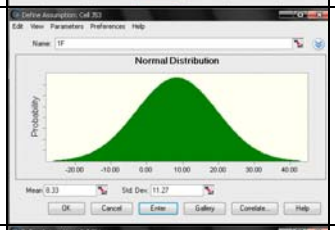
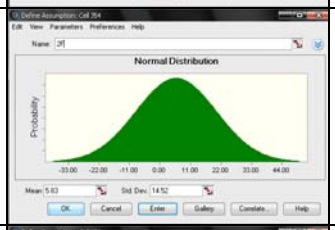
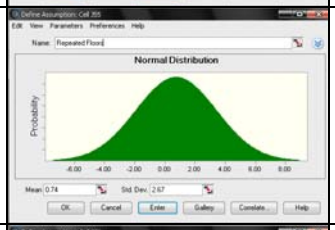
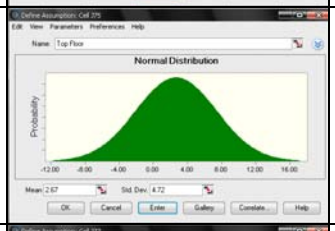
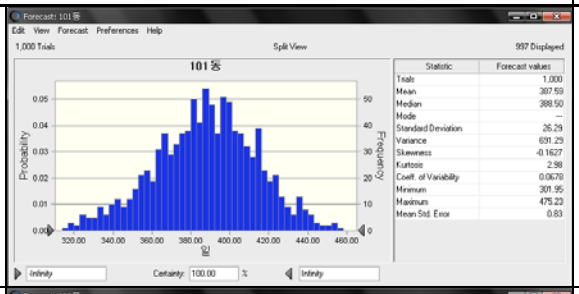
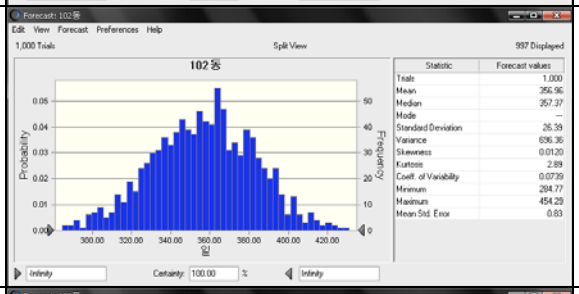
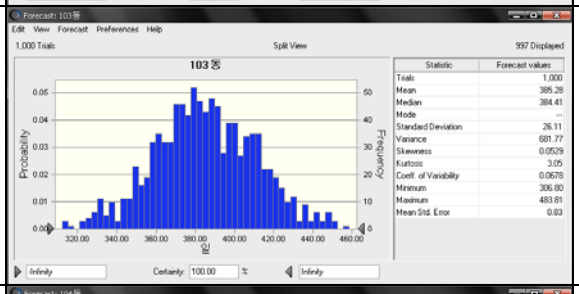
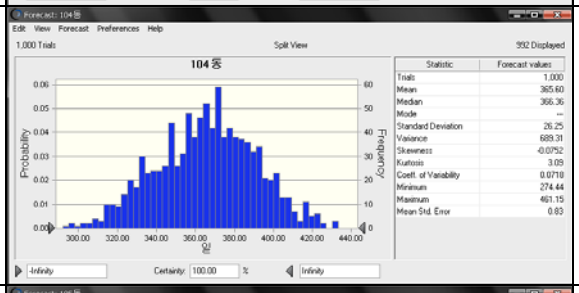
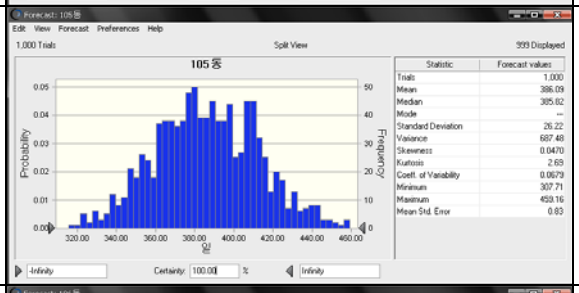
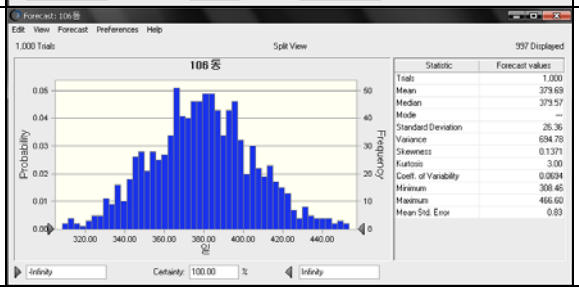
Probability Distribution			Standard Prediction Value
Assumption : Foundation Normal Distribution with Parameters Mean Standard Dev. Selected Range is from -Infinity to +Infinity	 5.67 3.83		5.67
Assumption : Basement Floor (Adjacent Foundation) Normal Distribution with Parameters Mean Standard Dev. Selected Range is from -Infinity to +Infinity	 -17.50 8.55		-17.50
Assumption : Basement Floor Normal Distribution with Parameters Mean Standard Dev. Selected Range is from -Infinity to +Infinity	 0.17 5.64		0.17
Assumption : 1F Normal Distribution with Parameters Mean Standard Dev. Selected Range is from -Infinity to +Infinity	 8.33 11.27		8.33
Assumption : 2F Normal Distribution with Parameters Mean Standard Dev. Selected Range is from -Infinity to +Infinity	 5.83 14.52		5.83
Assumption : Repeated Floor Normal Distribution with Parameters Mean Standard Dev. Selected Range is from -Infinity to +Infinity	 0.74 2.67		0.74
Assumption : Top Floor Normal Distribution with Parameters Mean Standard Dev. Selected Range is from -Infinity to +Infinity	 2.67 4.72		2.67
Assumption : P/H Normal Distribution with Parameters Mean Standard Dev. Selected Range is from -Infinity to +Infinity	 10.33 8.94		10.33

Table 4. Monte Carlo Simulation Result

Probability Distribution		Estimation Result
Forecast : Building #101 Monte Carlo Simulation with Parameters Trials 1,000 Confidence Level 95% Selected Range is from -Infinity to +Infinity		387.59
Forecast : Building #102 Monte Carlo Simulation with Parameters Trials 1,000 Confidence Level 95% Selected Range is from -Infinity to +Infinity		356.96
Forecast : Building #103 Monte Carlo Simulation with Parameters Trials 1,000 Confidence Level 95% Selected Range is from -Infinity to +Infinity		385.28
Forecast : Building #104 Monte Carlo Simulation with Parameters Trials 1,000 Confidence Level 95% Selected Range is from -Infinity to +Infinity		365.60
Forecast : Building #105 Monte Carlo Simulation with Parameters Trials 1,000 Confidence Level 95% Selected Range is from -Infinity to +Infinity		386.09
Forecast : Building #106 Monte Carlo Simulation with Parameters Trials 1,000 Confidence Level 95% Selected Range is from -Infinity to +Infinity		379.69

4.5 Monte Carlo Simulation Result

Above Table 4 is shown Monte Carlo Simulation process which executed with 1,000 Trials and 95% Confidence Level. After Simulation, result of simulation is quite a bit positive. Table 5 is shown Monte Carlo Simulation Result.

Table 5. Monte Carlo Simulation Result

	Building #101		
	Plan	Actual	Forecast
Duration (Days)	357.00	376.00	387.59
Error (%)	5.05	-	2.99
	Building #102		
	Plan	Actual	Forecast
Duration (Days)	329.00	359.00	356.96
Error (%)	8.36	-	0.57
	Building #103		
	Plan	Actual	Forecast
Duration (Days)	356.00	361.00	385.28
Error (%)	1.39	-	6.30
	Building #104		
	Plan	Actual	Forecast
Duration (Days)	338.00	388.00	365.60
Error (%)	12.89	-	6.12
	Building #105		
	Plan	Actual	Forecast
Duration (Days)	356.00	387.00	386.09
Error (%)	8.01	-	0.24
	Building #106		
	Plan	Actual	Forecast
Duration (Days)	350.00	393.00	379.69
Error (%)	10.94	-	3.51

In Monte Carlo Simulation Result, forecast result of Most Buildings except Building #103 is similar to Actual Duration.

They have less error than Planned Duration. It means this method has a value as a Duration Estimation Method.

But the case of Building #103 was little different. Because of its duration was nearly same Planned Duration.

Of course it could be possible, if uncertain factors occurred close to zero. But zero uncertain factors are hardly existed. So it was just exception which can occur accidently.

5. USING DURATION ESTIMATION METHOD IN BIM ENVIRONMENT

5.1 Basic Process

The ultimate purpose of this study is not only making Duration Estimation Method but also Application in BIM Environment.

For Application, it needs Basic Process about using estimation method in BIM Environment. In this Section suggested new process for application. Figure 3 is Basic Process about it.

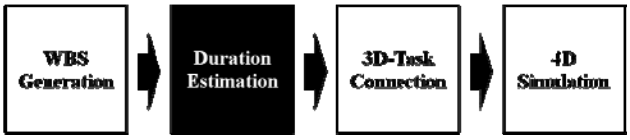


Figure 3. Floor Division for analysis

Generally, current BIM usually focused on 4D Simulation. So the purpose of this process also support advanced 4D Simulation.

First of all, WBS (Work Breakdown Structure) which related 3D BIM Model has to be generated. Current 4D Simulation Tools don't have those kinds of functions which related Schedule Management. Of course, most 4D Simulation Tools have Basic Scheduling functions. But they are not enough to use effective. Sometimes they occur much more rework time. So this step which suggested in this process is quite useful to reduce work time in BIM Environment.

And then, next is Duration Estimation Phase. Output of WBS Generation is Task Group. So they don't have any duration information. However, 3D Model Information already provided before WBS Generated, it is possible to estimate duration which near to Actual Duration.

After Duration Estimation, 3D Modeling and Tasks which have Schedule Information are connected. Nowadays most work time of 4D Simulations in BIM Environment charged this step. But this process has WBS which related 3D Model and has schedule information; it could reduce work time and would be more effective.

5.2 Expected Effects

Recently, BIM use a lot of Architecture, Engineering and Construction parts. BIM is possible to reduce work time and make more effectively. And Duration Estimation Method suggested this study is also effective.

Naturally, Duration Estimation Method could be used independently. And current BIM Technology is also very useful. But if they used together, it could be delivered huge effects in construction industry because of efficiency.

6. CONCLUSIONS

Precise construction duration estimation is really important in Schedule Management. But today's scheduling in construction industry is not close to real duration. It means the main purpose of Schedule Management which construction work makes effective is

not progressed. Because of this reason, this study suggested advanced duration estimation method for increase efficiency of Schedule Management.

To make duration estimation method, this study used Stochastic Approach based on Probabilistic Approach instead of Deterministic Approach which wildly used in previous Construction Scheduling. As part of Stochastic Approach, Monte Carlo Simulation executed. For progress of simulation, probability distribution value of prediction value in basic formula (eq.1) is calculated. Probability distribution is gaps between Master Schedule and As-Built Schedule.

The result of simulation is quite positive. Because of error between estimated duration and actual duration is almost similar. It means this duration estimation method has a value which could be complemented current Construction Scheduling.

However, establishment of advanced duration estimation is also purpose of this study. But the final aim of this study is application in BIM Environment; the basic process which could be used is suggested. Duration estimation method in BIM Environment is expected huge impact in Construction Industry.

But duration estimation method in BIM Environment which suggested in this study is limited Reinforced Concrete Structure and 4D Simulation. So it has to do more research and complement of this method.

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