LATENCY IN ERROR AND CHANGE MANGEMENT

SangHyun Lee[1] and Feniosky Peña-Mora[2]

ABSTRACT

One of the predominant causes of uncertainty and complexity in managing a project is errors and changes, which often result in prevalent schedule and cost overruns in construction. In particular, latency in managing errors and changes becomes an important issue when the project is large and complex. In this paper, the means by which latency disrupts construction is explored through a framework that finds connections among scope, process, and performance. This framework is converted into a working simulation model using System Dynamics to apply it to a real-world construction project. Applying this model to the laboratory building project, the authors conclude that in order to manage latency there is the need to add realism to schedule planning, take a proactive approach, and an institute an efficient coordination process. Finally, the web-based system that incorporates the developed model is discussed to explore the potential of supporting the coordination of errors and changes.

KEY WORDS

Error and Change Management, Simulation

INTRODUCTION

Managing errors and changes is difficult. One of the main reasons for the difficulty is that errors and changes often become iterative, meaning that errors and changes are not one-time events. Instead, they become a source or catalyst that generates consequent effects on the project due to construction activities' interdependency such as imposed, technical, and procedural relationships [Badiru and Pulat, 1995].

Furthermore, if timing issues are taken into account, the situation becomes worse. When errors and changes are not identified immediately, they become hidden and re-appear in a later stage of a project. This situation is called ***latency*** [Lee et al., 2005], and can cause significant impact on project performance considering interdependency in construction.

There have been many investigations into the impact of errors and changes. For example, Hester et al. (1991) conducted research on the impact of change orders on labor productivity at the craft level, and Hanna et al. (1999) performed research on the impact of change orders on labor productivity using linear regression model while Moselhi et al. (2005) did it using neural networks. All research contributed to the understanding of the impact of changes on the project. Nonetheless, the timing issue in changes has rarely been discussed.

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Recently, the authors raised the issue of the detrimental impact of latency on performance [Lee et al., 2005], and Ibbs (2005) discussed the timing issue of changes concluding that late change is more disruptive of project productivity than early changes. Furthering these discussions, this paper aims to develop an in-depth understanding of latency in managing errors and changes. For that, a framework that enables understanding of how errors and changes disrupt construction is proposed and in turn, converted into a working simulation model using System Dynamics. Applying the System Dynamics model into a real world construction project, simulation results and their implications are discussed. Lastly, the web-based system is discussed, which aims to incorporate the simulation capability as well as other functionalities that support the resolution of errors and changes.

UNDERSTANDING OF LATENCY

Figure 1 shows the framework that depicts the dynamic processes associated with errors and changes. This framework enables identification of the impact of errors and changes on performance. Particularly, the framework's focus on latency is necessary to understand how it can disrupt construction in the long run.

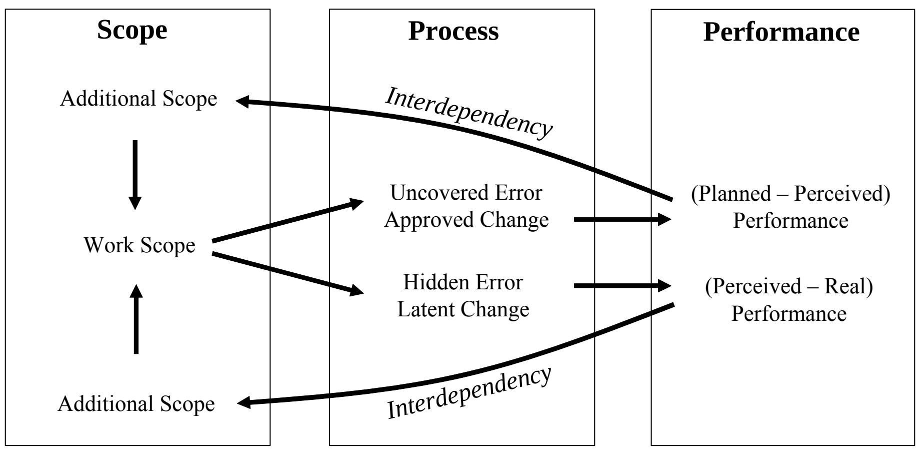


Figure 1. Framework for Understanding of the Impact of Latency on Performance

The framework in Figure 1 is composed of scope, process, and performance, respectively. Construction is processed based on the scope of the work, and the outcome of the processes is performance. Suppose we are installing 9 piles and performance is measured by the number of completed piles. In this case, the completion of 9 piles would be considered the outcome of the process, also known as the ***planned performance***.

However, errors can be uncovered, and changes can be approved during the process. Suppose in this pile installation example, during the quality management process one pile is decided to be erroneous. In this case, due to the erroneous pile, 8 piles were actually completed. This is known as the ***perceived performance***.

However, there can be latency in managing errors and changes. Errors and changes that have not been identified are called hidden errors and latent changes, respectively. Continuing with this pile installation example, suppose another of the piles is erroneous and at this time, it has not yet been identified (i.e., a hidden error). In this case, though we perceive that 8 piles have been completed, the ***real performance*** is the completion of 7 piles.

This gap between perceived performance and real performance has a crucial meaning in managing errors and changes. The existence of this gap implies that the decision making process to offset the gap between planned and perceived performance may start with inaccurate information because perceived performance may not be the same as real performance. Thus, there is high probability that the decision that aimed to solve the problem would generate unanticipated effects, thereby severely disrupting construction.

The detrimental impact of latency becomes more severe when the interdependency in construction is also taken into account. Control actions taken to offset the gap between planned and perceived performance are usually accompanied by an increase in scope. In this pile installation example, we may need to remove the existing erroneous pile and install a new one if re-work is the only solution. Thus, removing and installing a pile is added as additional, unexpected, work scope. On the other hand, succeeding tasks, such as installing columns, could be already completed in the case of latency. If a hidden error is discovered after installing the column, we may need to remove the column before removing the erroneous pile. The latency has caused the additional work to fix the error to increase beyond that required in the first case.

The increase of work scope during actual execution is one of the main drivers to disrupt a project because most plans are based on the initially estimated scope. For example, in this pile installation example the number of workers hired will be based on the initial work scope, the installation of 9 piles. To deal with additional work scope, more workers will need to be procured in the middle of execution. Furthermore, a schedule extension may not be allowed for this corrective work because keeping the schedule is one of the main objectives in most projects. Thus, more work-hours tend to be assigned at a late stage of the project through things like hiring new workers and adopting overtime. However, it is well known that this late assignment does not help productivity improvement [Sterman, 1992]. In summary, when latency and interdependency are taken into account together, construction becomes seriously disrupted due to the unexpected increase of the scope during execution.

SYSTEM DYNAMICS CONSTRUCTION PROJECT MODEL

The discussed framework is implemented as a working simulation model in order to apply it to real world construction projects. For that, System Dynamics (SD) is used to model this framework. SD was developed in the late 1950's to apply control theory to the analysis of industrial systems [Richardson, 1985] and has been applied to complex industrial, economic, social, and environmental systems of all kinds [Turek, 1995]. SD takes advantage of system structure to understand dynamic behaviors. This fits well with the characteristics of the framework and its aims to understand the associated structure in order to explain how errors and changes disrupt construction.

Using SD, the generic construction process is modeled. This model describes how construction is processed with errors and changes, how these errors and changes can be addressed or hidden and re-appear, and how they result in the scope increasing. For example, a process associated error and its latency is modeled using SD's stock and flow structure (i.e., stock represents stored quantities while flow varies the quantity of stock), as seen in Figure 2.

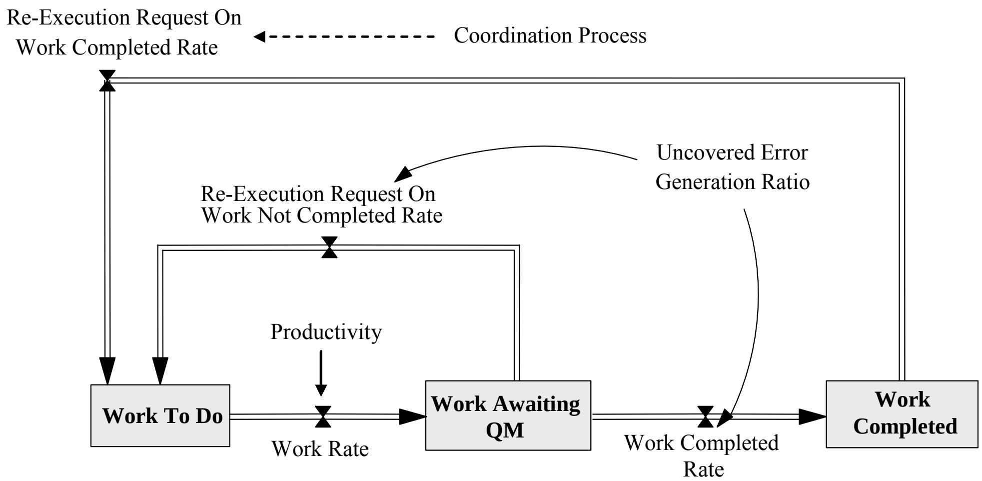


Figure 2. Error Iteration with Latency

In the model, all work is in the Work To Do stock prior to execution. When execution of this work begins, the quantity of Work To Do stock that moves to Work Awaiting QM (Quality Management) stock is based on Work Rate. If the work done passes QM, it can go to Work Completed stock. Otherwise, the work is considered error and has to go back to Work To Do stock to be performed again. On the other hand, the work that passes QM can contain errors due to imperfect quality management. These are hidden errors. In the model, this can be represented as Work Completed stock that has hidden errors which will be addressed at a later stage of the project through the coordination process (e.g., Request For Information process), as seen in Figure 2. The rest of the generic construction process, such as change management with latency, and the coordination process can be modeled similarly to this exmaple.

In the framework, we discussed the unexpected scope increase, which is amplified due to latency and interdependency, as a main reason for construction disruption. The developed model captures a total additional work amount caused by errors and changes by multiplying the original work scope by internal and external sensitivity, which are defined as the degree to which the corresponding tasks are interrelated within an activity or among activities, respectively.

There can be three cases where additional work scope is issued in the activity. First, errors and changes can be immediately issued in the activity. The second case can occur when errors and changes in the preceding and succeeding activities affect the activity under study. The last one can happen when hidden errors and latent changes rooted in the activity under study are later discovered and thus, additional work requests will be issued from succeeding activities.

On the other hand, together with the generic construction process and the scope increase, the other supporting model structures are needed. For example, when errors and changes introduce additional work scope, the project manager would not leave it as it is. Rather, he/she will put expend tremendous effort to deal with them to avoid a possible schedule delay, for example, by implementing overtime and hiring new workers. The developed model also captures such impacts of implemented policies on performance. For example, the model structure in Figure 3 simulates the process of adjusting the current workweek (work hours per week) when an overtime policy is implemented. First, the required work rate is calculated by dividing the remaining work by available time to completion. Then, schedule pressure (the stress in the workers' environment caused by compressing the time to complete) is determined by comparing the calculated required work rate against the normal work rate. In the model, when the required work rate is greater than the normal work rate, it is assumed that contractors and project managers perceive the schedule pressure with a time delay. Based on the perceived schedule pressure, the overtime ratio and workweek are determined. Here, the overtime ratio ranges from 1.0 to 2.0, which means that construction workers can work up to 80 hours per week depending on the extent of the schedule pressure, if we assume a normal workweek is 40 hours per week (considering that the overtime ratio can vary depending on construction conditions and policies, the model can have a different overtime ratio range based on a user's choice). This overtime ratio is used to calculate an actual workweek and consequently the gap between an actual workweek and a normal workweek can be used to calculate the fatigue of the workforce, which will result in productivity loss. As in this example, supporting model structures are designed to represent the diverse construction policies, which are generated from the scope increase caused by errors and changes. Due to space limitations, the rest of model structure has been omitted but is available upon request [Lee, 2003].

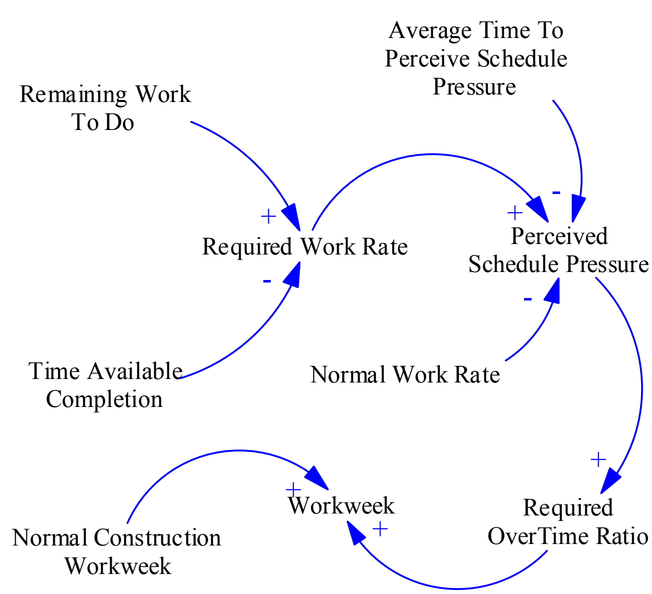
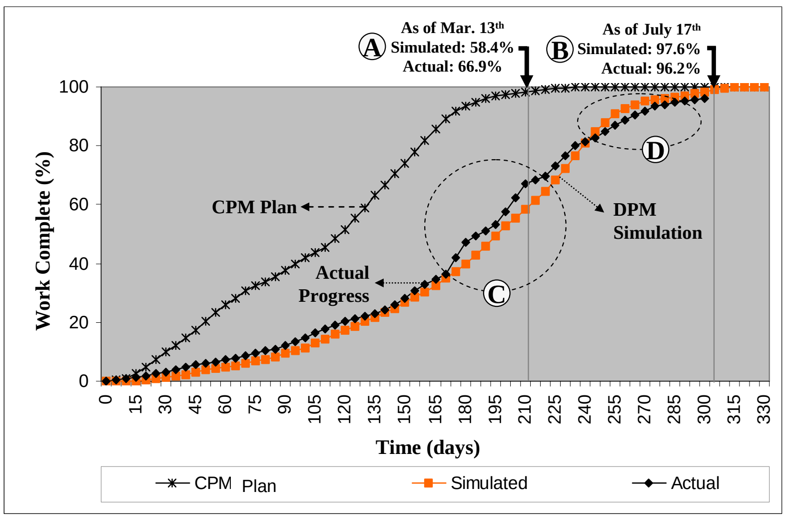


Figure 3. Example of Supporting Model Structures

CASE STUDY

The developed model has been applied to a laboratory building project in Malaysia (for confidentiality reasons, the project name is not stated). For simulation runs, input was obtained from the construction manager and scheduler prior to the project start.

As one of the validation steps, the actual Percentage of Work Complete (PWC) obtained weekly from the site was compared with the simulated PWC from the developed model. Figure 4 illustrates this comparison along with the initially planned PWC. As of March 13th, 2005 (A in Figure 4), while the actual PWC is far behind the planned PWC, the simulated PWC closely followed the actual PWC with 3.38% of Root Mean Square Error (RMSE).

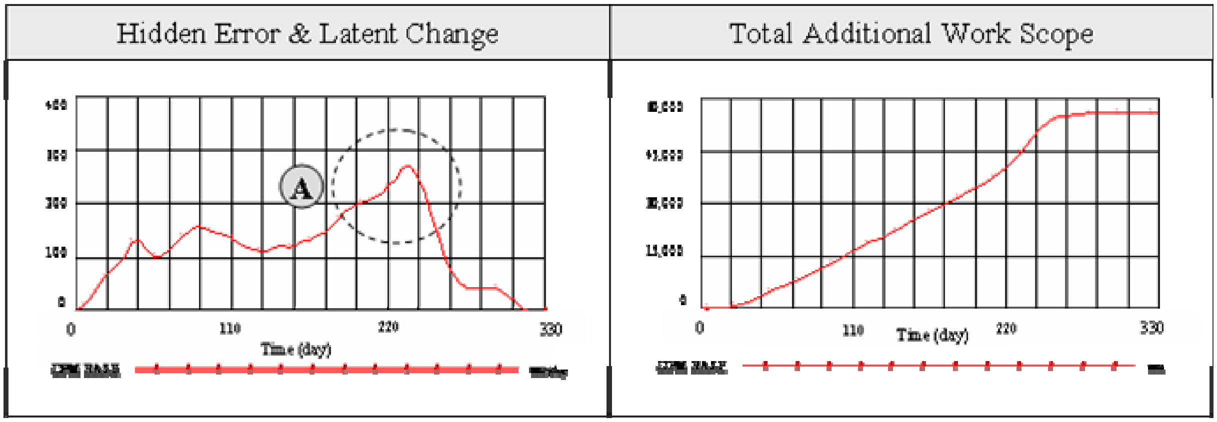


Till When	# of Datasets	Root Mean Square Error (%)
March 13th, 2005	43	3.38
July 17th, 2005	61	3.42

Figure 4. Planned, Actual, and Simulation Percentage of Work Complete

By March 13th, 2005, this project had adopted overtime to accelerate the schedule. However, adopting overtime did not prove very effective, and thus, new Indonesian workers were hired. Accordingly, this new policy was incorporated into simulation, and the remaining progress was generated, which resulted in 3.42% of RMSE.

Figure 5 shows the simulation results in detail. Based on simulation, it is observed that many errors and changes were introduced. In addition, when the project was accelerated to catch up with schedule delay, the rush caused some errors and changes to become latent, as seen in the left side of Figure 5. Consequently, a significant amount of additional work was generated in this project, as seen in the right side of Figure 5.



* Note: WU is used as a hypothetical work unit. 1 day's work is assumed to be worth of 1,000 WU.

Figure 5. Total Additional Work Scope Caused by Hidden Error and Latency Changes

On the other hand, there is a large fraction of work waiting for the RFI process and Change and Claim Management (CCM) decision (i.e., the decision making process that will decide if identified changes will be approved or not) due to long RFI and CCM response time, as seen in Figure 6. The follow-up survey showed that the average RFI response time was estimated at 19.6 days at a later stage of the project while 10 days at an early stage of the project. This longer RFI response time at the later stage of the project further delayed the resolution of errors and changes in this case project.

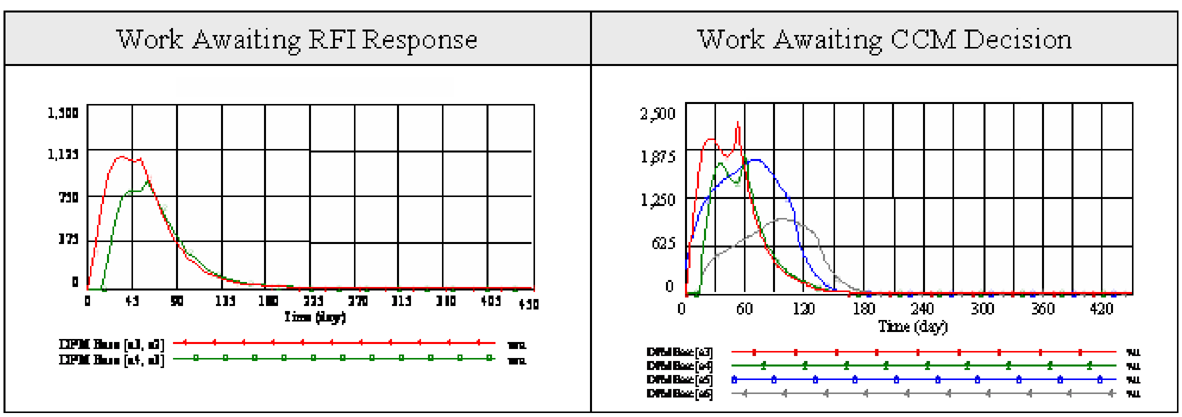


Figure 6. Coordination Work To Resolve Errors and Changes

Based on these simulation results, the following recommendations are made. First, there is a strong need to add realism to planning. If we know that errors and changes most likely will occur and can be latent, their impacts need to be taken into account in advance. By doing this, appropriate contingency plans can be prepared. In this case project, the project managers adopted overtime as a contingency action against scope increase. However, due to a lack of ability to estimate the actual amount of overtime necessary in advance, the scope issue was not handled well. Thus, the management team made the impromptu decision to hire new workers from the adjacent foreign country. However, some time later, the newly hired workers called a strike when they realized that they had received considerably less payment than the domestic workers. Fortunately, this strike was resolved in a short time. However, the project had to experience significant cost overruns due to the strike. This example shows the importance of early consideration of additional work scope because it is highly related to the determination of consequent contingency plans.

Second, a mechanism to identify latency as early as possible is necessary. One way this could be done could be a collaborative meeting among project participants before the activity begins. This meeting aims not only to discuss and identify potential problems but also engage in pre-planning to insure resource procurement for the constructability of this activity. Ultimately, this collaboration could reduce the number of RFIs which often take valuable days. Information about this collaborative meeting, implemented using a schedule buffer, can be found in another of our papers [Lee et al., 2006].

Third, an efficient coordination process can help resolve errors and changes quickly, particularly when errors and changes are latent, by reducing the time taken for the decision making process. As discussed earlier, coordination processes such as the RFI and CCM decision processes can cause significant delays. Considering the fact that construction is performed in open environments through a temporary alliance among multiple organizations [Slaughter, 1998], increasing the level of coordination among project participants (i.e., reducing RFI period and CCM period) could contribute to the resolution of errors and changes.

SYSTEM

Continuing with the coordination issue, we discussed that sharing on-site solutions to errors and changes quickly and reliably can contribute to facilitating the coordination process for errors and changes. Furthermore, as projects often take place at geographically distributed places, quick and reliable information sharing becomes crucial for managing errors and changes.

In this context, the developed model is incorporated into a web-based system named Dynamic Planning and control Methodology (DPM), as seen in Figure 7. Thus, real-time analysis is enabled by participants without limitation of time or location. In addition, all information is stored in the database. Thus, when there are changes such as activity duration, real time simulations can be calculated only by changing the necessary corresponding variables. The DPM system supports data exchange with the existing commercial software like Primavera. In addition, the system provides the results of traditional scheduling methods such as Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) for comparative purposes. Thus, the users have the benefit of comparing the simulation results with CPM and PERT results. Through the support of heterogeneous devices such as phone and PDA, the system also supports collaboration Thus, managers and workers who have these devices can take advantage of this functionality without the use of heavy PC and laptops.

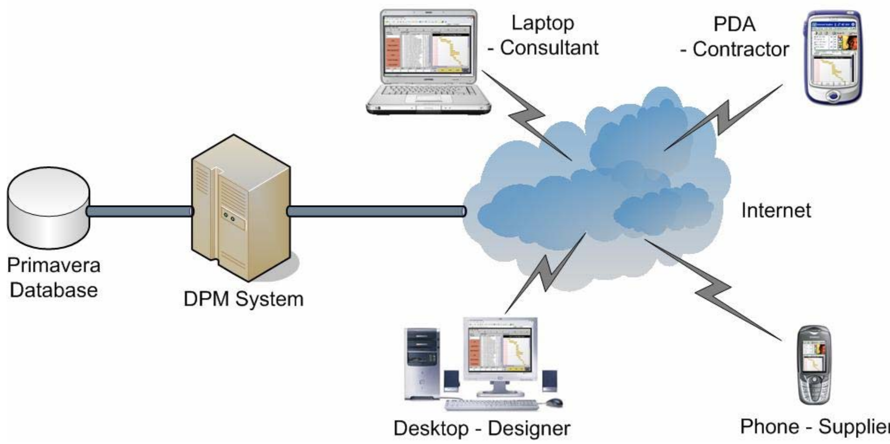


Figure 7. Web-based DPM System

In summary, the DPM system is developed to support the coordination process for errors and changes. As we discussed earlier in the case study, the support for the coordination process has a great potential in managing errors and changes, particularly considering that construction is a temporary alliance of multiple organizations.

CONCLUSIONS

The paper discussed latency in managing errors and changes. The proposed framework was developed to understand how latency can disrupt construction by identifying the gap between perceived and real performance and the consequential work scope increase. Developing the working simulation model and applying it to a real-world construction project, several recommendations for managing latency were made. Although the current framework and model showed the potential for understanding and managing latency in project management, further research efforts, including additional field and case studies, need to be made to improve the framework's and model's effectiveness in diverse situations. Particularly, the system needs to be validated through a usability study. The authors will report follow-up results in the near future.

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