The Impact of Design Rework on Construction Project Performance

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Abstract: *Rework in construction development projects can significantly degrade project cost and schedule performance. In a typical construction development project which involves design and construction, rework in the construction phase could increase construction cost by 10%-15% of the contract price (Burati. 1992, Josephson & Hammerlund 1999, Love & Li 2000). The proportion of money and time spent on rework in the design phase is usually higher (Smith & Eppinger 1997). In large, complex projects, undiscovered rework in the design phase can induce rework in the construction phase. The time when rework is discovered during the project development process affects the impact of rework on overall project performance. However, available knowledge is not always successful in improving project managers' understanding of the feedback mechanisms which drive undiscovered rework impacts on project performance, specifically the interaction between different phases during the developing process. The current work uses a system dynamics model of a two phase project development cycle to identify high leverage points for minimizing the impacts of rework on development project performance. Model analysis suggests that failing to discover rework near its creation in the project development process can magnify the impact of rework on project performance.*

1. Introduction

Rework is a common occurrence in construction projects and has been identified as one of the factors that can degrade project performance. Over the years researchers have developed definitions and interpretations of rework in correspondence to their own production systems. Love (2000) defines rework in the construction industry as the "unnecessary effort of redoing a process or activity that was incorrectly implemented the first time." The Construction Industry Institute (CII) defines field rework as "activities that have to be done more than once or activities that remove work previously installed as part of a project" (CII 2002). Rework in development projects can significantly degrade project cost and schedule performance. Research shows that rework in the construction phase could increase costs by 4% to 12% of the construction contract amount (Burati. 1992; Josephson & Hammerlund 1999; Love 2000). The proportion of money and time spent on rework in the design phase is usually higher than that of the construction phase, as design is an iterative process during which engineers try to solve coupled problems with complex relationships (Smith & Eppinger 1997). Sometimes design tasks are so closely related that each task, if not completed perfectly, has a probability of creating rework for another task. Under the pressure to improve project cost and schedule performance, many companies have accepted the fast-tracking approach under which the design phase and the construction phase overlap (Peña-Mora and Li 2001; Fazio, Moselhi, Théberge and Revay 1988). Because of this phase overlap it is possible that a contractor can start the construction phase with flawed plans that have undiscovered errors (referred to as "design undiscovered rework" in the current work). In large, complex projects undiscovered rework in the design phase can produce a significant amount of rework in the construction phase.

2. Problem Description

When rework occurs during the development process, a project can experience poor cost and schedule performance. In that case, the project manager's attention is focused on completing work faster with limited resources, which creates a "fire-fighting" situation. In the product development context, fire fighting describes "the unplanned allocation of engineers and other resources to fix problems discovered late in a product's development cycle" (Repenning, 2001). When fire fighting begins, the project managers may focus their attention on completing project scope or addressing known rework. This reduction in attention to quality assurance may result in a reduction in quality assurance effectiveness which would result in some errors going undetected and being approved as correctly completed work. Defective work that is approved is referred to hereafter as undiscovered rework. In traditional construction project delivery systems, the project development process consists of a design and construction phase. Undiscovered rework created during the design phase can create additional work in the construction phase. Two types of additional work may be created by undiscovered rework. One is work that was not in the initial project scope but has to be completed to support those parts of the project that are related to the part being reworked. Creation of this type of additional work is sometimes referred to as "ripple effects" and implies that additional work beyond the initial project scope is needed (i.e. new work is added to the project). The other type is work that was in the initial project scope and was initially installed correctly but needs to be reworked because it's closely related to a separate item of work being removed. Consider the situation in which an engineer designing a roadway project made an error sizing storm sewer pipes that pass under the roadway and this error was not identified by the design quality assurance process. During construction the wrong size pipes were installed underneath the pavement and the error in pipe sizing is not discovered until after the pavement covering the pipes has been placed. In order to correct the pipe sizing error (the undiscovered design rework), the pavement above the pipe must be demolished (work that was completed correctly but required rework due to rework in adjacent systems) and the excavation must be shored (work that was not required as part of the original project scope).

In complex projects where activities are closely related to each other, the longer it takes to find the mistake, the more additional work can be created in the process of correcting the mistake and the more the total project performance can be degraded. In the previous example, had the pipe sizing error been discovered during the design phase, additional design time would be required to correct the rework but this would have been much less than the cost of replacing the pipes after installation. However, in the traditional design-bid-build construction process total project cost is determined by the summation of the design costs (managed by the designer) and construction costs (managed by the contractor). Discovering design errors during the design phase can decrease the overall project costs but it could also increase the design cost which works against the profit motive of the designer. Failing to discover design errors during the design phase decreases the design costs while increasing the construction cost (which works against the profit motives of the contractor). The project owner is concerned with the entire project cost but does not have direct management of the design and construction costs. How can undiscovered rework be best managed under the feedback dynamics of the design and construction process?

Previous research has examined undiscovered rework (Ford and Sterman 1998) and rework induced ripple effects (Taylor & Ford, 2006, 2008) in single phase project development processes. The current work extends this research by investigating the impact of undiscovered rework on project performance in the two phased construction project development process. The objectives of this research are: (1) identify the feedback mechanisms that drive the behaviour of undiscovered rework in the two phased construction project development process; (2) identify the impacts of undiscovered rework on project cost and schedule performance within the two phased construction project development process; (3) design and test policies for managing rework in the two phased construction project development process.

3. A Simulation Model of Project Developing Process

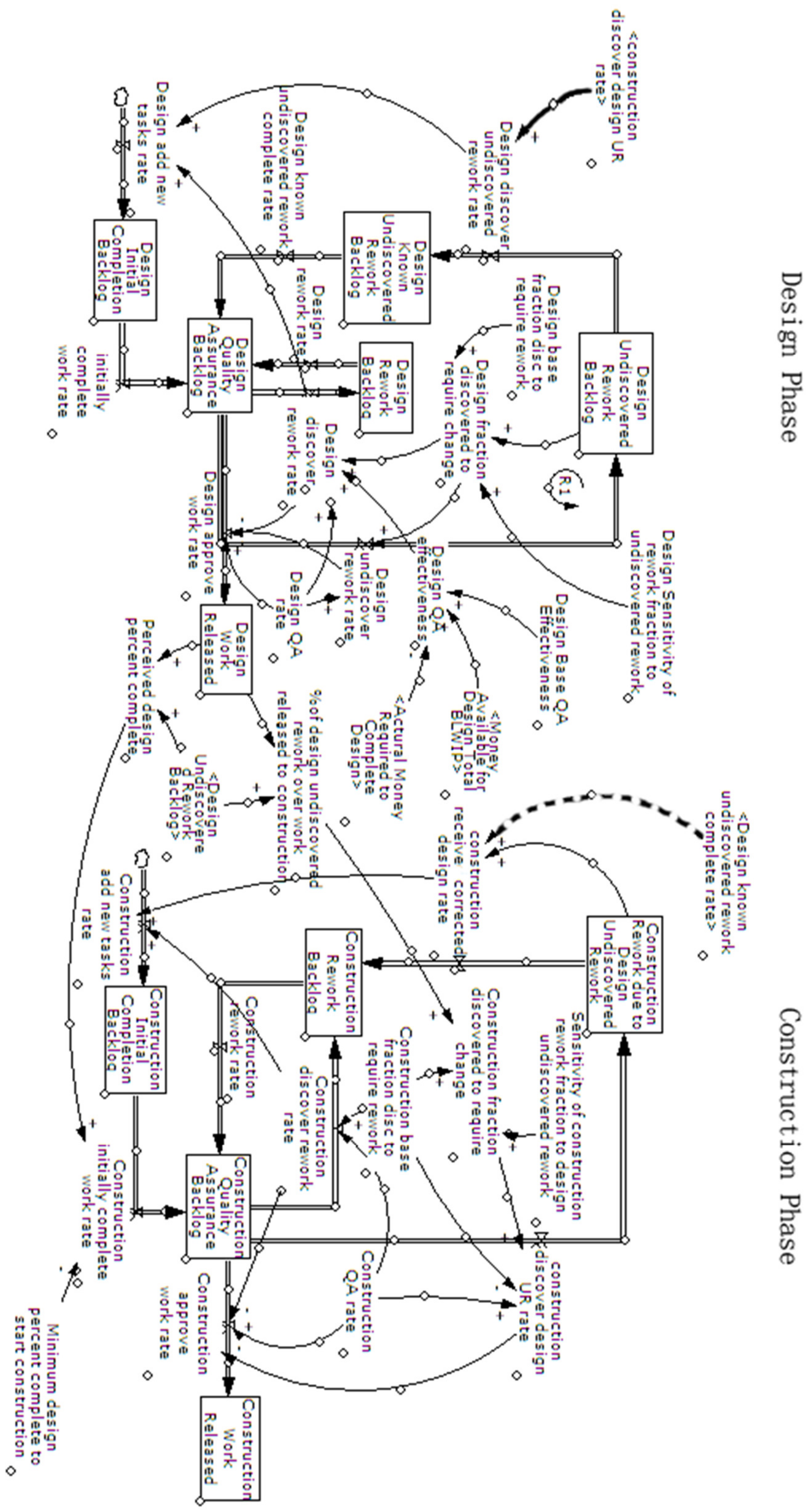
System dynamics is a methodology for studying and managing complex systems (Sterman, 2000). System dynamics models have been successfully applied to project management issues including the effect of rework on project performance (Cooper 1994), tipping point dynamics (Taylor and Ford 2006, 2008), failures in fast track implementations (Ford and Sterman 1998). The system dynamics methodology was selected for the current work because it clearly illustrates the dynamics of design error induced rework in the two-phased construction project development process. The system dynamics model used in the current work is based on the structure of Taylor and Ford’s (2006, 2008) tipping point model. The current work expands this model by using the tipping point structure to model undiscovered rework in the two phase construction project development project. The model consists of three sectors: A work flow sector, a resource allocation sector, and a cost accounting sector. Figure 1 is a simplified version of the work flow sector. The model contains a design phase and a construction phase. For each of the two phases, the model uses the basic workflow structure used in the Taylor and Ford's (2008) model. The "rework fraction" variables indicate the possibility that a work package is completed incorrectly during initial completion. The "Design QA effectiveness" variables indicate the possibility that design quality assurance staff catch an error and send it to rework backlog.

The feedback loops identified in Figure 1 (R1) can be used to describe the impact of having undiscovered rework on the project performance within the same phase. When quality assurance is not 100% effective, mistakes are not identified by quality assurance and are sent to the "Undiscovered Rework Backlog." However, since the errors were not identified, the project manager perceives that this "undiscovered rework backlog" as being included in the stock of "Work Released." This undiscovered rework can create additional rework. For example, having installed underground water pipes of the wrong size without knowing it until the end of the project may create rework in foundation, masonry, electrics, painting, etc. Since having undiscovered rework can create more rework, it increases the rework fraction of the same phase which increases the number of errors. With the same quality assurance effectiveness, more mistakes will be sent to "Undiscovered Rework Backlog" which will further increase the rework fraction.

The stock-flow structure in the construction phase is slightly different from that of the design phase. For simplicity the current model assumes that that construction quality assurance is 100% effective (i.e. all errors are discovered) so that errors made in the construction phase which resulted from design undiscovered rework can be tracked and therefore the impact of design undiscovered rework on construction performance is captured.

The two phases are related according to the following logic. The construction phase only starts when the design reaches a certain percent complete, which is determined by the project management team. Having undiscovered rework in the design phase could also increase the rework fraction in the construction phase if the design error is not identified before it is implemented in the construction phase. When the construction staff identify a design error, the design staff must rework the work package. In Figure 1, this situation is reflected by the "Design discover undiscovered rework rate." This flow moves work packages from the "Design Undiscovered Rework Backlog" to "Design Known Undiscovered Rework Backlog" as construction staff finds design errors. The bold arrow in Figure 1 corresponds to this feedback from construction phase to design phase. The "Design Known Undiscovered Rework Backlog" stores undiscovered design rework identified by construction staff but have not been corrected by the design staff. As the design staff fix the error, the relevant work package will then be re-released in the construction phase, through the "Construction receive corrected design rate" in Figure 1. The bold dashed arrow in Figure 1 corresponds to this feedback from design phase to construction phase.

Figure 1 Simplified Model Structure (Work Flow Sector Only)



In Taylor and Ford's 2008 model, resource (manpower) is allocated to all the backlogs in direct proportion to the amount of work packages in each backlog. The structure of the resource allocation sector in the current model is similar to the Taylor and Ford's 2008 model with the design and construction phases having separate resource allocation sectors.

In the design phase, the cost is determined by the total number of tasks the designers perform, which is an indicator of the size of the project. The model assumes that an experienced project manager would be able to forecast the cost of rework according to past practice before the project starts and include the extra effort in their initial budget. So if the original scope is made up of n work packages, each work package has to go through two (2) tasks (initial completion and quality assurance) to get released, each task costs A dollars, and the estimated rework fraction (r) is 0.2, the initial project budget will be:

$$\text{Initial Budget} = \frac{2\text{nA}}{1-\text{r}} \quad (1)$$

As the project proceeds, the project manager tracks project cost to date and estimates the money required to complete the rest of the project. The method is to check the number of work packages in each of the backlog in progress, i.e. the "Initial Completion Backlog", the "Quality Assurance Backlog", the "Rework Backlog" and the "Known Undiscovered Rework Backlog" in the design phase. The project manager then estimates the number of tasks needed for one work package in each of these backlogs, and apply task unit cost to get the money needed to complete the rest of the project. For example, for each work packages in the "Initial Completion Backlog", if the estimated rework fraction is r, then the chance that it will take two (2) tasks (initial completion and quality assurance) to complete this work package is (1-r). The chance that it will take four (4) tasks (initial completion, quality assurance, rework and quality assurance again) to complete this work package is r * (1-r). The chance that it will take six (6) tasks (initial completion, quality assurance, rework, quality assurance, rework again, and quality assurance again) to complete this work package is r^2 * (1-r), and so on. Therefore the expected number of tasks needed for each work package in the initial completion backlog is:

$$\sum_{\text{i}=1}^{\infty}[2\text{ir}^{\text{i}-1}\,(1-\text{r})] = \frac{2}{1-r} \quad (2)$$

Similarly, the number of tasks needed for each work package in the rework backlog and the known undiscovered rework backlog is:

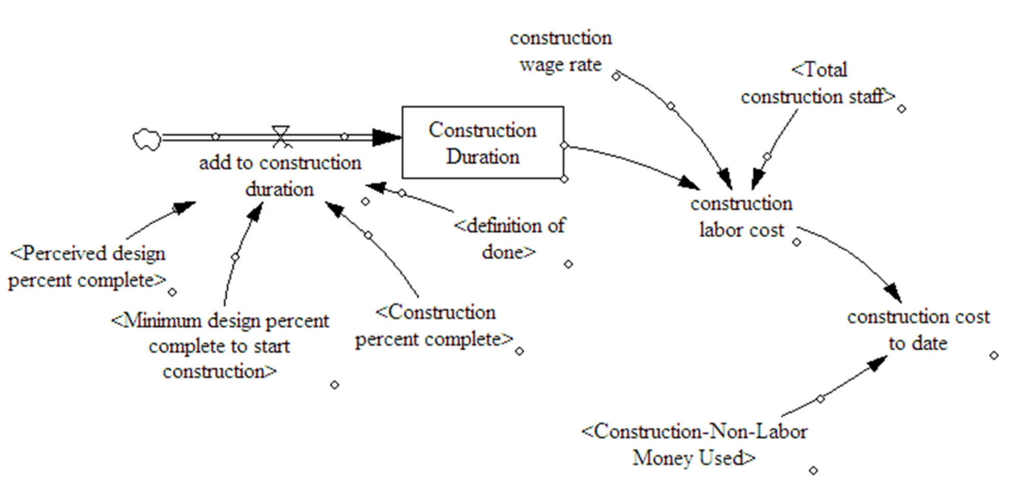
$$\sum_{\text{i}=1}^{\infty}[2\text{ir}^{\text{i}-1}\,(1-\text{r})] = \frac{2}{1-r} \quad (3)$$

And the number of tasks needed for each work package in the quality assurance backlog is:

$$\sum_{i=1}^{\infty}[(2i-1)r^{i-1}(1-r)] = 1+\frac{2}{1-r} \tag{4}$$

Construction labor cost and non-labor cost are calculated separately. The same structure as described above is used to track construction non-labor cost. Construction labor cost is calculated according to wage rates, crew sizes and construction duration (See Figure 2).

Figure 2 Construction Labor Cost



The total project costs are then determined using the following equation.

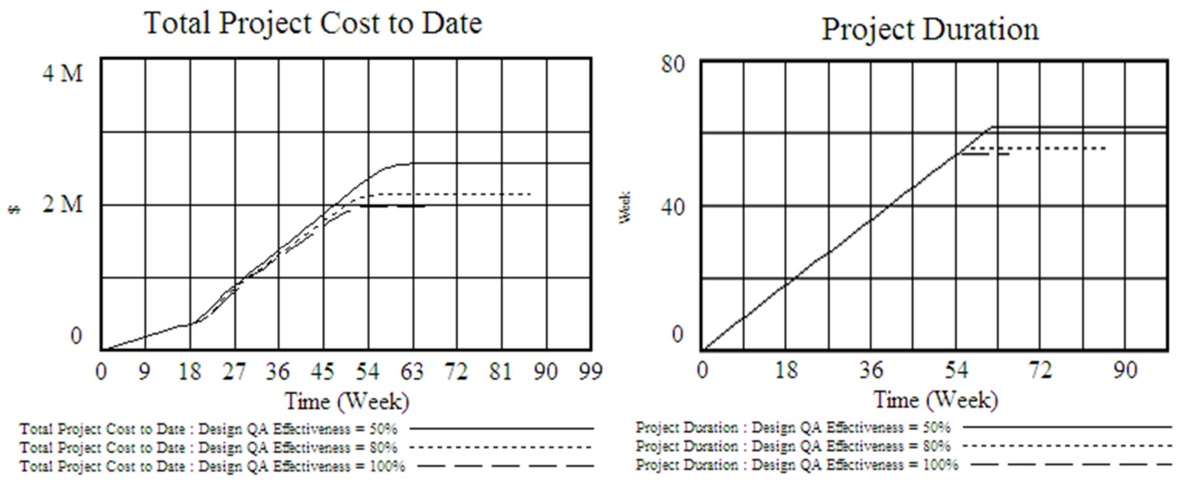
$$\text{Total Project Cost} = \text{Design Cost} + \text{Construction Cost} \tag{5}$$

When the project experiences cost overrun, the project team is running in an "under-resourced" condition, which causes the "Design QA effectiveness" to decrease as the management team focuses their attention on other issues.

4. Typical Model Behaviour, Testing, and Analysis

The model was tested using standard system dynamics procedures (Sterman 2000). The model is able to reflect situations and comparison of different conditions as expected. For example, when design quality assurance effectiveness is 1 (perfect quality assurance), no work is placed in the "Design Undiscovered Rework Backlog" and the "Construction Rework Due to Design Undiscovered Rework" backlog. When quality assurance effectiveness drops, undiscovered rework is placed in the "Design Undiscovered Rework Backlog" and the lower the design quality assurance effectiveness, the more undiscovered rework is created. When quality assurance effectiveness drops, both cost performance and schedule performance degrade. Figure 3 shows significant degrade in cost performance and schedule performance when design quality assurance effectiveness is 80% and 50% as compared to 100%.

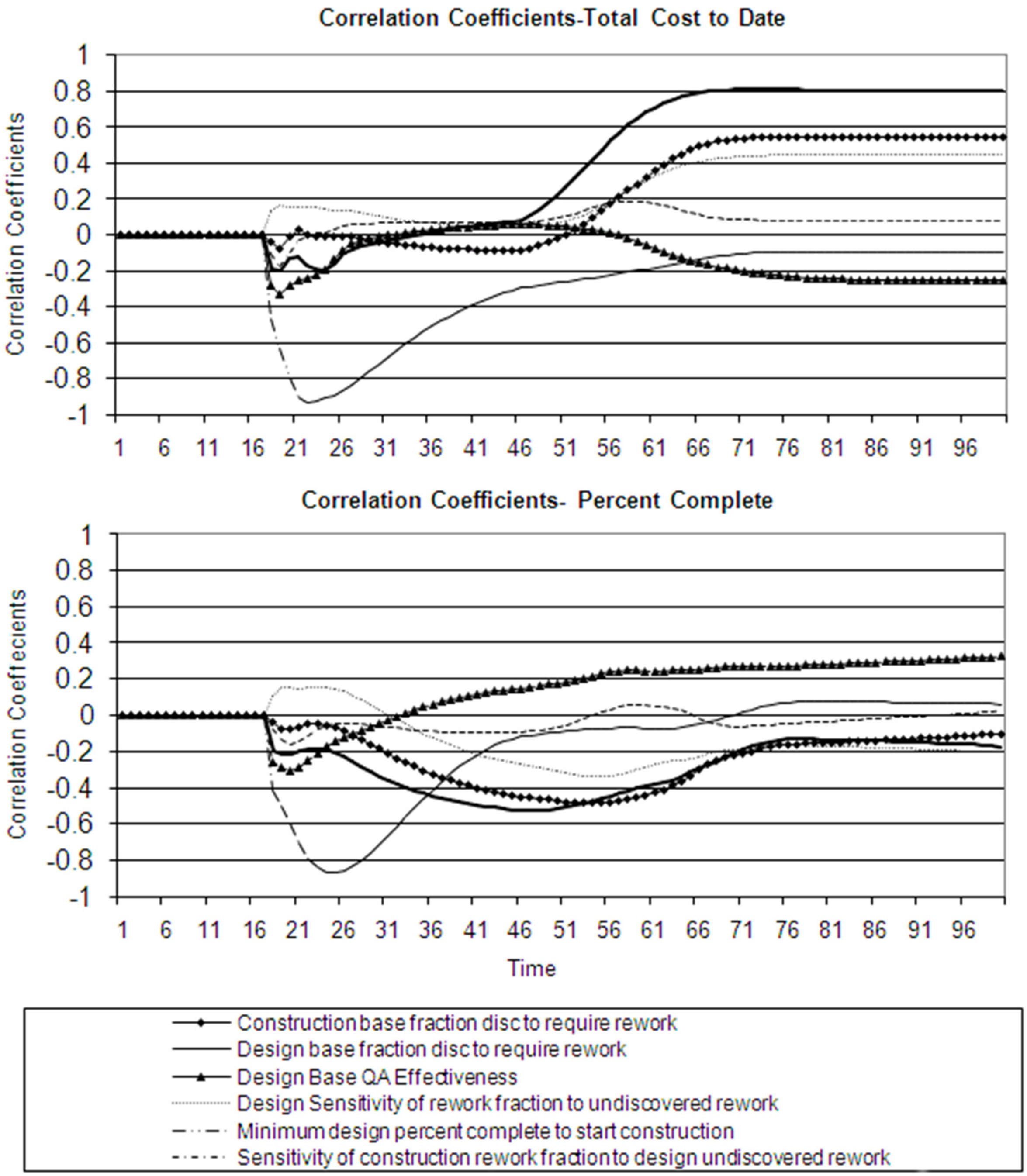
Figure 3 Comparison of Project Cost Performance and schedule performance



To further test if all the major control variables impact the system behaviour in reasonable ways, we performed statistical screening test (Taylor et al, 2010) on six (6) major control variables regarding the correlation coefficient between them and the total project cost to date. Statistical screening is a simple, structured, and user-friendly method of identifying high-leverage model parameters. It uses multiple simulations generated by varying model input parameters to calculate linear correlation coefficients that measure the direction and strength of the relationship between input parameters and a user-defined system performance variable. Since we are most interested in project cost performance, we selected total project cost to date as the performance variable. When choosing control variables, we selected the exogenous parameters that describe the interaction of the two design phases and the rework fractions in both phases, since they indicate the project's level of complexity and are related to a great number of other variables in the model. We assigned an uncertainty of ±25% from the base case value for each control variable and varied the parameter values according to a uniform distribution. This range is determined by taking both reality and rationality into consideration. For example, the base case value for design quality assurance effectiveness is 0.6 and the value used for each simulation can't exceed 1 because the quality assurance staff can't find more errors than there actually are.

In Figure 4, if the correlation coefficient is between -0.2 and 0.2, the correspondent control variable is not significantly related to the performance variable (Taylor et al, 2010). If a correlation coefficient is above 0.2, the polarity between the control variable and the performance variable is positive, which means the control variable and the performance variable move in the same direction (i.e. an increase in the input causes an increase in the model output and vice versa). The higher the correlation coefficient is, the stronger the relationship. If a line goes below -0.2, the polarity between the control variable and the performance variable is negative, which means the control variable and the performance variable move in the opposite direction (i.e. an increase in the input parameter causes a decrease in the model output and vice versa). The lower the coefficient is, the stronger the relationship.

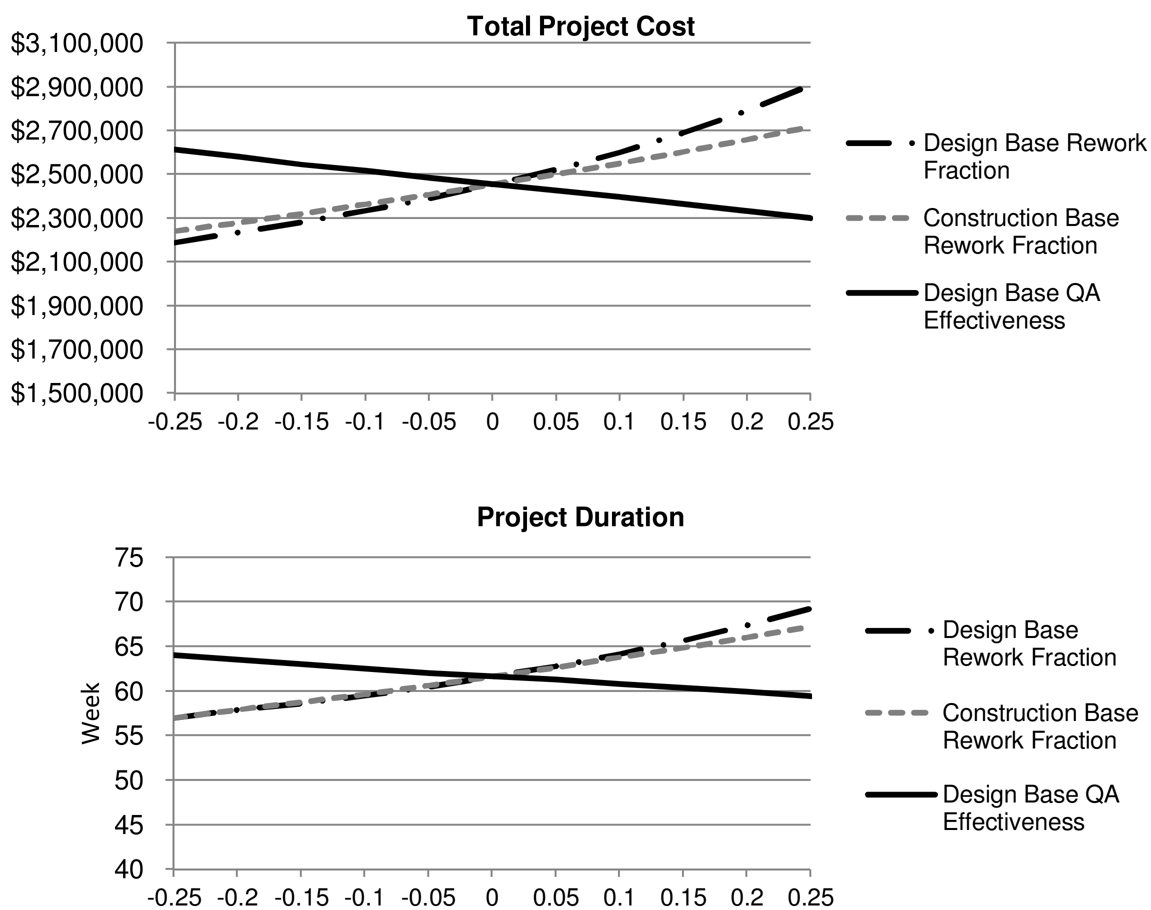
Figure 4 Correlation Coefficients-Total Cost to Date and Construction Percent Complete



The test results show that with this model structure, increasing the design rework fraction or construction rework fraction will increase total project cost and cause significant delay in project schedule. The design rework fraction has a slightly stronger influence to both performance variables, since design rework impacts both phases. Improving the design base quality assurance effectiveness will slightly improve cost performance. The earlier construction phase is started, the greater the project cost given the increased potential for rework.

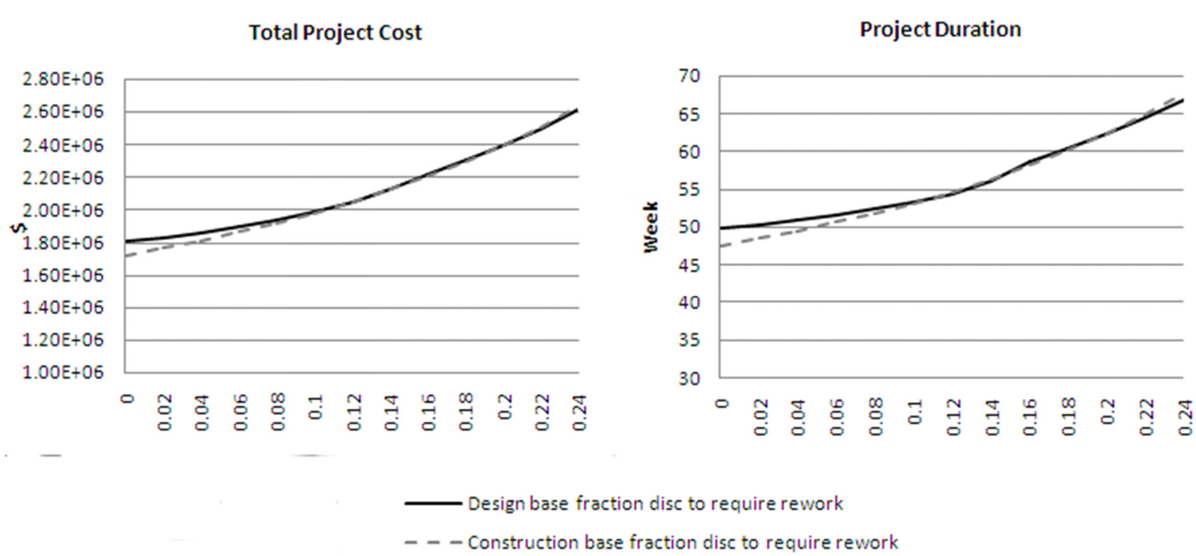
To identify high leverage points that managers can use to improve project performance, a sensitivity analysis was performed on the six (6) major control variables in the model, and results show that design rework fraction, construction rework fraction and design quality assurance effectiveness have the greatest impact on project cost performance. While it can be difficult for a project manager to reduce the rework fraction, design quality assurance is more within the project manager's control. Figure 5 below shows the overall project cost when design quality assurance effectiveness, design base rework fraction and construction base rework fraction vary from -25% to +25% as compared to their base case values. In the base case, the design rework fraction and construction rework fraction are set to be 0.2, and design base quality assurance effectiveness is 0.8. The relationship between total project cost and design base quality assurance effectiveness and that between project duration and design base quality assurance effectiveness appear to be linear within this interval, while the design base rework fraction line and the construction base rework fraction line resemble an exponential growth curve.

Figure 4 Sensitivity Analysis (only showing the three most influential variables)



To further investigate the relationship between the two most influential variables and project performance variables, a sensitivity analysis with wider intervals on these two variables were performed. Results are shown in Figure 5. For each line in Figure 5, while the indicated control variable varies, the other control variable remains its base case value (0.2). For projects that are simple (those have low design rework fraction and construction rework fraction), the development process only generates limited number of rework and undiscovered design errors, and the performance variables are more sensitive to construction base rework fraction, since construction task unit cost is much greater (three times in the model) than design task unit cost and it also takes longer to complete a task in construction than in design. As the two control variables move into the higher range, the model becomes more and more sensitive to the design base rework fraction. High design rework fraction usually means that the project is unique or very complex. Model analysis shows that for this type of projects, the manager should pay particular attention to minimizing the design rework fraction and preventing design errors from entering the construction phase.

Figure 5 Sensitivity Analysis on Design Base Rework Fraction and Construction Base Rework Fraction



The statistical screening and sensitivity analysis results suggests that failing to discover rework near its creation results in more rework which degrades project cost performance. In the base case run, the design quality assurance effectiveness starts at 80%, and then drops as the project experiences cost overruns. When compared to a project with the same amount of base rework but a 100% effective quality assurance, the base case results in a 22% cost overrun compared to the effective quality assurance policy.

5. Project Management with Design Rework

Although the design rework fraction and construction rework fraction are the two most related variables to project performance, they are difficult to reduce by project manager. They depend in some part on the level of complexity of the project and the competency of the project team. However, there are strategies that a project manager can use to improve design quality assurance effectiveness or at least eliminate the impact of design undiscovered rework on the construction phase since the construction costs typically represent the majority of the total project cost in a real construction project.

One obvious theoretical solution to solve the problem caused by design undiscovered rework is to implement a design quality assurance program that identifies all design errors (i.e. 100% quality assurance effectiveness) (Policy 1 in Table 1). Simulated results show that this policy could lead to a 5.86% improvement in design cost, a 21.82% improvement in construction cost, and a 17.72% improvement in total cost over the base case. For a project manager, keeping design quality assurance perfect means never compromise quality assurance under any conditions. Even when the project team is experiencing budget and schedule pressure, the project manager must still provide sufficient resources and competent personnel to the quality assurance department. What is most interesting with Policy 1 is that due to the structure of the two phase design process and the increased cost of construction compared to design in the model the Contractor receives a greater benefit of adopting Policy 1. However, the Contractor does nothing to help solve the problem in this scenario (i.e. the contractor does not participate in the design process).

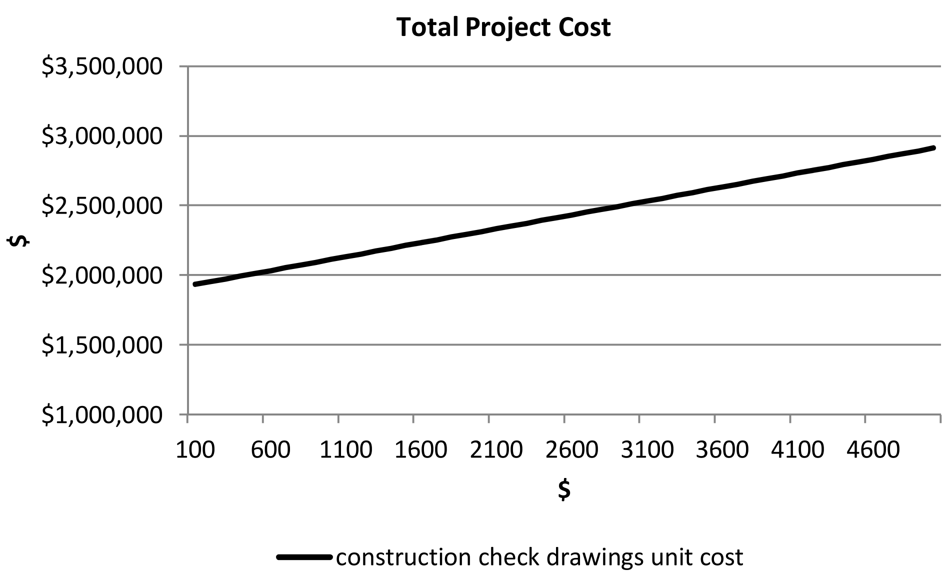
Table 1 Comparison of improvement by using two policies.

	Base Case	Policy 1	Policy 2
Description	With the problem of undiscovered rework	Design staff finds design UR before construction (design QA perfect)	Construction staff finds design UR before construction initial completion
Total Project Cost ($)	$2,416,000	$1,988,000	$2,162,000
% Improved	-	17.72%	10.51%
Design Cost ($)	$621,290	$584,876	$559,135
% Improved	-	5.86%	10.00%
Construction Cost ($)	$1,794,710	$1,403,124	$1,603,865
% Improved	-	21.82%	10.63%
Project Duration (week)	63	54	54
% Improved	-	14.29%	14.29%

The problem can be solved by the construction firm, too. Knowing that design quality assurance is not always perfect, the construction project manager can improve construction performance by eliminating the impact of design undiscovered rework on the construction phase. For example, they can hire a couple of engineers to recheck the drawings that were approved by design quality assurance department prior to initial completion in the construction phase (Policy 2 in Table 1). By doing this, most of the design errors can be found before the work is installed. Since the design firm is doing less work than in the scenario of Policy 1, they will enjoy lower cost (a 9.33% improvement in design cost compared to 5.86% of Policy 1). But the Contractor needs to pay extra money to the engineers they hired to recheck the drawings. When taking the extra cost into consideration, Policy 1 is clearly more attractive than Policy 2 for the Contractor. This highlights a structure problem inherent in the traditional design-bid-build process. Both the Engineer and the Contractor want to improve their own performance, but neither of them would want to perform extra work for less improvement in return. Then balancing effort and reward will be up to the Owner's project management team to coordinate the Engineer and the Contractor to achieve the lowest overall project cost for the owner.

The above comparison of policies is based on the assumption that the cost for checking the drawings in the construction phase equals the cost of checking them in the design phase (design quality assurance unit cost). But this may not be the case in real practice, and the difference in costs for checking the drawings may alter the preference between the two policies. Therefore, another sensitivity analysis was conducted on the difference of costs for checking the drawings in the design phase and in the construction phase. The control variable is the unit cost for checking drawings in the construction phase with the unit cost of checking drawings in the design phase being $1,000. The results are shown in Figure 6.

Figure 6 Sensitivity Analysis on Checking Drawings Cost between Two Phases



Referring to Table 1, the total project cost for adopting Policy 1 is $1,988,000. If Policy 2 is used, the total project cost is less than Policy 1 only when the cost of checking the drawings in the construction phase is less than half of the cost of checking the drawings in the design phase. Otherwise Policy 1 will be the preferred policy.

6. Conclusions and Implications for Practice

Project cost and schedule performance are controlled by the feedback mechanisms in the development process and the current work shows that the rework cycle can alter project performance. Looking at the whole entire two-phase construction development process, it is always good to realize and fix the rework near the point of rework creation. When more than one phases are included in the developing process, which is always the case for a construction project, the errors missed by quality assurance staff and therefore released from the preceding phase can have an great impact on the performance of the following phase. By identifying high leverage points using the model described in this paper, the current work shows that having undiscovered rework in the design phase will result in a significant cost overrun in the construction phase. Both the design phase and the construction phase will benefit from eliminating the impact of design undiscovered rework. First, all the parties involved in the project must understand the potential result of having design undiscovered rework, then they must work together toward the same goal, i.e. the ultimate project performance, in the meanwhile balancing effort and reward of each party.

The current work offers several contributions to the existing body of knowledge. The proposed model structure provides a structured feedback description of how design undiscovered rework impact project performance in both the design phase and the construction phase, as well as evaluates possible solutions to the problem of interest. This model structure is based on previous accepted model, so that is can be calibrated to be suitable for typical development projects. The added structure offers a view into the interaction between the design phase and the construction phase from a system dynamic perspective.

The current work has several limitations which can be addressed in future work. The proposed model structure mostly focuses on the impact of design phase on the construction. There are possible feedbacks from the construction phase to the design phase as well, but are not recognized in our model. For example, some construction mistakes could be better handled by modifying design, rather than tearing the work down and reinstalling according to the original design. The model work can also be expanded to test the effectiveness of other strategies in managing the design-construction process (i.e. design-build). Finally, the model can be expanded to test the impact of undiscovered design rework on tipping point dynamics (Taylor and Ford 2006, 2008) in the design and construction process.

7. References

Burati, J. J. 1992. Causes of quality deviations in design and construction. *Journal of Construction Engineering and Management,* 118: 34-49.

Fazio, P., Moselhi, O., Théberge, P. and Revay, S. 1988. Design Impact of Construction Fast-Track. *Construction Management and Economics*, 5: 195-208.

Ford, D. 1995. *The Dynamics of Project Management – An Investigation of the Impacts of Project Process and Coordination on Performance*. Dissertation. Massachusettes Institute of Technology, Cambridge, MA, USA.

Ford, D. N. and Sterman, J. D. 1998. Dynamic Modeling of Product Development Processes. *System Dynamics Review*, 14: 31-68.

Ford, A and Flynn, H. 2005. Statistical Screening of System Dynamics Models. *Systems Dynamics Review*, 21: 273-303.

Hwang, B., Thomas, S., Haas, C. and Caldas, C. 2009. Measuring the Impact of Rework on Construction Cost Performance, *Journal of Construction Engineering and Management,* 135: 187-198.

Josephson, P. 1999. Causes and costs of defects in construction a study of seven building projects. *Automation in Construction,* 8: 681-687.

Love, P.E.D., and Heng, L. 2000. Quantifying the causes and costs of rework in construction. *Construction Management and Economics,* 18: 479-490.

Nelson. P. Repenning. 2001. Understand Fire Fighting in New Product Development, *Journal of Product Innovation Management*, 18: 265-300.

Peña-Mora, F. and Li, M. 2001. Dynamic Planning and Control Methodology for Design/Build Fast-Track Construction Projects. *Journal of Construction Engineering and Management*, 127: 1-17.

Smith, R. P. and Eppinger, S. D. 1997. Identifying Controlling Features of Engineering Design Iteration. *Management Science*, 43:276-293.

Sterman, J. D. 2000. *Business Dynamics – Systems Thinking and Modeling for a Complex World* , McGraw Hill, New York, NY, USA.

Taylor, T. and Ford, D. 2006. Tipping Point Failure and Robustness in Single Development Projects. *Systems Dynamics Review*, 22: 51-71.

Taylor, T., Ford, D., and Ford, A. 2007. Model analysis using statistical screening: Extensions and example applications. *Proceedings of the 25th International Conference of the System Dynamics Society*. July 29-August 2. Boston, MA, USA.

Taylor, T. and Ford, D. 2008. Managing Tipping Point Dynamics in Complex Construction Projects. *Journal of Construction Engineering and Management,* 134(6), 421-431.

Taylor, T. and Ford, D. 2010. Improving Model Understanding Using Statistical Screening. System Dynamics Review, 26: 73-87.