The Influence of Schedule Target on Project Performance

Xiaoqian Ning[1] **Qifan Wang**[1,2,3] **Bing Wu**[1]

(1.Tongji Development Institute；2.School of Management and Economics, Tongji University；3. School of Management, Fudan University）

Postal Address: Professor Qifan Wang, School of Management, Fudan University, Shanghai, 200433, China

E-mail: qfwang@fudan.edu.cn

Abstract: Many organizations set ambitious schedules for their product development projects to gain competitive advantages. However, ambitious schedules might be the main factor to deteriorate project performance. The features of system dynamics application in project management is discussed and a generic simulation model is built for studying the effects of schedule pressure and providing a helpful tool for project management to understand feedbacks, delays and nonlinear relationships among projects and how project behaviors are driven by project structures. Finally, the future works about this study are discussed.

Keyword: Project Management, System Dynamics, Model.

1. Introduction

In keen competition, many organizations set ambitious schedules for their product development projects to gain competitive advantages. However, ambitious schedules might be the main factor to deteriorate project performance, which is usually measured in time, cost and quality, rather than leading to a faster new product delivery.

Consider the following, all-too-familiar scenario. An organization sets a tight schedule for a product development project where its scope is not fully defined initially. Soon it becomes apparent that underestimated changes are reducing actual productivity and causing extra work. The project falls behind its ambitious schedule. The delays expose the project to unexpected technological and regulatory changes, and hence more rework and lower productivity. Suppose that there is no provision in the project schedule and budget for any of this. Further delays and cost escalation prompt the organization to change the number of tasks to be produced to stay within budget limit and agree to a even more ambitious, success-oriented, and potentially disastrous “rescue plan” to salvage the project.

The example above demonstrates that the effects of willingness and decision to hasten projects might be quite counter-intuitive and often prompt dysfunctional management actions. This is because projects are ”complex” systems as they 1) consist of multiple interdependent components and feedback processes; 2) are highly dynamic; 3) involve nonlinear relationships; 4) involve both “hard” and “soft” data. The impacts of management decisions and actions are delayed, non-linear, indirect, and self-reinforcing. Hence, before the fact or even after they have occurred their full significance is difficult to perceive.

To manage such complexity properly, a model must be capable of representing system with those complex characteristics, and it must be understandable and usable by the managers of the projects. System Dynamics is just such a powerful methodology for analyzing the complexity systems and System Dynamics models appropriate and effective tools understand project process and performance.

This paper uses system dynamics simulation model to study the influence of project schedule on project performance.

2. System Dynamics Approach to Project Management

System Dynamics was created by Forrester as an approach for modeling and analyzing the behavior of complex social-economic system, particular in as industrial context. The system dynamics approach to project management is based on a holistic view of the project management process. In contrast with traditional project management methodology, the primary objective of a system dynamics model is to capture the major feedback processes responsible for the project system behavior, with less concern about the detailed project components. There is a strong focus on human factors and managerial policies as these are considered to dominate that feedback structures. The system dynamics approach employs a high-level perspective in its model of project work. It is generally represented by a continuous flow of units of work that change from the initial state “to be done” to the final state “done”, as the staffs allocated to the project perform their tasks. A project could be viewed at different levels of detail by decomposing this flow of work into several phases or stages according to its life cycle.

3. Model Description

The model simulates single-phase project, which consists of similar work, such as preparation of construction drawings in real estate development project, the writing of software code or testing of product prototypes.

One important level of aggregation assumption concerns the fundamental units that flow through projects. These units are defined as “tasks”. Conceptually a task is an atomic unit of development work of the project. Tasks are assumed to be uniform in size and fungible and to be small enough to be flawed or correct but not partial flawed.

The project is disaggregated into three activities: base work, quality assurance and rework. Base work is the completion of a task the first time. Subsequent completions, which are required to correct flaws or iterate for quality, are referred to as rework. Rework includes all forms of iteration regardless of cause. The search for flaws is quality assurance (QA). Flaws include errors that must be corrected for product functionality and optional improvements for quality.

Project resources have been aggregated into a single labor type. And it is assumed that there is no cost constraint on the project, i.e. to finish on time is most important, which is a very common phenomenon in many projects.

3.1 Project Process Sector

Project Process is modeled as Figure1. Tasks flow into and through three stocks: TasksToBeCompletd, TasksToBeChecked and TasksToBeReworked. Tasks are completed for the first time through the performance of base work. They accumulated in the TasksToBeChecked stock. If no tasks are flawed or those flaws are not found, tasks leave the TasksToBeChecked stock and pass through the ApproveAndRelease flow into the TasksReleased stock. Tasks that are found to be flawed flow to TasksToBeReworked stock. The Rework flow returns corrected tasks to the TasksToBeChecked for quality assurance again.

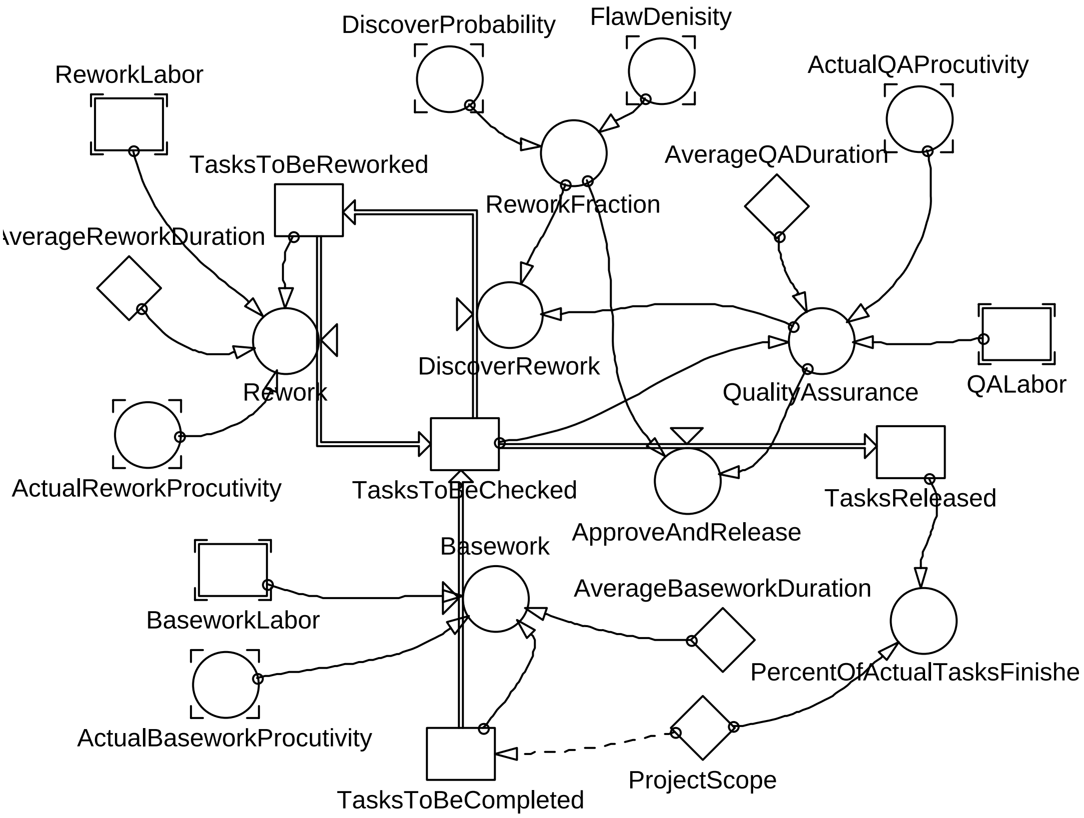


Figure 1: Project Process

Average activity duration describes the time required for each activity if all required information and resources are available.

Labors allocated to each activity and their productivities, the probability of a task being flawed and the probability of a flawed task being found if it exists are all influenced by schedule pressure, which is determined by target schedule, as discussed below.

3.2 Labor Sector

3.2.1 Labor Level Management

Figure2 depicts human management subsystem that determines labor level. As the figure shows, a project's total labor is assumed to consist of two work levels, namely, New Labor and Experienced Labor. New Labor is not only less productive but also more error-prone than their experienced counterpart. After a period of assimilation, New Labor becomes experienced and flows into Experienced Labor stock. The assimilation delay is formulated in the model as a first-order exponential delay.

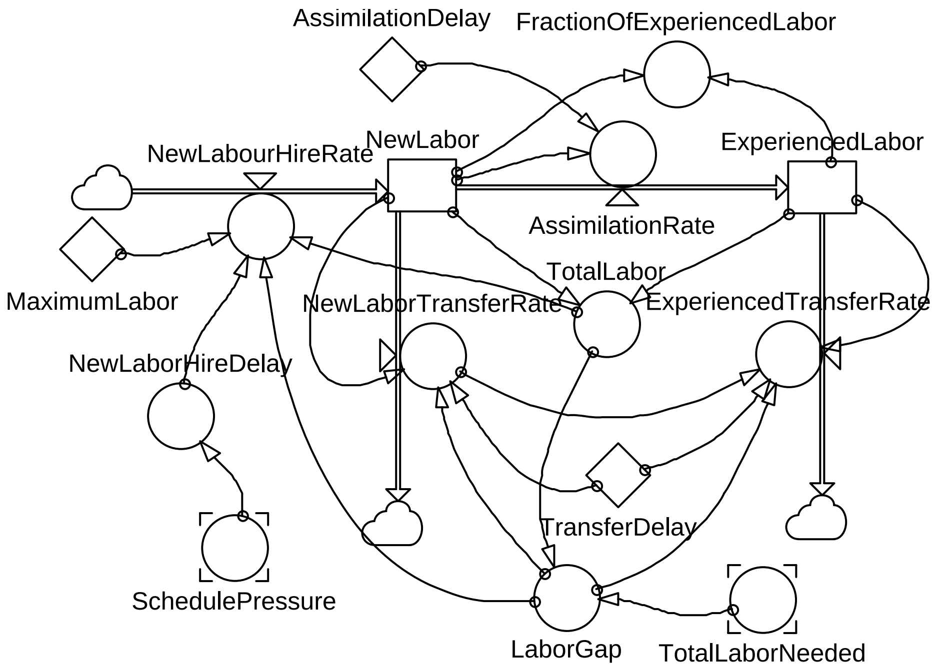


Figure 2: Labor Level Management

The most important factor in deciding the level of Total Labor Needed is the current scheduled completion date of the project. As part of the planning function, management determines the labor level that it believes is necessary to complete, within the schedule completion time, the project tasks perceived to be remaining based on the perceived labor productivity. In addition, management should determine the maximum labors which could be settled within the available working conditions. Once the determination is made, management will face one if three situations. First, Labor Gap between Total Labor Needed and Total Labor could be zero. In that case no further action is necessary. Second, and more likely, Total Labor Needed is larger than the current Total Labor. In this case, new labor will be hired within the limit of Maximum Labor, which, of course, takes time. This time reflects the willingness of management to hire more labor and depends Schedule Pressure. The larger the Schedule Pressure, the more willingness of management to hire labor and the shorter of New Labor Hire Delay. The third possibility is that Total Labor Needed is less than the current Total Labor. In this case, labor will be transferred out of the project. It is assumed that if there are new recruits still in New Labor stock, these will be the first to be transferred out. If still more transfers are needed, they would be then be made from stock Experienced Labor. Those being transferred require some period of time for paper work and transfer arrangements before they actually leave the project.

3.2.2 Productivity

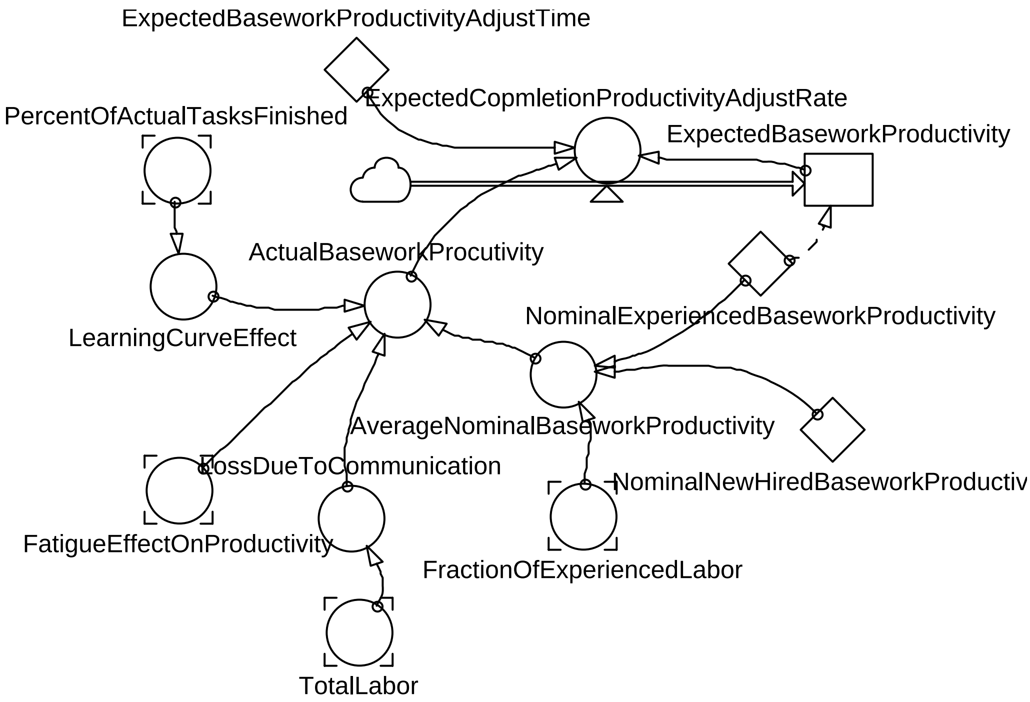


Figure 3: Base Work Productivity

Figure 3 depicts base work productivity. Quality assurance productivity and rework productivity sectors have the same structure.

In Figure 3, Nominal Productivity represents the maximum level of base work productivity that can occur when the labor employs the available resource and information to perform the tasks. There are fours factors make the actual productivity differing from the nominal one. They are labor experience level, project familiarity, communication complexity among project and labor fatigue.

To integrate the effect of experience, the model use two nominal potential productivity parameters, one for average experienced labor and the other for new hired labor. At any time in the project Average Nominal Productivity for the labors as a whole is the weighted average of the two parameters.

As a project proceeds, the implementers learn their job better. The learning curve is the rate of improvement. Many literatures suggested that an S shape curve characterizes the rate of improvement.

Loss due to communication represents unproductive inter-person communication that includes verbal communication, documentation, and any additional work. It is widely held that communication overhead increases in proportion to n^2, where n is the team size. In the model, Loss due to Communication is zero when one person carries out the project; as team size increases, Loss due to Communication increases in proportion to n^2.

More fatigue decreases productivity. Fatigue is modeled as the response to the ratio of the Average Working Hours to the Normal Working Hours. The relationship of fatigue to productivity is nonlinear with little influence when the Average Working Hours is less than normal. A maximum effect is reached as the Average Working Hours exceeds a certain limit.

3.3 Quality of Practice

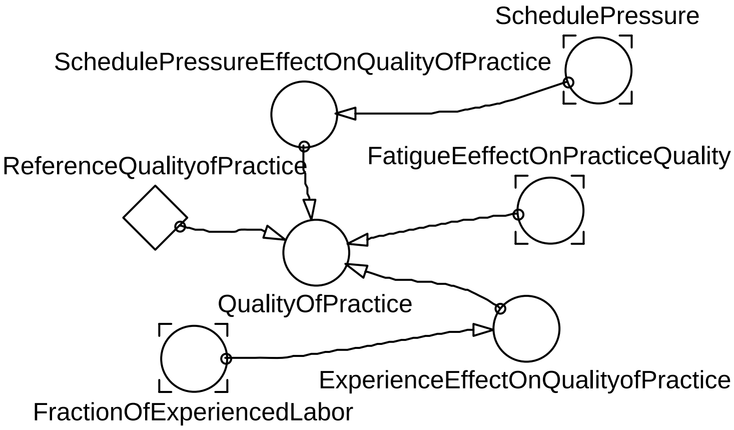


Figure 4: Quality of Practice

The Quality of Practice sector (Figure 4) models the impacts of schedule, experience and fatigue on quality of work performed by the developers. The project's quality of practice impacts its flaw generation and discovery rates.

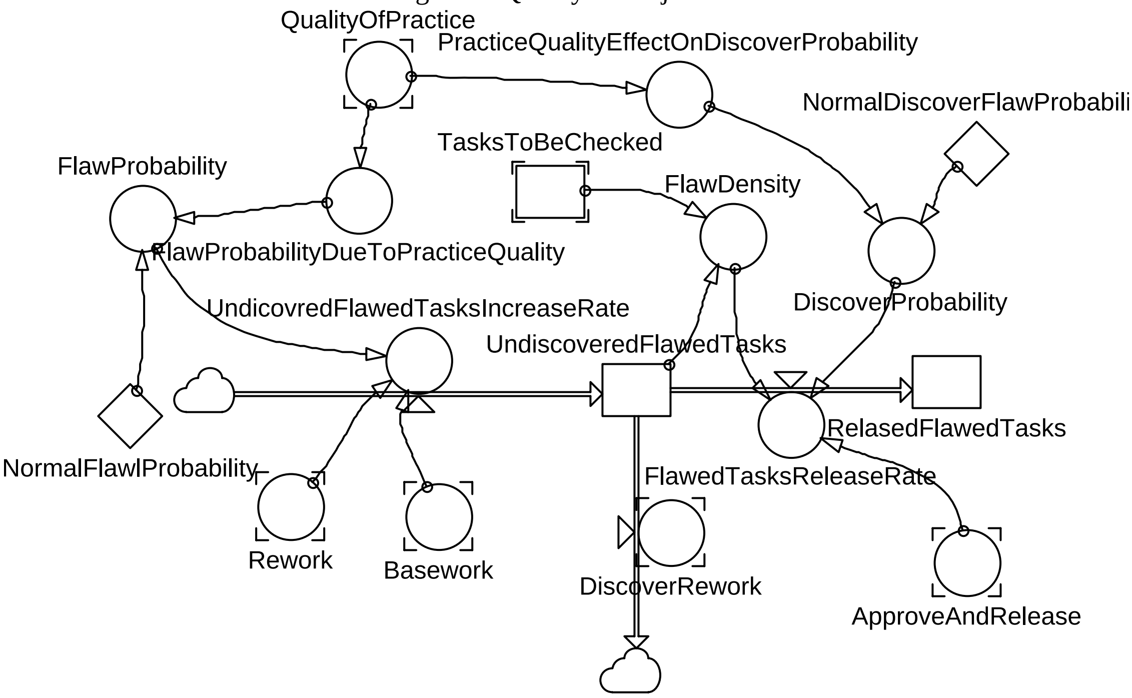
Increasing schedule pressure decreases Quality of Practice because the developers are working faster to recover the time and therefore not doing as good a job. Schedule pressure is assumed to only hurt and never help Quality of Practice. A lower limit is placed on this relationship, reflecting the assumption that professional developers will retain some Quality of Practice even under extremely high schedule pressure conditions.

Experience Effect on Quality of Practice is modeled responding to labor mix. As mentioned in Labor Level Management sector, New Labor is more error-prone than Experienced Labor. So the higher proportion of New Labor will decrease Quality of Practice.

More fatigue decreases Quality of Practice too because developers are working tired. The relationship of fatigue to Quality of Practice is nonlinear with little influence when the Average Working Hours is less than normal. This reflects the assumption that any time made available due to needing to work on the project less than the normal working time will be absorbed. A maximum effect is reached as the Average Working Hours exceeds a certain limit.

3.4 Quality of Project

Figure 5: Quality of Project



The quality of project is measured by Released Flawed Tasks. Flaw generation is decided by Flaw Probability. The probability of flaw generation is based on two factors that combine to cause flaws. The inherent complexity of the task is reflected in the normal probability that a task is flawed. The impacts of the development work are reflected in the probability of a flaw being generated by Quality of Practice. Each of these probabilities is used to find the probability of no flaw being generated by the task complexity or Quality of Practice. These "clean" probabilities are combined to find the probability of a task being flawed by neither of these factors. The resulting probability of no flaw is used to find probability of a flaw by subtracting from 1.

A portion of flawed tasks is uncovered during quality assurance, which is determined by the probability of discovering flaw if it exists. Undiscovered flawed tasks flow into stock Released Flawed Tasks.

3.5 Schedule

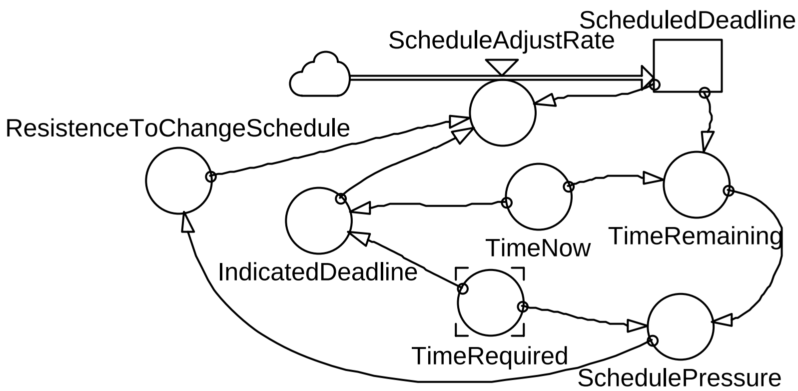


Figure 6: Project Schedule

Project Scheduled Deadline moves towards the indicated project completion date when Schedule Pressure, which is defined as the ratio of Time Required to complete the project and Time Remaining until the current scheduled project deadline, is greater than 1. Schedule Pressure reflects the psychological impact of current project schedule conditions on managers. A lager-than-one Schedule Pressure represents behind of schedule, while a smaller-than-one Schedule Pressure represents ahead of schedule.

4. Simulation Results

Figure 7, 8, 9 demonstrate project performance, which is measured in time, cost and quality, under different target schedules. It could be seen that project has its own mechanism to determine its behaviors. The impacts of relax schedule target is little, while unreasonable ambitious schedule target will deteriorate project performance. The tighter the unreasonable ambitious schedule target is, the more deteriorated the project performance is.

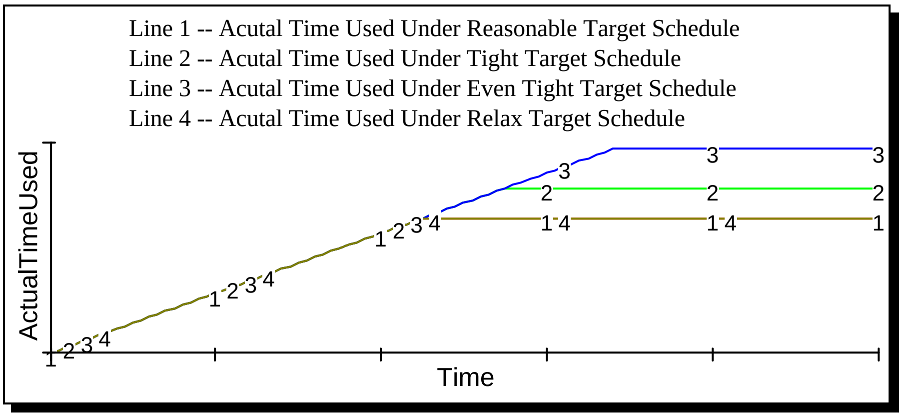


Figure 7: Time Performance under different Target Schedule

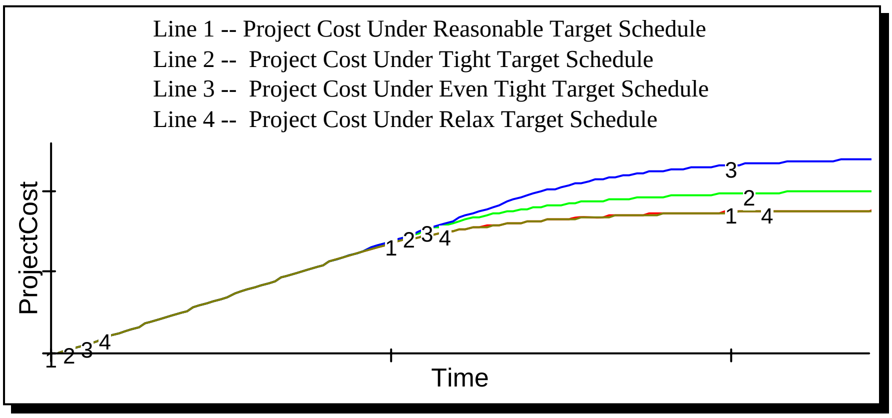


Figure 8: Cost Performance under different Target Schedule

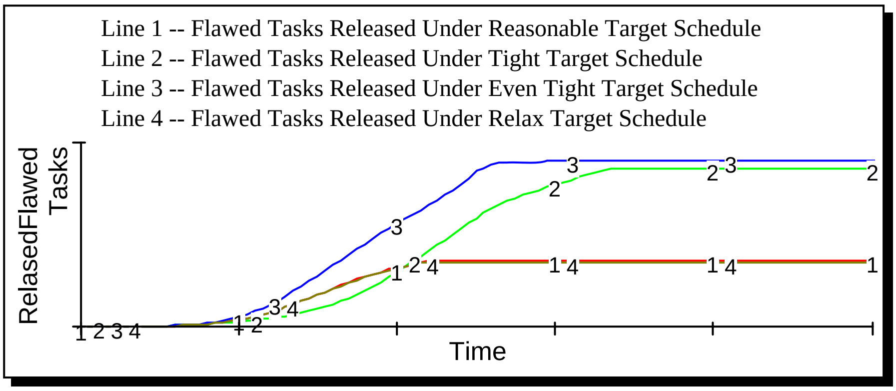


Figure 9: Quality Performance under different Target Schedule

5. Discussion and conclusion

The reason for above project behaviors under different schedule target is that once schedule pressure is huge to a certain limit, the side effects of those policies adopted by the management to rescue will be dominant and the project will be pushed to the other side contrary to the desire of management. Figure 10 demonstrates the effect of those policies. Three policies are usually adopted. They are hiring more labor, overworking and allocating more labor to base work. Among them, the effect of allocating more labor to base work is clear, which is to alleviate schedule pressure by scarifying project quality as depicted by feedback loop B1 in Figure 10. The effect of hiring more labor and overworking are much complex and out of rationality of management's mental model.

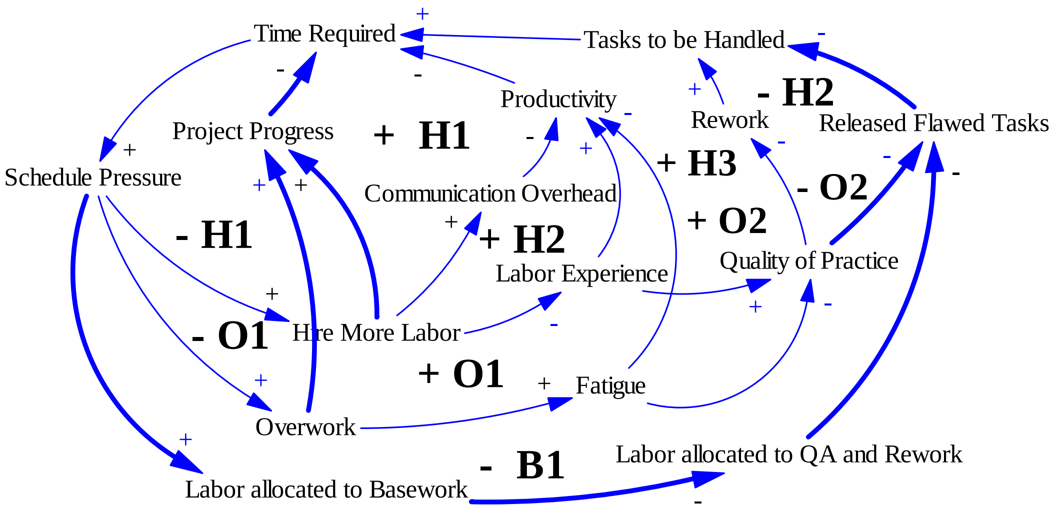


Figure 10: Effects of Schedule Pressure

Hiring more labor to relieve schedule pressure mainly has five impacts, two of them are balancing (-H1 and -H2) and the other three are reinforcing (+H1, +H2, H3). More labor will accelerate project progress (-H1). However more labor will lead to complex communication among project team, which will reduce productivity, therefore strengthen schedule press (+H1). In addition, a large proportion of new labor will reduce productivity (+H2) and quality of practice. The reduced quality of practice leads to more rework, which prolongs project completion time (+H3), and more released flawed tasks, which is helpful to reduce schedule pressure in the price of project quality (-H2).

Overwork acts through spending more time on project, so accelerating project progress (-O1). However the fatigue caused by overwork will reduce productivity (+O1) and quality of project too. The impacts of deteriorated quality of practice are as same as those of a large proportion of new labor (+O2, -O2).

It could be seen clearly that management must understand the structures that drive project behaviors, before setting target schedule or adopting actions to accelerate project progress. System dynamics can be applied as a useful tool to analyzing the feedbacks, delays and various nonlinear relationships in project. By altering the parameters, the model could be applied to represent different projects. And it is convenient to carry out sensitivity analysis of project behavior to different policies.

6. Future works

System dynamics approach and its model can be applied to following aspects:

- Project requirement analysis. Requirement analysis phase is a critical phase of project development cycle. Many times it's the bottleneck of project development and directly impacts project performance. System dynamics simulation model can be applied to testing this impact quantitatively.
- Multiple projects development. In multiple projects development environment, the competition for resource of each project will influence resource allocation among projects. System dynamics model can be applied to studying this influence.
- System dynamics model can also be used to studying the impacts of organization factors on project performance, such as the costs of turnover, effectiveness of difference project organization, the short term and long term of objective management.

References

[1] Junsi B. Modern project management. Beijing: Mechanism & Industrial Press, 2002

[2] Bi Xing, Zhang Li. Project management. Shanghai: Fudan University Press, 2000

[3] Burke R. Project management. Planning and Control. New York: John Wiley & Sons, Inc. 1993

[4] Ford D N. A behavior approach to feedback loop dominance analysis. *System Dynamics Review,* 1999, 15 (1):3-36.

[5] Forrester Jay W. Industrial dynamics. Portland OR, USA: Productivity Press, 1961.

[6] Rodrigues A, Bowers J. The role of system dynamics in project management. *International Journal of Project Management.* 1996, 14(4):213-220.

[7] Wang Qifan. System dynamics. Beijing: Tsinghua University Press, 1994.