Decision support for human resource allocation in the context of a multi-project environment using system dynamics modeling

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Project management in a multi-project environment(MPE) requires knowledge and experience for project managers to share human resources across projects. Generally, project-based organizations share resources to regulate and plan the multi-project environment. This resource allocation process can be elevated through the estimation of required resources by accessing different strategies. In this work, a system dynamics (SD) simulation model has been developed primarily as a project dynamic model where the resources are allocated from a shared resource pool. Three different resource allocation scenarios have been explored and computed project performance through project behavior analysis. The obtained results show the effect of varying resource allocation scenarios on resource utilization, overtime period, and rework. Our contribution focuses on how a resource-constrained and scheduled-constrained project management policy can meet planned project performance while working in an MPE with a shared resource pool and knowledge discovery of expert project managers from simulation results.

Keywords: resource allocation, shared resource pool, multi-project(MP), multi-project environment (MPE), system dynamics(SD)

1. Introduction

In a multi-project environment (MPE), usually, one project manager leads multiple projects concurrently. Hence, a significant challenge in an MPE concerns allocating human resources and scheduling across projects. Resource management and scheduling problems in MP may differ due to environmental characteristics, project characteristics, and geographical distributions [1]. Furthermore, due to uncertainty, skill, and knowledge of the resources, project priority, it is often difficult to compute accurate resource allocation to each project [2]. Hence planning proper resource allocation decisions based on resource-constrained must be made to set resource requirements policy by designing several scenarios and modeling them in the problem space explicitly for quickly understanding and describing the problem.

Considering these situations, this study aims to develop a simulation model as a decision support system to model resource-constrained multi-project for effective management of human resource allocation to the projects. Furthermore, our goal is to grant managers guidelines for efficient resource allocation using a shared resource pool to practice based on their primary objective and management style.

2. Methodology

2.1 Proposed methodology

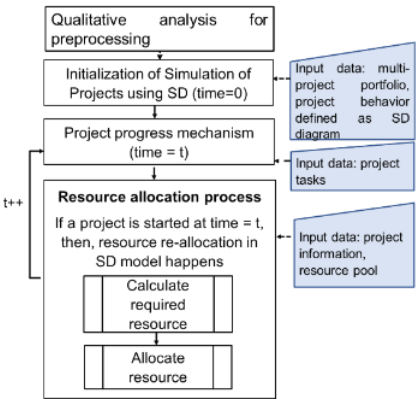


Figure 1. Overview of the methodology

A multi-project setting can be regarded as a group of staff being assigned to multiple tasks simultaneously, all of which must be completed within a certain amount of time. Thus, project workforces are engaged in the form of time-sharing at the individual level, allocating efforts to numerous projects to satisfy demands for progress from various project managers at the same time. Considering this environment, the overview of the proposed methodology is shown in Figure 1. The model for effective resource allocation has been developed using system dynamics (SD).

i. Qualitative project model

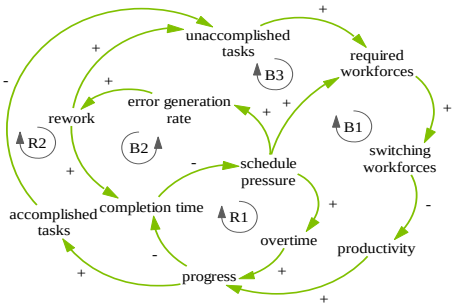


Figure 2. CLD for tasks accomplishment process

Figure 2 depicts the qualitative project model regarding dynamics of effective project task development and resource allocation parameters as a causal loop diagram (CLD), a part of SD. The reinforcing loops R1 shows the effect of schedule pressure on progress completion time, and R2 shows the relationship between project task accomplishment and the required workforces, which causes switching workforces and affects productivity. The balancing loop B1 depicts the relationship between schedule pressure and its effect on workforces and project progress. Finally, the impact of schedule pressure on rework, rework with unaccomplished tasks, and completion time is shown in Loops B2 and B3.

ii. Project progress mechanism

Figure 3 is a stock-flow diagram built on rework cycles used as a project progress mechanism to determine each project's progress rate. Each project consists of tasks referred to as *original work to do*. After completing these tasks are referred to

as *work done*. When tasks begin to develop, the error-based tasks initially move to the stock undiscovered rework. Rework is an error-based task that must be redeveloped to finish the project, the stock rework to do increases the number of unaccomplished tasks. The workforce will be allocated through a shared resource pool. A shared resource pool and the potential interdependencies in multi-project organizations create the need for interaction between the project process and activities to determine how the human resources are to be (re)allocated and distributed. Resource sharing from a shared resource pool has the advantage of efficient use of the resources.

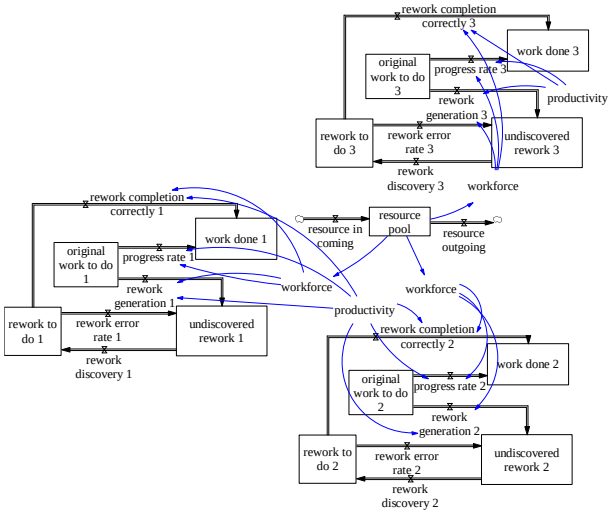


Figure 3. Project progress mechanism

3. Case study

In MPE, several projects need to be executed either simultaneously or singularly, depending on project status and delivery time. Projects in an MPE usually execute simultaneously. This situation often causes schedule pressure if there is a resource-constrained problem [3]. In this study, three different projects with the same scope have been considered. Through the simulation result, the resource utilization for each project, the effect of the overtime period, and rework have been discussed, which will help to knowledge discovery of expert project managers.

3.1 Resource allocation scenarios

Since we considered a shared resource pool, hence based on projects' deadlines and resource requirements, three different scenarios have been evaluated in this study for project behavior check, as shown in table 1.

Table 1 Scenario list for simulation

No.	Scenario type	Description
Scenario 1	Resource dedication scheme	Dedicated resources will be assigned to each project, and projects will start concurrently
Scenario 2	Relaxed resource dedication scheme	Resources that are finished on one project are allocated to new projects. The project will start one after another
Scenario 3	Shared resource scheme	Resources will be shared with the projects whenever a new project arrives

3.2 Result analysis

3.2.1. Resource allocation

During project development, we considered the buffer size 0. Hence a 0% buffer represented a full utilization of the resources to complete the projects. Since the scope is the same for all projects, for scenario 1, resources are distributed equally when all projects start concurrently. In scenario 2, all resources are allocated to one project until it is finished. For scenarios 1 and 2, since resources are dedicated to the projects, the staff's productivity remains the same.

On the other hand, in scenario 3, there is a delay between the project's start time based on project arrival. Hence, when a new project arrives, resources are switched and shared among the projects and thus affect resource utilization. Due to resource switching from one project to another, productivity is affected adversely. The resource utilization has been obtained while analyzing the project completion for each project, as shown in Figure 4. The impact of resource switching on productivity is shown in figure 5.

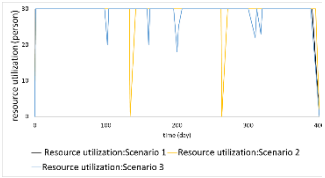


Figure 4. Resource utilization of each scenario

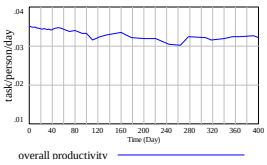
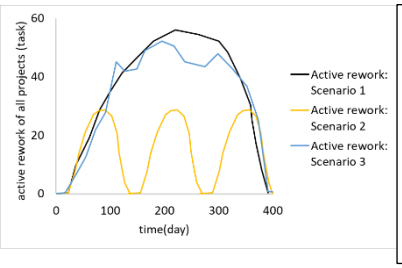


Figure 5. Productivity affects due to resource switching

3.2.2. Rework behavior

Resource capacity and allocation process, shifting resources from one project to another, affect project behavior. During the simulation, resource switching due to new project arrival, productivity, and progress are responsible for rework production. Figure 6 shows the rework behavior of the projects for each scenario.



- Peak is affected by the number projects developed **at a time**.
- 1 project low peak, 3 projects high peak
- Resource switching causes ups and down to the peak value

Figure 6. Rework behavior of all scenarios

For scenario 1, when projects start simultaneously, rework for each project also happens accordingly. Because three projects are being developed simultaneously, the amount of rework is substantial in this situation. In scenario 2, since projects are completed one after another, the amount of rework has been depicted separately. Rework generation is affected by the number of resources and the project duration. Switching

resources depending on new project arrival affects productivity and progress, resulting in delayed rework production in projects evolving under scenario 3. However, because there is a concurrency between projects, the quantity of rework becomes significant. Therefore, the project manager can depict the impression of a resource sharing scheme on rework in an MPE through the rework behavior.

3.3.3. Overtime impact

While working in a resource-constrained and schedule-constrained environment and resources are allocated from a shared resource pool, overtime is obvious to meet the project deadline. During our analysis, overtime has been computed based on the gap between the expected completion time and the deadline. Since rework increases unaccomplished tasks, it also causes overtime to meet the deadline. The working hour is represented by AFMDP (Actual Fraction of Man-Day in a project). When the workforces work with nominal working hours, the value of AFMDP is 1. However, working overtime increases the value of AFMDP is > 1. Figure 7 shows the overtime impact for each scenario.

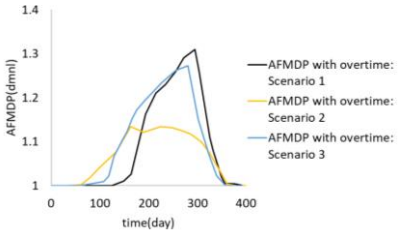


Figure 7. Overtime impact to all scenarios

The overtime behavior for each scenario happens as follows

Scenario 1

- Overtime happens later due to longer duration
- Since rework goes to peak slowly, it requires high overtime later

Scenario 2

- Overtime happens earlier as projects are happening as single
- Requires low overtime as resources are high and happen for a long time

Scenario 3

- Overtime happens moderately as resources are average due to resource switching
- Since rework goes to peak, moderately overtime finished earlier
- Resources switching causes starting overtime earlier than scenario 1

The obtained results show the effect of the allocation strategies on resource utilization, rework, and overtime. In an MPE setting, the generated resource allocation results serve as a useful paradigm for assessing the interplay among project performance variables and the effects of managerial decisions for resource allocation.

4. Discussion

The proposed SD project dynamic model exhibits an approach of resource allocation from a shared resource pool, affecting the MPE's potential to accomplish planned project milestones. This outcome is beneficial when working in resource-constrained MPEs. Projects are intended to be executed on time with this fixed capacity, relying on the workforce to work overtime. As explained through the scenarios, the arrival of new projects causes resource switching and affects project performance behavior. Furthermore, the presence of rework causes the same effect. Hence, when the resource capacity is fixed, and a shared resource pool is used to allocate each project, our proposed method gives a proposition of using a resource allocation scheme and an excellent way to handle project performance.

i. Dedicated resources are assigned to every single project in the multiple-single project setting. Through this scheme, the resource allocation problem is settled at the beginning of the projects. As a result, the complexity of controlling the portfolio of projects in execution is comparable with controlling a single project.

ii. Using a relaxed resource dedication scheme, a project can obtain full staffing in the early stages to meet the due date more quickly. But in this case, the focus is as a single project environment mainly focused on the individual project's performance characteristics.

iii. For a shared resource scheme, a shared resource pool is used for resource switching by all projects in the portfolio. Thus, it has the advantage of efficient use of resources. However, switching resources from one project to another causes a delay and conflict if there is a lack of resources.

The resource allocation in a multi-project setting is complex. Hence our proposed method acts as a decision support system for resource allocation strategies which gives an explicit impression on project performance behavior, including the uncertainty of rework generation. Moreover, project managers can trace the issue of needing and sharing the resources from a shared resource pool, resource availability, and interdependency between projects and operations to be a complication in an MPE.

5. Conclusion

We have developed an SD simulation model as a decision-support system to model resource-constrained multi-project for effective management of human resource allocation. We performed the case study by exploring three different resource allocation scenarios. The simulation results would help understand efficient resource allocation and its impact on performance while working in an MPE. Project managers can use this allocation category based on their primary objective and management style.

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