

## **The challenges in scheduling multiple collaborative design projects in the front-end phases**

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## **Management summary**

In large engineering organizations, multiple projects run in parallel, and their progress is controlled through scheduling. Schedulers often go through the cycles of scheduling: making schedules, executing them, monitoring the status, receiving changes in decisions, and updating schedules again. The schedules easily mismatch with how the projects actually go, and generating a new version takes much efforts. Disagreement between stakeholders sometimes arises. Some faulty decisions are made in a hasty start of projects. This thesis investigates how to boost the efficiency of scheduling.

To boost the efficiency of scheduling a group of projects, the factors that constrain the scheduling efficiency need to be investigated. First, various stakeholders are interviewed about the efficiency issues. Second, the main ideas obtained in interviews are tested through a survey. The survey ranked the impact of various factors and measured the time usage on different activities. Third, project tasks that have been finished are analyzed in terms of the cause of delay.

The causal relations between issues are built through analyzing the data obtained. The causal relations explain how the causes lead to the problems in project scheduling. The first category of causes lie in the uncertainty in the inputs leads to the uncertainty in the schedules. The uncertain inputs are listed in the following paragraphs.

First, the work to be done is uncertain. At the early stages of a project, whether the project will remain selected is uncertain. Not all ideas for projects are able to be supported due to limited budget. Therefore, different project proposals need to be compared in terms of costs and other figures. In the selection procedure, some projects get approved while some are stalled. At the beginning of each project, it is not sure how much the project will cost. The project cost is influenced by the project's scope, design, and outsourcing strategy, which is not static. The ambiguity in a project's cost affect whether the project is better than other projects. The client may change the decision in project selection, in scoping and in design. Such changes affect the workload, and the workload affects how long the project work takes.

Second, the order in which the projects are processed is seldom stable and clear. Within a large company, the engineering department often receives multiple projects from multiple internal clients. Limited engineering resources lead to clients competing for resource usage. Lack of coordination between clients often leads to changing priority ranking. Even for the same client,

there are competitions between new projects and existing projects.

Third, the resource supply could also vary. When the demand of resources exceeds the amount of engineers in the organization, the wished deadlines for projects specified by clients become infeasible if internal resources are only used. The engineering party needs to negotiate with clients whether to postpone some projects, or outsource some projects. Clients are usually reluctant to agree to outsourcing because the outsourced work ought to be paid from the fixed budget, according to the financial policy of the company. Such disagreement leads to uncertainty in resource supply. Besides, sometimes emergent tasks appear which occupy the hands of the task performers who were reserved by projects.

Fourth, coordination between different tasks is challenging. Engineering projects usually involve cooperation between multiple disciplines, professions, or business functions, since the artifact built through a project consists of various parts delivered through different tasks. Each task is undertaken by different task performers. Different parts of a project's deliverable have to be compatible, implying the discussion in the interface. Chronologically, the tasks in a project need to be carried out sequentially, and thus one slip in some task may hinder the progress of succeeding tasks. Delays often arise which make the baseline schedule unfeasible. Even when tasks' deadline is extended, delays remain.

Therefore, the actual status of projects varies with changes in such inputs. Dividing such a varying schedule into fine-grained time intervals would generate more uncertain items. The increased amount of uncertain items soon overwhelm the attention of managers.

The second group of causes responsible for low efficiency in scheduling is that, schedulers tend to expect the progress on every time interval matches the actual status. Such a pursuit of perfect match leads to unexpected side effects. Each task owner protects his/her commitment date by placing buffers. Later such buffers prove to be used on other tasks. Task performers switch attention between multiple tasks, and postpone the start or progress of tasks with later deadlines. At the last moment for a task, things easily go wrong, leading to delays. Third, the decisions that influence project schedules are not easily made and tend to change: the relevant input information is scattered; misinterpretation of technical design diagram sometimes arise; different stakeholders prefer different design options; etc.

Based on the understanding about the causes that constrain scheduling efficiency, measures for

coping with such challenges are devised. The solutions include: first, the decisions whose execution depend on low chance preconditions, should be removed from schedules to make the schedule more robust. To prevent optimism bias in setting deadlines, multiple estimation methods should be adopted. Second, some insignificant discrepancies between the baseline schedule and the actual progress, could be tolerated. Tasks had better be coordinated through a relay-race style, letting early completions in some tasks offset delays in other tasks. Third, multi-tasking should be reduced to make schedulers figure out the dedicated progress speed when task performers focus. It is better to promote project progress rather than making task performers busy. Fourth, the updates in information needed in scheduling should be pushed into a shared database as soon as updates arise. The inconsistencies between information should be eliminated. Fifth, rules for resolving disputes should be developed to avoid deadlock or indecision in making some joint decisions.

The proposed solution is tested conceptually with the problems aforementioned. The relevant empirical studies which have adopted similar solutions in tackling similar problems are mentioned, serving as evidence for the effectiveness of the solution in this thesis. The implementation plan is discussed, which attempts to provide a step-by-step roadmap towards the changes.

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## Table of Contents

1.	Introduction .....	9
1.1.	Portfolio scheduling brings problems .....	9
1.2.	Research questions .....	10
1.3.	Research context .....	11
1.4.	Boundary .....	12
1.5.	Methodology and research philosophy .....	13
1.6.	The logical steps of my research .....	15
1.7.	Thesis project plan and steps .....	18
1.8.	The methods to be adopted .....	20
1.9.	A brief summary of all chapters .....	22
2.	A rudimentary description of the problems .....	23
2.1.	The content of a portfolio schedule .....	23
2.2.	Interrelations between decisions .....	24
2.3.	Each project's life cycle .....	26
2.4.	The workflow of portfolio scheduling .....	27
2.5.	The decisions, planning activities, and stakeholders .....	31
2.6.	The symptoms that indicate projects are out of out-of-control .....	33
	Symptom 1: The fine-grained plans often need to be revised greatly .....	33
	Symptom 2: Cost estimations tend to be inaccurate .....	34
	Symptom 3: The order of projects are ambiguous, changing or contentious .....	35
	Symptom 4: decisions about design choice or outsourcing are contentious and changing .....	35
	Symptom 5: information about project selection and scoping is often ambiguous, changing, scattered and inconsistent .....	35
	Symptom 6: Multiple half-finished projects co-exist .....	36
	Symptom 7: Task delays persist .....	36
2.7.	Summary .....	36
3.	Literature .....	37
3.1.	The decisions relating to scheduling .....	37
3.1.1.	Decisions for each project .....	37
3.1.2.	The decisions in a portfolio level .....	46
3.1.3.	The process for updating a portfolio plan .....	48
3.2.	The theories .....	52
3.2.1.	Decision tree diagram usage in presenting decision relations .....	52
3.2.2.	Assumption Based Planning .....	54
3.2.3.	Critical Chain theory .....	55
3.2.4.	Theory of Constraints (TOC) .....	58
3.3.	Summary .....	60
4.	The analysis on portfolio scheduling .....	61
4.1.	Using Assumption-based planning to explain symptom 1 .....	61

When the preconditions hold, finer grain size is more effective in controlling project progress .....	63
4.2. Using the prediction theories in prediction to explain symptom 2 .....	64
4.3. Using stakeholder analysis to explain symptom 3,4 and 5 .....	66
4.3.1. Information dispersion .....	66
4.3.2. Contentious decisions .....	67
4.3.3. Defected decisions lead to rework .....	70
4.3.4. Survey of time usage and factor ranking.....	70
4.4. Using critical chain theory to explain symptom 6 and 7 .....	70
4.4.1. The causes for delay located in the estimation stage .....	72
4.4.2. The causes for delays located in task execution stage.....	78
4.5. Using system thinking to understand the relations between symptoms .....	86
4.5.1. Explaining symptom 1 .....	90
4.5.2. Explaining symptom 7 .....	91
4.6. Explaining the symptoms using Theory of Constraints (TOC) .....	92
4.6.1. Using Current Reality Tree (CRT) diagram to find the causes .....	92
4.6.2. Using Conflict Resolution Diagram (CRD) to identify the conflicts.....	94
4.7. Summary .....	97
5. Improving the portfolio planning process .....	99
5.1. Limitations: the causes/symptoms that are not able to be resolved.....	99
5.2. Solution-designing approach.....	100
5.3. Major changes .....	103
5.3.1. Coping with task delays .....	107
5.3.2. Not specifying low-chance conditional decisions.....	114
5.3.3. Reducing indecision by setting rules in discussion.....	116
5.3.4. Pushing project information updates to a shared database.....	118
5.4. Summary .....	119
6. Evaluating the effects of the measures proposed .....	120
6.1. The expected effects to be tested.....	120
6.2. Selecting the evaluation methods .....	120
6.3. Evaluating the effects using different methods .....	122
6.3.1. Evaluating the suggestions using static analysis method.....	122
6.3.2. Evaluating the effects through thought experiments (gedankens) .....	124
6.3.3. Using Future Reality Tree to simulate the effects of the changes .....	125
6.3.4. Evaluating the suggestions using descriptive evaluation method .....	127
6.4. Summary .....	128
7. Conclusion and implementation plan.....	129
7.1. Conclusion—answering the research questions .....	129
7.1.1. Why is the current portfolio planning process inefficient? .....	129
7.1.2. How to fix the problems of inefficiency .....	130
7.1.3. What are effects of the measures?.....	131
7.2. Implementation plan for the changes .....	131
7.2.1. The designing process for implementation plan .....	132
7.2.2. Implementation plans.....	134

7.3. The correspondence between symptoms, causes, and solution measures .....	136
7.4. Suggested future research directions .....	138
Bibliography .....	139
Appendices.....	147
Appendix A: Interview records brief.....	147
Interviewee A: a discipline coordinator.....	149
Interviewee B: double roles: task manager and resource manager .....	150
Interviewee C: one person as both an engineer and task manager .....	151
Interviewee D: two task managers .....	152
Interviewee E: a discipline coordinator.....	153
Interviewee F: a task manager.....	153
Interviewee G: an engineer .....	154
Interviewee F: a functional department manager .....	154
Interviewee G: a plant representative.....	155
Interviewee H: a plant representative.....	156
Interviewee I: a scheduler .....	157
Interviewee J: two task managers .....	158
Interviewee K: a project manager .....	159
Interviewee L: a project engineer.....	159
Interviewee M: a project engineer.....	160
Interviewee N: a task manager.....	160
Interviewee O: a plant representative.....	160
Interviewee P: a task manager.....	161
Interviewee Q: a manager on scheduling and an engineer.....	162
Appendix B the survey results .....	163
Appendix C: the figures referenced in the main text .....	166



# 1. Introduction

Nowadays more and more endeavors in businesses are carried out in the form of projects (Midler, 1995). A project is an endeavor required to be completed within a limited period (Turner & Müller, 2003). Projects are usually crucial to their owners (Project Management Institute, 2010), because they consume a large amount of resources, or embody the strategic goals of the whole organization, or impact the whole organization in other profound ways.

Big engineering companies often carry out multiple projects in parallel (Wani, Adam, Abdullahi, & Ibrahim, 2012). The projects in a company are usually grouped. Each group of projects shares the same pool of resources. These resources include: financial resources like budget, equipment or fixed asset, and human resources. A group of projects is usually called as a project portfolio or program (Project Management Institute, 2013). There are discussions on which projects should be grouped together to qualify as a portfolio (Ghasemzadeh & Archer, 2000). However, this thesis will not concern much about which projects should be selected because it is written from an engineering perspective.

To ensure that each project or a project portfolio is carried out effectively, plans or schedules are a typical way of managing a portfolio (Academic Success Website, n.d.). The term “plan” concerns more what the tasks involved are, while the term “schedule” emphasizes the timing of those activities more: when should each task start and complete. A plan is the prerequisite for its corresponding schedule. Later on, the terms "plan" and "schedule" are used interchangeably when it is not necessary to highlight their differences.

## *1.1. Portfolio scheduling brings problems*

**For practitioners:** It takes planners a lot of efforts to update a project portfolio schedule and monitor its execution. When a version of portfolio schedule is carried out, it often encounters mismatches between what is specified in the baseline plan and the actual status or progress. Usually, the discrepancies between what the original plan expects to happen and how things actually go are so big that the plan must be adapted to fit the new situation and work progress status. However, a new plan needs to be agreed between different stakeholders. Therefore, a

plan-revision process can get stuck. The issues happening in a plan-updating process impact the quality of the decisions project schedules. Therefore, updating a portfolio schedule is a painstaking and error-prone process, and the plan that comes out of the process may become outdated soon after.

There are some missing gaps in project planning studies. First, many mathematical papers about developing algorithms for scheduling, start their reasoning with some strict and impractical preconditions, such as no disturbance from external or internal events (Turner, 2010). Second, for new approaches for planning developed in other fields, it needs to be checked whether they apply to project planning process. For example, within the long term strategic planning field, a new approach named Assumption-Based Planning (ABP) arises (Dewar, 2004). ABP attempts to incorporate strategies attempting to reinforce the robustness of a plan into phases when a plan is made or maintained (Dewar, 2004). However, there is little discussion about whether ABP applies to project planning. Third, the interactions between stakeholders in the planning process probably affect the process efficiency as well as the quality of the plan. Therefore, a field study about project plan-making and plan-maintaining will cover the gap within the existing literature.

To sum up, an empirical study on the difficulties to make a feasible plan for a dynamic portfolio, are of pragmatic value and they are academically interesting. For companies, such a problem concerns the performance in project portfolio control for big investment projects. For academia, investigations about making plans for a dynamic future can be seen in many fields. Although various explanations, proposals and experiments have been provided for over 20 years, the problem persists. Therefore, our study attempted at gaining more understandings of the problem and proposing new thoughts for possible solutions.

## ***1.2. Research questions***

This thesis aims at finding ways to enhance the efficiency of portfolio planning, without hurting the effectiveness of portfolio plans. One characteristic that a portfolio schedule is effective is that the projects proceed as planned. The efficiency of portfolio scheduling is indicated by the efforts spent on updating a plan and monitoring its execution.

To achieve such a research objective, our **main research question** is: what are the effective and feasible ways that help enhancing the efficiency of portfolio planning, without hurting the

effectiveness of control?

To figure out the ways that are effective and feasible, we need to answer the following sub-questions sequentially.

**Sub-question 1:** what are the main causes that make portfolio planning inefficient?

**Sub-question 2:** what can be done to influence this inefficiency of portfolio planning versus what are not able to be changed?

**Sub-question 3:** how will the proposed measures affect portfolio scheduling?

The process for seeking the answer to the main research question, is divided into three steps, first, it is researched why the current situation is like this; what are the reasons for the symptoms we observe. Second, knowing the causes for the symptoms, we need to find out our limit in the capability to change the current status: which causes are hard to tackle, or which solutions would be feasible. Third, we need to predict the effect of our suggested measures: what changes those measures will bring, what will be the cost, requirements for those measures and what will be the benefits, and ultimately we need to figure out, will the benefits justify the costs for adopting each measure?

### ***1.3. Research context***

**Types of projects:** The projects we investigate are about the engineering work for chemical facilities or plants. The word “engineering” here means designing the structure of the facilities. Such projects are highly specialized and tailor-made. By “specialized” we mean the users/clients of such projects know what they want to get from the projects. By “tailor-made” we mean that every project is special and has never been carried out. Even the project teams are not sure which design will work and how much a project will cost beforehand. Such projects are usually large and involve a lot of specialized knowledge from multiple disciplines or fields. Such a wide range indicates that integrating the efforts of different specialists seamlessly is essential.

**Stages/phases of the projects:** unlike most project management studies which assume that the scope and design is clear and stable, this thesis attends to the early phases of the engineering projects. The early phases are characterized by their greater extent of uncertainty. For example, when a client is considering launching a project, he/she may not know the cost and time it takes to complete the project successfully. The client may give up the project if the project is less

profitable than other project ideas or proposed projects. Or the client may reduce the scope of the project to lower the cost. Or the project's design will be modified radically when the design proves to be unfeasible.

**Type of company:** the companies or organizations this thesis focuses on, are large engineering organizations, which sponsor and carry out multiple projects concurrently. Such companies often receive a lot of ideas for projects but can only sponsor some of those proposals. When the sponsor knows that some project turn out to cost more than expected, it may abandon the project and fund other projects.

**Reason for choosing such projects and companies:** we happened to have access to one such company. This company is also interested to boost the efficiency of portfolio control and planning. Apart from the pragmatic concerns, the large engineering organizations who run many engineering projects in parallel are one type of challenging project management environments. Such projects carry some traits that are similar to other types of projects. And thus the insights derived from such projects and organizations, are to some extent applicable to other projects and other organizations.

### ***1.4. Boundary***

The sponsor of my thesis is the engineering department of the company we obtain data from. The engineering department cares most about how to react to the changes and uncertainties when carrying out multiple engineering projects. They do not answer the question why some projects are selected or cancelled. The selection of projects into a portfolio or out of a portfolio is carried out by the client or higher management levels.

This thesis does not concern the construction phase of the engineering projects. It is the engineering phases, and the idea inception phases of projects that are more uncertain or turbulent to be managed well.

The research will focus on the project tasks, which means that the project tasks will be isolated from other activities the project team members take. We might consider how busy each project member is, as this will affect his/her pace of progress on project tasks, but we only treats the non-project tasks as exogenous variables.

This thesis focuses on the schedule of all projects within a portfolio. There are other types of plans in project control, like stakeholder communication plans, budget/cost plans, etc. We mention those

factors only when they affect the progress of the project tasks. Project progress is what we focus on.

The research pays attention mainly to the efforts that schedulers or task managers spend on making and updating project schedules. It will rarely mention other issues that relate to project scheduling, like the effectiveness of controlling task progress, or the extra cost brought scope change. These other issues will only be mentioned when they influence the efficiency of planning.

### ***1.5. Methodology and research philosophy***

The research philosophy that underlies the process of seeking answers to the research questions in this thesis, is post-positivism. The first reason for choosing a post-positivist epistemology is that we will use multiple methods to collect data—the data that support the answer to the research questions in this thesis. A “post-positivist epistemology provides a better framework to integrate different methodologies and methods into a coherent body of theory”(Toll, 2012). The second reason for choosing post-positivism is that we took the stance of post-positivists that “all theory is revisable” (Manuel, 2013) and therefore we start with observing the phenomena directly rather than focusing on the evidence that have been highlighted by the existing theories. There are other considerations why a post-positivist epistemology has been choisen, and Table 1 summarizes how the research design embodies the post-positivism philosophy:

**Table 1 how this thesis embodies the post-positivism philosophy**

	<b>The traits of Post-Positivism</b> (quia website, n.d.)	<b>The corresponding embodiment in this thesis</b>
<b>Aim</b>	Understanding to predict	First, seeking understanding why the inefficiencies exist. Next, proposing measures to change the current situation, based on the causal-effect relationship within the project controlling system.
<b>Assumptions About Reality</b>	Reality is changing and is contingent on context	The main causes that constrain a project control system may shift as changes are incorporated into the system. Therefore, the specific solutions raised by this thesis will

		be contingent on the specific situations we face.
<b>Assumptions About Knowledge</b>	Knowledge comes from convergence of different studies; subjective; both Researcher & Participants represented in interview	Comparing the phenomena in our case company with other empirical studies, the studies carried out in other industries, other companies or other types of project.
<b>Assumptions About Method</b>	Method is flawed; can't be perfected; characteristic errors, so use multiple approaches	Using multiple methods to solicit observations and explanations from multiple stakeholders. Then comparing the findings from different sources to synthesize the understanding towards our observations.
<b>Stance Toward Values</b>	Neutral—avoid bias	Admitting different opinions and different explanations towards the same issues.
<b>Stance Toward Persons Studied</b>	Participants are "things;" "its." Researcher is value laden	A participant's role would probably affect it
<b>Stance Toward Validity</b>	Unavoidable bias; slanted view; only get partial view of the phenomenon	Admitting that there may be some bias in our view for the research problem.
<b>Research v. Practice</b>	Knowledge from Researchers; comes from convergence of different studies using different researchers & different methods. No average.	Comparing the findings from different empirical studies. And the findings are acquired through different methods.
<b>Whose Voice is Represented in Accounts?</b>	Researchers; Multiple voices each with its own bias	Multiple views are presented in this thesis: the client, the engineers, the function department managers, etc.

Based on the post-positivist philosophy, qualitative methods are chosen as the main approach

for collecting data. First, interviews with the people who influence the schedule for different portfolios are conducted. Second, we will participate in the project meetings to observe how different stakeholders interact. Third, a survey will be held on how different activities are carried out: how long the activities take, and what the main reasons are for the time spent on such activities. Fourth, we will group the delayed tasks according to their reason for delays. We will compare the data collected from different sources and through different methods, in order to depict a faithful account of what happened and why things happen like that.

### ***1.6. The logical steps of my research***

The thesis' research objective is to propose measures that boost the efficiency of scheduling in a project portfolio. It is similar to what (Hevner, March, Park, & Ram, 2004) called a design science research. Design science research aims to create some artifacts to achieve certain goals (Hevner et al., 2004). This thesis adopted a design science framework proposed by (Hevner et al., 2004).

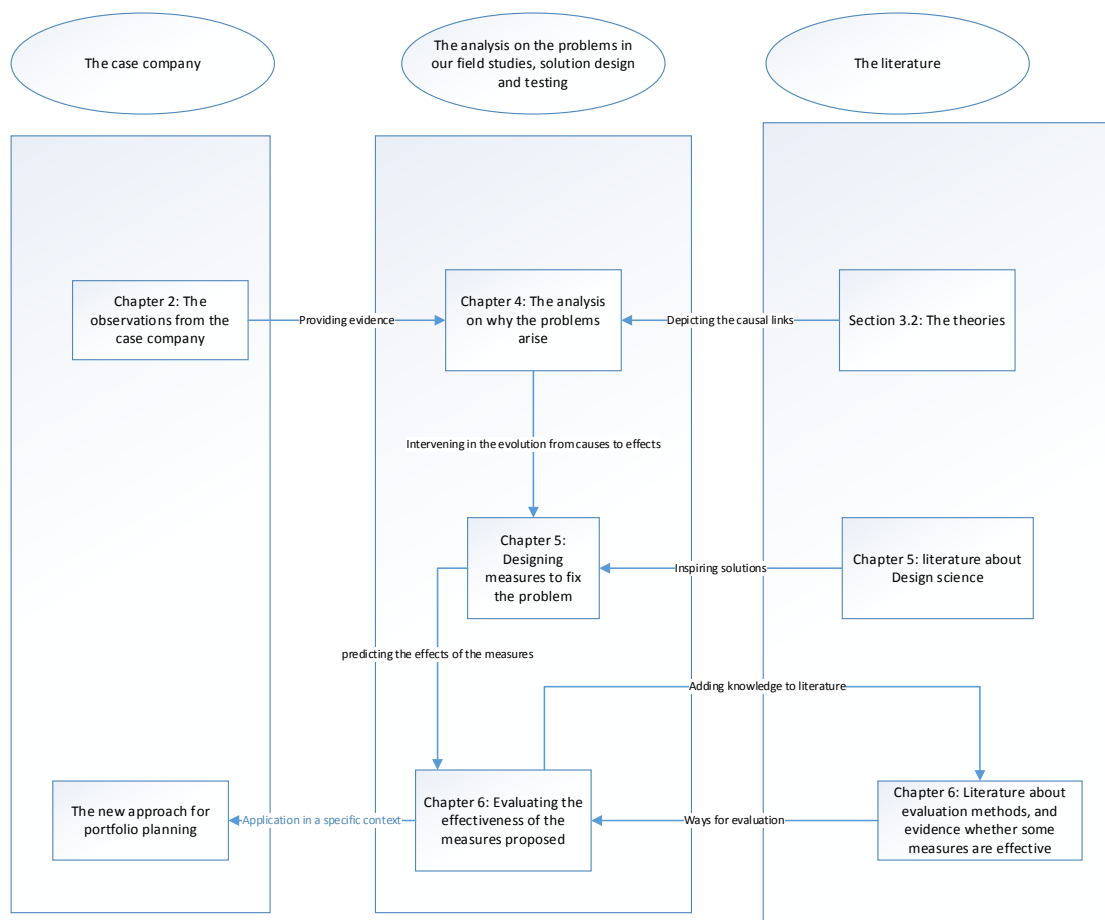
According to the design science framework, the proposed measures are based on explanations why the problems arise. That means, based on the discovered causal links, measures to tackle the problems will be designed. The measures will be grounded on the explanations. For example, if we discover scope change is the main reason why the schedules need to be adjusted, the corresponding measures should be how to tackle scope changes or their impacts. We will take some measures to intervene in the process in which scope changes causes plan-revisions.

These explanations will be supported by the evidence observed within the case company. For instance, if we claim that scope changes are the main reason for an unsteady schedule, evidence needs to be provided that scope changes happen frequently or that they disturb the schedule greatly.

Before those measures will be proposed to the case company, the effects that the measures will bring has to be evaluated: what will be needed if certain measures are taken, what are the benefits or harmful effects of those measures, etc. Such an evaluation will enhance the credibility of the suggestions.

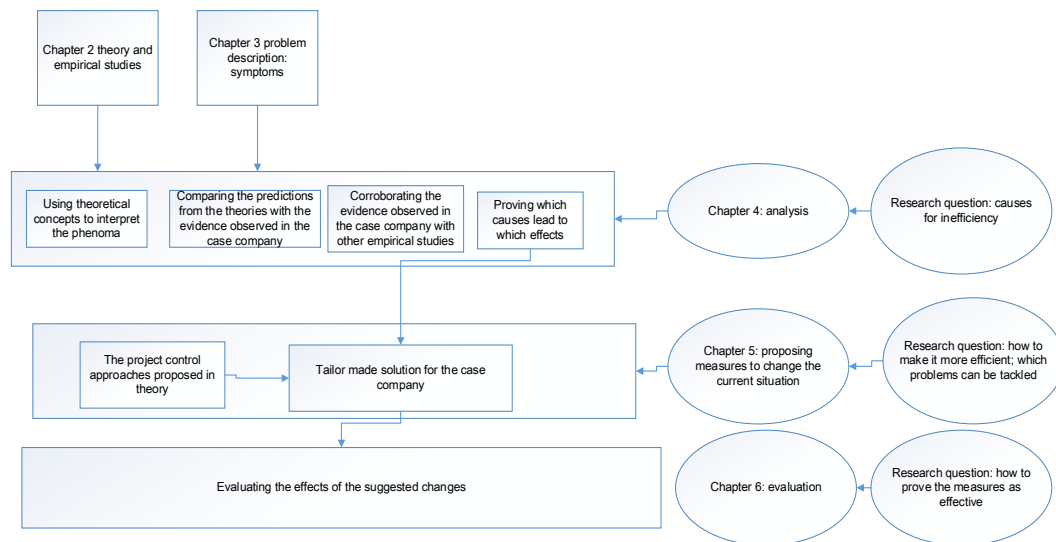
First, during the process of seeking solutions, academic and technical reports that mention similar phenomena in other companies or fields will be used. Second, the explanations why problems arise in portfolio scheduling will borrow ideas from existing theories. The observations drawn

from the case company will help to test the existing theories. For example, if some evidence contradicts with the predictions made by some theory, it is worthwhile to examine whether the theory needs to be falsified. Third, some empirical studies may mention some project controlling techniques they prove as effective. If we incorporate such measures, these suggestions will be credible since those measures withstood the test in practice. Fourth, the suggestions can be referenced by companies facing similar problems. The value of the proposed improvements to be referenced by others, indicates the scientific value of this field study. The summary of the thesis' logical structure is shown in Figure 1.



**Figure 1 grounding of the field study—adapted from (Hevner et al., 2004)**





**Figure 2 logical structure of the thesis**

Figure 2 displays the logical correspondence between each chapter with research questions. It also brief the major parts within each chapter.

Besides (Hevner et al., 2004), there is another framework for problem-solving called Theory of Constraints(TOC). TOC propose changes to a problem based on the interpretations towards the symptoms observed in the problem. After digging out the causes for the symptoms, the measures to change the current situation work through intervening in the process when some causes lead to certain effects. The mechanism is illustrated by Figure 3. The “UDE”’s in Figure 3 refer to the Undesired Effect, while the “DE”’s refer to Desired Effect. In Figure 3 “TOC injections” refer to the measures to be injected into the evolution process in which UDE is prevented and DE is formed (W. H. Dettmer, 1997).

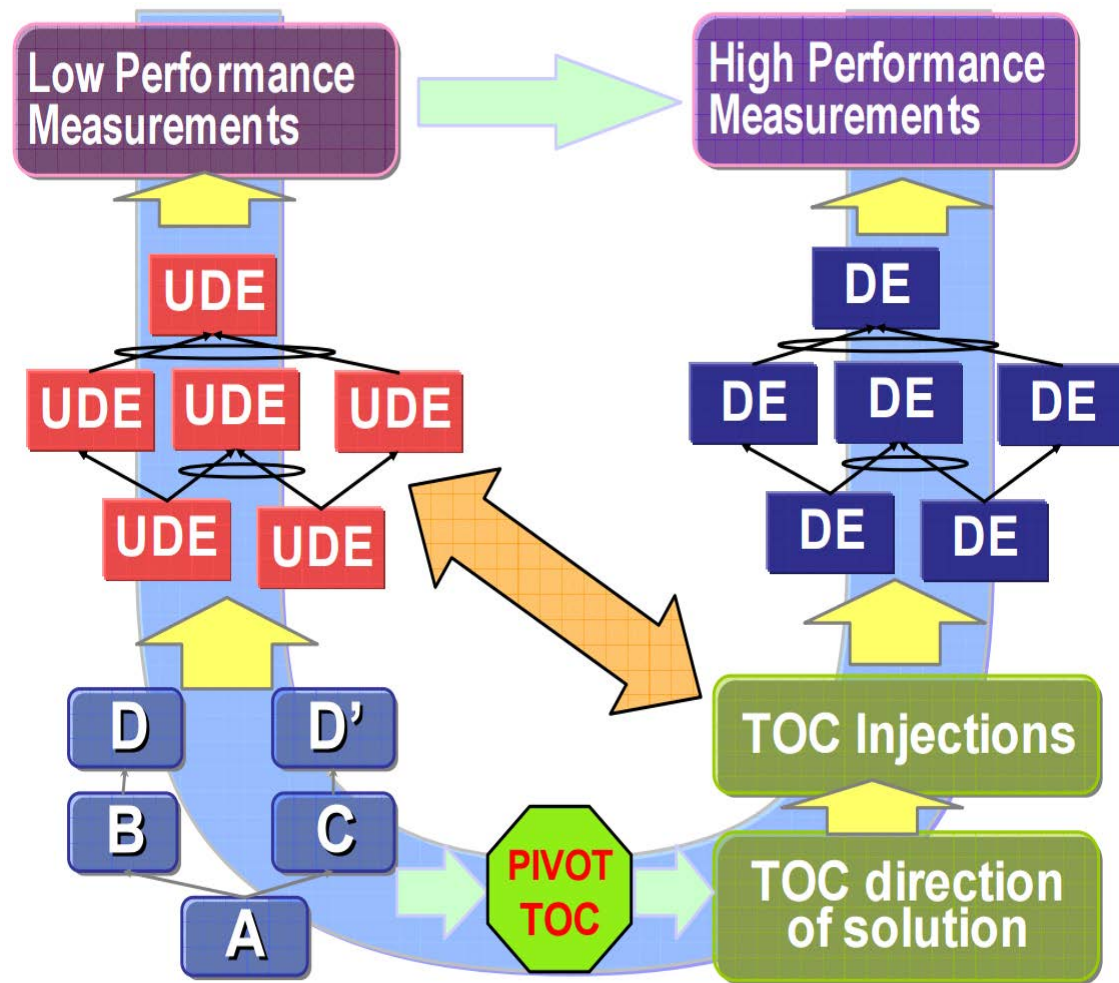


Figure 3 the relations between the symptoms, the cause-seeking analysis, and the basis for suggestions

Source: (Cohen, n.d.)

### *1.7. Thesis project plan and steps*

The thesis project will pursue the answer to the research questions through the following steps sequentially.

First, the managers in the case company about the inefficiencies in portfolio scheduling will be interviewed. The interview questions will be mainly: what is the role of each stakeholder in portfolio planning; how do they influence the content of the schedule at a portfolio level, at a project level or at a task level; what is their expectations towards a portfolio schedule, how accurate should the schedule be; how often do the baseline schedules mismatch with the actual progress; which decisions are more likely to slip and why; how the decisions influence each other, etc. The aim for such questions is to get an overview of a portfolio schedule, how the stakeholders

influence the schedule, and the activities through which the schedule is made, monitored and updated.

The stakeholders that will be interviewed consist of the client representatives of projects, the project managers who oversee the whole project portfolio, the technical managers for projects who are responsible for coordinating tasks between different disciplines and between the client and engineers; the schedulers who are responsible to monitor and update the schedule for a group of projects; the task managers who provide the estimate how long each task will take; the human resource managers who supply engineers to multiple project portfolios; the engineers who carry out the tasks. The reason why different stakeholders will be interviewed is that, different persons see different issues and they view the portfolio control from different perspectives/angles.

Second, the findings will be summarized, and the key concepts will be extracted from the findings. how different concepts or items influence each other will be found out, and the causal links between those items will be drawn.

Third, to figure out which factors impact the efficiency of portfolio scheduling more significantly than others, a questionnaire will be designed to measure the factors. The questionnaire will ask the respondents to estimate how long they spend on portfolio planning, and which activities account for the biggest portion in the planning time, which factors dictates how long they complete each activity, etc. For example, if a project meeting takes two hours, whether the time is spent on exchanging information or on debating over some decisions. The questionnaire will also ask the respondents, which decisions are more likely to be not carried out as planned, how often do such mismatches happen, and whether different types of mismatches affect the usability of the existing plan to different extent. For example, the delays of some tasks probably bring less trouble than a change in design, and thus it takes the planners more time to update a plan due to design change than due to task delays.

Fourth, there are some records of the delayed tasks within the case company, the causes for the task delays will be grouped and the most frequent causes for the delays will be found out.

Fifth, the causal links could guide us to find the main causes that lead to the majority of the most troublesome issues in project control. The root causes will be dug out using the tools in Theory of Constraints (W. H. Dettmer, 1997) (Goldratt, 1999): current reality tree and conflict resolution tree. The grounds for the measures proposed, are the causal links we discover within this step. For

example, if scope changes are discovered as the main reason for prolonging the duration of projects, scope changes would be suggested to be anticipated on the outset, or scope changes be suggested to be not accepted without regulations.

Sixth, after knowing the major causes of the problem, what we are able to do to tackle the problems, will be investigated. In other words, which major causes which impact the efficiency of portfolio planning could be influenced by the measure, will be checked. And there may be some issues that cannot be changed. For instance, at the inception of a project, the cost will not be predicted accurately, and the limitation of the knowledge at that stage will be admitted. An example for what can be influenced, may include scope change: when receiving a scope change request from the client, the engineer may be able to tell how this scope change will prolong the duration of the project, and ask for an extension of deadline beforehand. Knowing which issues can be influenced and which cannot, this thesis gets to know what will be the limit for the proposed measures.

Seventh, how the measures we propose, will help in improving the current situation, need to be proved. We prove the effectiveness through several ways, first the causal links discovered in the understanding of the current situation can be used: what causes the problem we face. Second, other empirical studies will be quoted to seek the evidence that some measures we propose actually worked in solving similar problems in other organizations. The third approach could be a simulation of the future using the tools in the Theory of Constraints. Such tools include: future reality tree—how to achieve a certain desired status step by step, prerequisite tree—what conditions are needed to fulfill certain goals, and the transition trees—how each step can be implemented specifically (W. H. Dettmer, 1997).

### ***1.8. The methods to be adopted***

According to the post-positivism philosophy, multiple methods of data collection will be used. The data collected from different sources and through different methods, will be compared for checking the validity or consistency of the data.

The main method used will be a case study. The reason why a case study is chosen is that the research problem's scope is wide and it consists of multiple factors. Starting with observing the phenomena directly, the researcher is likely to see more issues than observing the issues through

the lens of some existing theories. Most theories focus on certain concepts or variables and build their correlations or causal relationship. And theories are often derived through an induction process from the investigation over certain cases. Therefore, we start observing the phenomena in the case company before turning to specific theories.

### **Data collection for understanding the current situation**

In the case study, different stakeholders in project control are interviewed first, to get a qualitative understanding of the research problem. The reason to choose the interview method is that interviews can lead to unexpected findings. Each researcher can have his/her constraints in observing and interpreting the data. The interviewees, who have been observing the project control issues for a long time and from different angles/perspectives, can provide fresh opinions on the research problem (Jacob & Furgerson, 2012). The questions in the interviews are not fixed and static. Interviews often enable the interviewees to express their opinions fully, leading the researcher to unexpected findings. Therefore, interviews are a good way for acquiring a broad and deeper understanding towards the research problem.

After the interviews, some key concepts will be extracted. The examples for such concepts may include: scope change, dispute about design, unrealistic deadline, etc. Furthermore, it is indicated how the concepts relate to each other. This step enables the researcher to discover the causal links or correlations between concepts. For example: how scope changes lead to task delays. When the causal links are mapped and collected, the root causes are likely to be exposed.

To verify the summary out of interviews and to measure the efficiency of planning quantitatively, a survey is used. In the questionnaire, the planning activities and the main factors that are extracted from interviews will show up as options for the questions in questionnaire. The respondents will be asked to select the key activities from the options, and to rank the factors that affect the efficiency of planning.

To verify the main reasons for task delays, the task delays' reasons/causes will be grouped. The incidence frequency of those events that lead to task delays, indicate the major obstacles in controlling task progress.

### **Analysis and suggesting changes**

The data will be processed and interpreted, using the theories mentioned in literature. As the causal relationship between concepts is established, the measures to change the current situation

are raised through intervene the process in which some causes lead to the symptoms.

### ***1.9. A brief summary of all chapters***

The first chapter, Introduction, briefly describes the problem, the methodology we adopt, and the specific methods we will use to tackle the research problem.

The second chapter will present the problems in portfolio planning at a rudimentary level. The symptoms of the current portfolio planning approach will be listed, which will help to guide the research direction.

The third chapter discusses to the literature that is relevant to scheduling a portfolio. First, the definitions for the concepts encountered in the field studies will be provided. Such concepts include, what is a project portfolio, how the projects proceed, etc. Second, phenomena that exist in other studies and are similar to the issues in the case company will be mentioned. Such a similarity shows how the field study contributes to the scientific knowledge base. Third, some theories that explain why projects fail to proceed as planned will be quoted. Such explanations establish the causal links between the concepts or factors..

The fourth chapter contrasts the explanations why problems are caused with the evidence taken from the case company. Here it is decided whether to adopt or reject certain explanations. The phenomena in the case company will be interpreted using the concepts borrowed from theories.

In the fifth chapter, measures to tackle the problems in portfolio scheduling will be proposed. Such measures are grounded on the explanations why some issues take place.

The sixth chapter will evaluate how the suggestions impact the efficiency of portfolio scheduling. Some measures may have been adopted in other companies.

The seventh chapter will contain the discussions and conclusions of this thesis. First, the rigor of the reasoning process will be discussed: how the evidence supports the explanations why some issues arise, and how the understandings lead to design suggestions. Second, the research questions will be answered. Third, directions for future research will be provided.

## **2. A rudimentary description of the problems**

This chapter introduces the decisions in a portfolio schedule, and the process during which the decisions are made/updated and monitored. After the background information, this chapter briefly describes the symptoms of our case company's portfolio scheduling approach.

The symptoms the company is facing, are the target to be tackled in this thesis. The symptoms dictate the relevant literature topics and theories in chapter 3, the center of the analysis in chapter 4, and the measures to be proposed.

The project scheduling approach and the symptoms are mainly collected from interviews with the stakeholders for portfolio schedules, and from observing the project meetings. The source of the descriptions will be mentioned, and readers could turn to the corresponding interview records in the Appendix of this thesis.

### ***2.1. The content of a portfolio schedule***

An example of the schedule for a group of projects is shown in Figure 103. As indicated by the interview records Line 2 to Line 9, a schedule for a group of projects specifies when each project is expected to start and finish. Since this thesis adopts the perspective of the engineering department, the portfolio schedule is specified as detailed as the timing of each constituent task or even sub-task. The reason why the detailed task schedule is relevant is that when some task does not actually start or finish on its scheduled date, the planners may need to update the schedule to make baseline schedule match the actual progress status.

Briefly put, three key decisions lie in the center of a portfolio schedule. The first decision is, which project will be in the portfolio? The second decision is, how should the project ordered, in terms of which project should be carried out before others. The third decision is, how much time should be reserved for each project. When such three questions are made, the timing for all projects in the portfolio is able to be decided.

The three core decisions are affected by other decisions. For instance, the duration for each project, depends on the duration of its constituent tasks. Which tasks are there in a project, depends on the design of the project. How long each task will take, depends on the difficulty/content of the task,

the availability of the resources required by the task, etc. And the duration for each project or when will each project finish, will affect when the next project is able to start. Therefore, a portfolio schedule is built on a set of decisions. Figure 4 displays the hierarchy of decisions underlying a portfolio schedule.

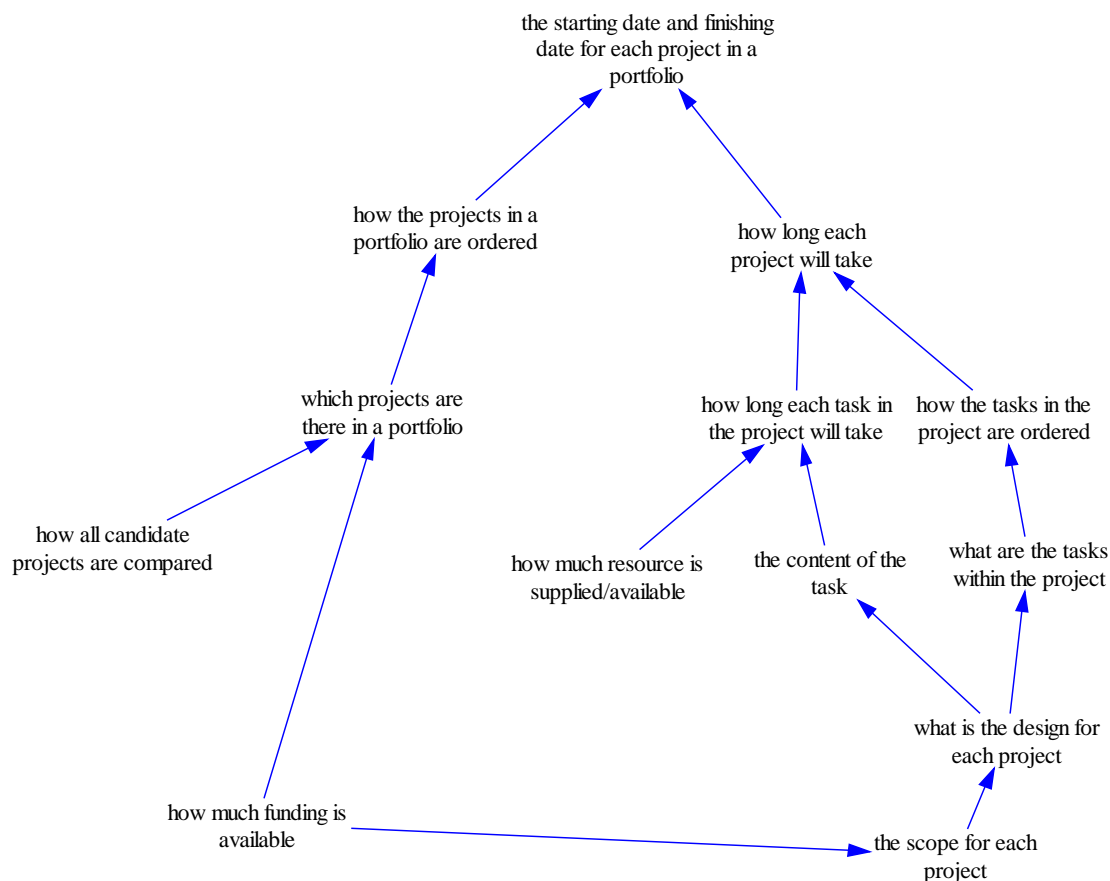


Figure 4 the decisions underlie a portfolio schedule

## 2.2. Interrelations between decisions

As suggested by the interview records Line 329 to Line 339, at the start of each year or each financial period, the company appropriates a certain amount of money for carrying out new projects. Each chemical plant submits a bunch of proposals, each proposal suggesting a new project. In each project proposal, the cost and benefits of the project will be estimated. The available funding usually is less than the total cost of all proposed projects. Therefore, the business managers need to choose the “best” projects to support, and say no to other projects. The amount of money that is given to a certain project is called the project’s budget. **The number of projects within a portfolio, is affected by the funding level.**

As suggested by the interview records Line 329 to Line 339, when multiple projects get approved,



their budget is usually pooled together. There are some projects whose budget is assigned individually. But most projects' budget is managed collectively. Each plant who has received such budget, decides how the budget is actually spent on each project. When receiving the budget, each plant usually push all approved projects to the engineering department. The clients/plants assume that all projects will be affordable. However, later some plants discover that some projects cost more than expected. The remaining funding level is not able to support all the projects. According to the corporation policy, plants can hardly acquire extra money. Facing shortage, plants usually delete some projects from the portfolio. Sometimes, some plants discover that some projects cost less than expected. Surplus of funding appear. Since the company policy dictates that the remaining funding must be returned back to the corporation, plants tend to use up the remaining funding through various ways. The plants may add new projects, or expand the scope of existing projects, or buying some expensive equipments. **The amount of remaining funding, dictates the amount of projects, or which projects will be in a portfolio. For projects whose funding is reserved individually, the funding level affects the scope of such projects.**

As indicated by the interview records Line 250 to Line 252, when a plant add a project into a portfolio, it also state that when the projects should finish, as the plant wishes. The plants are grouped into several business areas. The engineering department will order/prioritize all the projects within an area. When the number of projects in an area exceeds the capacity of the engineers, it is inevitable to rank the priority of the projects. **The deadline of projects wished by the client, affects how the projects should be ordered/prioritized.** When some projects conflict in timing, some adjustments will be taken.

As indicated by the interview records Line 95 to 99, how many man hours are needed for each project, are determined by the design of the project. The design dictates what tasks are involved in a project. Then what are the tasks, dictates how many man hours will be needed. **The choice of design, dictates the demanded amount of engineering resources.**

As indicated by the interview records Line 296 to 298, **the design of each project, is affected by the scope.** A project's scope specifies what the client wants out of a project's deliverable. Based on the scope, the engineers come up with a solution or design that fulfils the requirements of the client. When a project's scope is modified, the design often needs to be adapted.

As indicated by the interview records Line 10 to 21, when receiving the demand on engineering

resources indicated by the tasks, the engineering department needs to check the availability of the engineers: how many engineers are there and how busy they will be at certain periods. Sometimes the engineering department needs to increase the supply of the engineers. After deciding the amount of engineers in supply, the task managers in engineering department will estimate how long each task will take. Finally they generate a feasible completion date for each task, or each project. **The availability of resources, together with resource demand, dictates what is the feasible completion date or the feasible duration for each project.**

To sum up, the decisions in a portfolio schedule are interrelated. The funding level determines the number of projects, which projects remain in a portfolio, how large each project's scope is. The funding level lowers down as the money is spent on the costs in design and construction. The wished deadline for each project dictates how the projects should be ordered. Each project's scope affects the design for the project. The design for a project dictates what tasks are involved. What tasks are involved in a project dictates the man hours needed for each discipline. The supply of engineering resources, compared with the demand, decides the feasible completion date for projects.

### 2.3. *Each project's life cycle*

As suggested by the interview records Line 32 to Line 35, and Line 329 to Line 339, at the beginning of a project, the beneficiary or client needs to submit a proposal. In the proposal, the project's cost, duration, required resources, and other figures need to be provided. The reason why those figures are needed, is that there are always limit in funding: the money needed by all proposed projects exceed the available budget. Some managers need to decide which project they should support based on the estimated costs for each project.

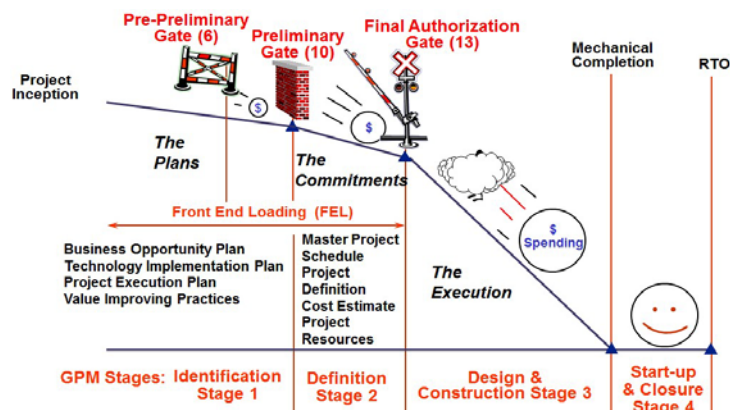


Figure 5 the stages that a typical project will go through

**Source: an internal document of the company being investigated**

As suggested by the interview records Line 169 to 171, the estimated cost for each project depends on the design for the project. When the design is not specific, the cost estimates ranges widely. And each project's design is clarified step by step. First, when the scope for the whole project is determined, the engineers come up with the design for the whole project. After that the project scope will be decomposed into modules/sub-systems and sub-modules. And then the design for each component will come out based on the scope for each component. Sometimes one scope can be implemented through different design/solutions. When multiple options are available, the stakeholders need to agree on which one to choose.

As a project's design is clarified, the project's cost is able to be estimated with smaller range. That means the accuracy of those estimates increases. Receiving the updated estimated figures, the business managers will compare the benefits and costs of each candidate project, and decide which project they support. A typical project need to go through two evaluations on whether this project should continue or not. Such evaluation time is called "gate". And a decision whether a project is allowed to continue or not, is often called the "go/no-go" decision.

#### ***2.4. The workflow of portfolio scheduling***

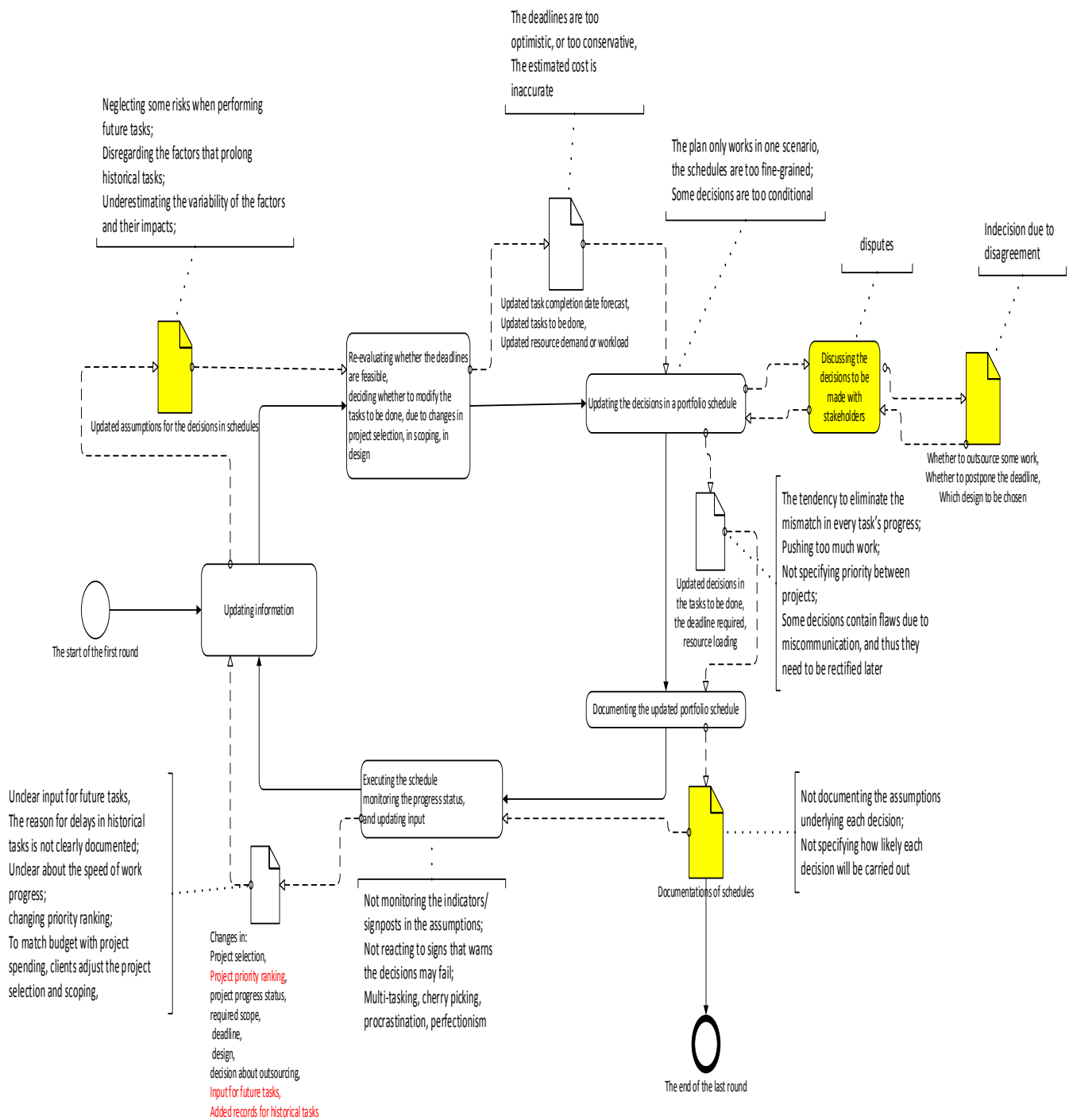
A portfolio schedule consists of a series of decisions. Those decisions specify what should be done and when the tasks should be done. Multiple stakeholders affect those decisions. Which stakeholders affect which decisions, is illustrated in Figure 102 and Figure 6. And the diagram is explained in more detail at Table 2. It is worth noting that, some activities are combined and thus some roles are omitted from Figure 102 and Figure 6.



Technical managers for projects, also called project engineers	Responsible for coordinating different engineering disciplines' work progress; passing information between engineers and the clients
Project portfolio schedulers	Making schedules for a group of projects and monitoring the execution of the schedules;
Maintenance department	Raising some requirements towards the design or engineering solutions for each project; maintaining the artifact that are built in the projects
Construction companies	Building the artifacts according to the design

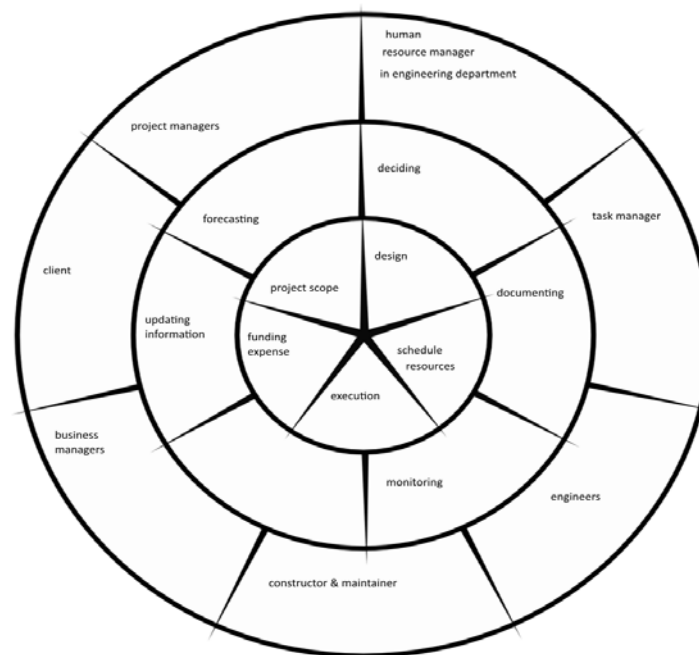
### **The weak spots in portfolio scheduling**

Figure 6 is condensed further into a process consisting of major steps and major information/decisions, which is shown in Figure 7. In Figure 7, the description of the scheduling activities is made quite abstract, but the explanations are indicated in the data objects and the text notes linked to them. The text annotations are mainly used for pinpointing the weak spots in the planning process. The weak spots refer to the locations where things tend to go wrong. For instance, when discussing project design, disputes tend to arise, and the decisions can hardly be reached quickly. The weak spots identified in chapter 2 will be further analyzed and explained in chapter 4. The measures that will be proposed in chapter 5, are based on the analysis of the weak spots, and are targeting at addressing the weak spots.



**Figure 7 the weak spots in portfolio scheduling**

## 2.5. *The decisions, planning activities, and stakeholders*



**Figure 8 presenting the various aspects of a project plan**

Figure 8 presents the overview for making a plan for a project, the business managers are responsible for approving the funding/budget for project. Most projects' budget is pooled together as a bucket, while a small portion of projects' budget is assigned to one project only. The budget determines whether the corresponding projects will be approved. Based on the budget, the amount of project, or whether a specific project is allowed, will be known. The budget is determined by the calculation of the engineers'/designers' estimation.

The amount of budget/funding affects how many projects will be carried out, or how much a specific project can spend. The clients refer to the production units/plants who decide how to spend the budget. They dictate which projects will be pursued, and how big is the scope of each project. The clients also specify the deadlines when the projects they wish to finish at. That is, how the projects are ordered and scheduled in a rough sense. The clients indicate which project is more urgent or important.

Based on the scope, the internal engineering department provides the design for each project, and estimate how long the project will take. They provide the feasible completion dates for the projects. And they will suggest outsourcing some work when there is a shortage of human resources. The clients will decide whether to outsource the work, or to accept a postponed

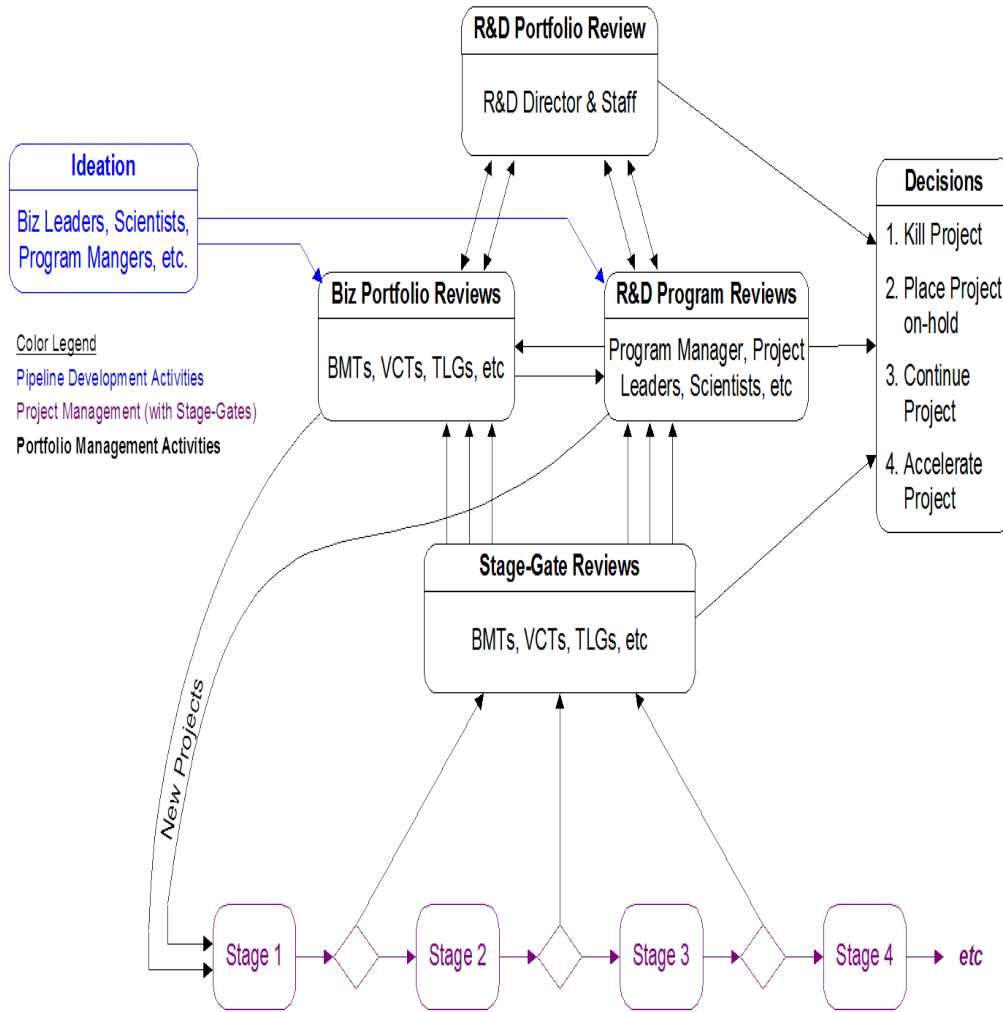
completion date.

Within the engineering department, there are task managers who are responsible to take care of the task progress in one project group. And there are resource managers who supply the human resources for all project portfolios in a discipline. The disciplines are a specialized field like pipeline, civil engineering, instrumentation, and mechanics.

The design for the projects affects the cost of the projects. As the money comes out, the remaining funding level lowers down. When the funding is in short, some projects need to be canceled, or the scope of some projects will be reduced. When the funding turns out to be more than expected, the client tends to use up the remaining money, since the remaining need to be returned back to the company. They increase the expense by adding new projects, or spending more on existing projects. For example, some equipment in the existing projects will be replaced with better ones.

As a task scheduler or project scheduler in engineering department, updating schedules starts with collecting information. The information includes whether some projects are cancelled, whether some tasks take longer than expected, etc. After that, the scheduler needs to re-evaluate the feasibility of the existing schedules. Such an evaluation is a prediction on whether projects or tasks will finish on the deadline specified in existing schedules. If the existing schedules will not hold, the timing decisions need to be updated, which corresponds to the decision making step. The updated decisions will be documented. And the execution of the updated schedules will be monitored, in which new information is gathered. Next planning cycle starts. Figure 9 is a diagram illustrating the process for updating the decisions in portfolio management.





**Figure 9** an illustration of the project program management process, from the case company

To sum up, a portfolio schedule contain various interrelated decisions. Such decisions are affected by various stakeholders. A portfolio schedule is updated periodically or on an ad-hoc basis. Each planning cycle goes through similar stages.

## ***2.6. The symptoms that indicate projects are out of out-of-control***

The stakeholders for a project portfolio progress mentioned that many issues arise when they carry out a portfolio schedule. The signs that indicate something goes wrong in project portfolio control, are summarized as follows.

### **Symptom 1: The fine-grained plans often need to be revised greatly**

As mentioned in interview records Line 46 to 48, some task manager wishes to make the schedules for their project tasks as fine-grained as possible. By fine-grained, they mean they want

to specify the work for each day or each hour. When they specify the work for each specific time span, at each specific time point the task performers know what to do, without spending time to wonder what they should do next.

However, as expressed in interview records Line 106 to 110, some task managers point out that fine-grained schedules tend to be fragile. For instance, when the work progress is specified at an hourly basis, an unexpected task would render the original baseline schedule into outdated.

As mentioned in interview records Line 38 to 42, fine-grained plans for remote future are so fragile that the planners avoid make such plans. At present, the task managers only specify their progress for the next two or three months on a weekly basis. That is, they specify which work should be done at which week. For the future period beyond the next three months, the task managers give up making the weekly schedule, because they discover that the weekly schedule for far future is too fragile when facing the uncertainties.

Although the task progress is defined at a weekly basis, the deadline for each task is specified at a certain date. As mentioned in interview records Line 121 to 125, some resource manager believes that the due dates for tasks should be set as a bigger time interval: task T should finish at week W, not a specific day D. The reason is, they cannot control the progress pace of each task at the accuracy level of each day.

## **Symptom 2: Cost estimations tend to be inaccurate**

As mentioned in interview records Line 173 to 175, the actual cost or duration may turn out to be far higher or lower than expected, especially in early phases of each project. As indicated by interview records Line 333 to 343, usually the budget for a group of approved projects is pooled together. The budget amount is set as the sum of the estimated cost for each project. When some projects' actual cost turns out to be higher than expected, the collective overspending on a portion of projects may leave other projects out of money. The budget can hardly be increased. Sometimes, when some projects turn out to cost less than expected, a surplus of remaining funding appear. Due to the corporation's financial policy, the remaining budget must be returned to the corporation. Therefore, most project owners tend to use up the budget. The budget users increase their expenditure, through multiple ways: they either add more projects, or expanding the scope of the existing projects, or buying equipments that are more expensive. Such changes usually affect the

schedule for the existing projects.

### **Symptom 3: The order of projects are ambiguous, changing or contentious**

As mentioned by interview records Line 255 to 262, there are multiple clients in the case company. And each client wants its projects to be prioritized. Some client even do not rank their own projects, the clients tend to disregard the amount of engineers when setting project deadlines. As mentioned by interview records Line 271 to 276, the priority ranking between projects tends to change from time to time. Such changes disturb the on-going work.

### **Symptom 4: decisions about design choice or outsourcing are contentious and changing**

As mentioned in interview records Line 60 to 65, the first type of disputes arises when the client of a project disagrees with the engineer over which design is appropriate for a project. For example, when a client wants to expand its production capacity of an existing facility, he/she believes that a simple expansion in some parts of the system suffice for their need. However, the engineers point out that the whole facility needs more renovations, because there is bottleneck for the capacity expansion elsewhere, or the expansion will affect the surroundings nearby. The client does not want to increase expenditure or wish to complete the project faster, and thus he/she disputes with the engineers.

As mentioned in survey records Table 9, the second type of disputes arises between engineers from different discipline. Each discipline proposes some solutions. But they are not able to reach a consensus quickly.

As mentioned in interview records Line 27 to 29, the third type of dispute is over outsourcing. When the workload exceeds the capacity of the internal engineering resources, the engineering department suggests outsourcing some work. According to the rule of the company, the work outsourced need to be paid by the client. Therefore, the client tends to keep everything done in house.

### **Symptom 5: information about project selection and scoping is often ambiguous, changing, scattered and inconsistent**

As illustrated by interview records Line 318 to 323, the information here refers to the factors or

inputs that affect the decisions in a portfolio schedule. For example, whether a project's scope is modified, affects the schedule. Therefore, the planners need to update the relevant information for updating schedules.

As mentioned in survey records Table 8, the information is often scattered: whether a project's scope or design satisfy the client's needs, is stored in the client side; how many man hours are needed for each task, is known better by the task managers in engineering department. Schedulers need to integrate all those factors to form a feasible schedule.

### **Symptom 6: Multiple half-finished projects co-exist**

As mentioned in interview records Line 278 to 281, the managers in engineering department usually accept all project requests, and push the tasks to the engineers' desk. Multiple projects often run in parallel. Therefore, multiple half-finished projects pile up on the engineers' desk. The projects are half-finished for various reasons: the requirements for some tasks are not specified clearly and thus the engineers wait for input; some on-going work is interrupted by emergent tasks; some tasks involve contacting the vendor and waiting for their response.

### **Symptom 7: Task delays persist**

As mentioned in interview records Line 49 and 50, task delays are common, and they impact a portfolio more significantly than delays within the single project context. Some big portfolio contains more than 100 projects, and the amount of tasks is big. When one task gets delayed, usually many subsequent tasks need to be postponed. Such a butterfly effect, leads to unpredictability in project duration.

## ***2.7. Summary***

This chapter introduced the following topics: what are the major decisions in a project portfolio schedule; how each project is approved or cancelled; how the decisions relate to each other; which stakeholders influence which decisions through which activities; what are the symptoms in managing a project portfolio.

Such observations guides the directions of literature review in that they indicate what topics are relevant, what theories can explain the phenomena we observe, what constrains the efficiency of planning, what are the current status from which we start.

### **3. Literature**

In order to show how each literature topic relates to our research questions, we place each literature topic under the research question it addresses. The literature topics are arranged into several categories. The first category of literature shows the problem that our case company is facing, can be found in other companies or other industries. Therefore, our field study helps in understanding the common issues. The second group of literature is used to analyze the problem. That is, why portfolio planning tends to be insufficient. We use theories that identify the reasons for inefficiency. The third category of literature serves at designing new ways of planning. The fourth category aims at evaluating the effectiveness of some new management system.

#### ***3.1. The decisions relating to scheduling***

The empirical evidence aims to show that other companies or other industries manage their project portfolio in a similar approach and they encounter similar issues on planning efficiency. Therefore, our field study could help understanding project portfolio management in general and thus is of relevance to academia.

How the literature topics are ordered, is that, we first mention the decisions in a project portfolio plan. Second, we mention the general traits in the process for updating a plan. Third, we point out the decisions which easily mismatch with the reality.

##### **3.1.1. Decisions for each project**

A project portfolio consists of multiple projects, therefore, we start with the management of each project: the schedule for each project. The decisions for each project's schedule are part of a portfolio schedule. However, as we will point out later, the projects in a portfolio are more likely to be cancelled, scope-changed, re-ordered, etc. And since we investigate the early stages of the projects, the design for each project is more likely to be modified. Therefore, much of the traditional project management knowledge can hardly apply to a dynamic group of early phase projects.

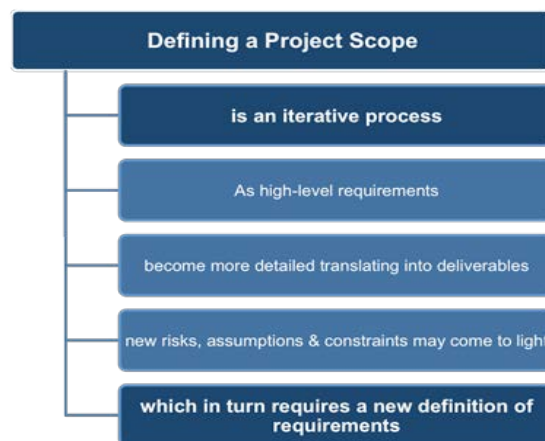
There are several decisions that affect a project's schedule: project scoping—how to decide/specify a project's scope, whether to modify or stick to the original scope; choosing

design—finding the solution to fulfill a project's scope; timing—how long each project will take.

### 3.1.1.1. Project scoping

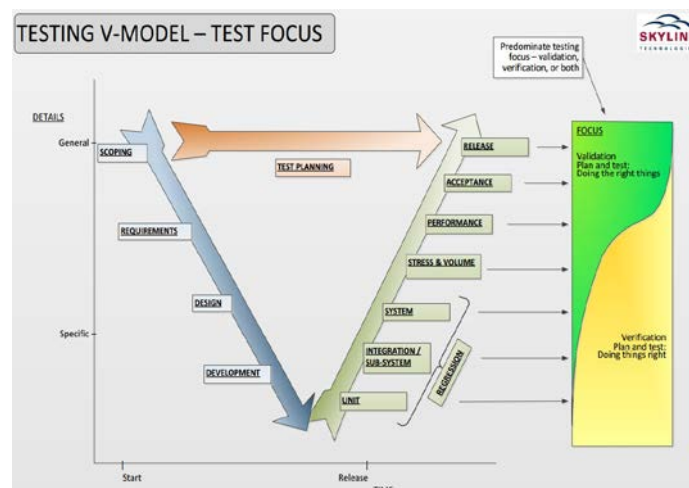
Project scoping means to define the scope of a project. A project's scope refer to “the project's technical and marketplace merits” (Harvey A. Levine, 2005). (Larson & Gray, 2011) claimed that “poorly defined scope or mission is the most frequently mentioned barrier to project success”.

Each project's scope becomes more and more specific step by step. (Project Management Body of Knowledge, n.d.) used Figure 10 and (Manning, 2013) used Figure 11, to illustrates how a project is detailed gradually.



**Figure 10 a project's scope gets specified in more detail as the project advances**

**Source:** (Project Management Body of Knowledge, n.d.)



**Figure 11 the gradual increase in detailedness in scope specification**

**Source:** (Manning, 2013)

Within the context of managing a project portfolio, many constituent project's scope is more

likely to vary. And such changes in scope possess impact towards project schedule.

### **3.1.1.2.Choice of design**

Design refers to the specific solution to a project, given the requirements and constraints of the project. (Hevner et al., 2004) view each design as the path between what we have now—the available resource constraint, and the desired status after the project’s completion—the scope, the functions the client want to get.

As (Hevner et al., 2004) states, finding an appropriate design is a searching process within the solution space. (Hevner et al., 2004) and (Suss, Grebici, & Thomson, 2010) claimed that engineering design is conducted in an iterative style, which means each design task need to be modified within several feedback rounds. The design for a project, at the early stage of the project, tends to be uncertain. (Williams & Samset, 2010) use a term “concept” to refer to the design in my thesis. (Williams & Samset, 2010) said “a major challenge in the front-end phase is to identify and evaluate one, or several, viable concepts”. (Williams & Samset, 2010) “Several concepts could be envisioned as alternative solutions to the same problem - all essentially different, in that they are not merely variants of one specific solution to the problem”.

### **3.1.1.3.Resource loading and leveling**

Each project’s design translates the required scope of the project into a specific solution. In the solution all tasks/modules are specified. Each task or module is often specialized that it needs to be assigned to the task performers within a certain discipline or profession. In other words, the design needs to be decomposed, and the work is divided among different task performers.

Resource loading “describes the amounts of individual resources an existing schedule requires during specific time periods”(Meredith & Mantel, 2009). An illustration for resource loading is shown in Figure 12. In Figure 12, the bars shaded in different colors in Figure 12 represent different profession/roles. And the man hours demand is mapped along the calendar.

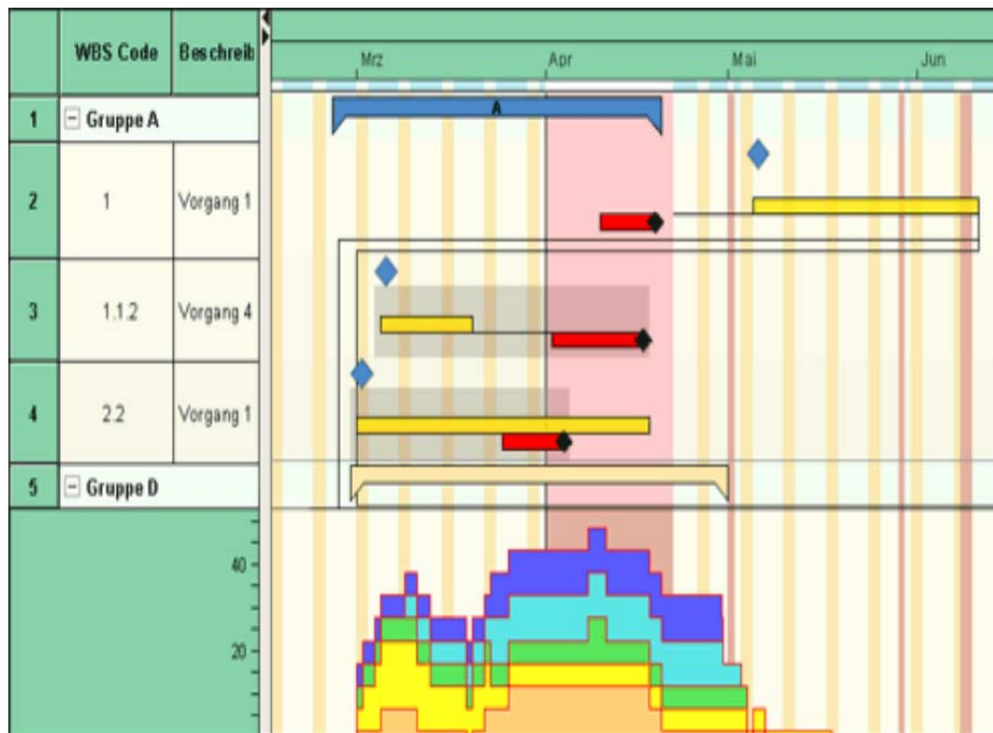


Figure 12 an example for resource loading

Source: (Cherf, 2012)



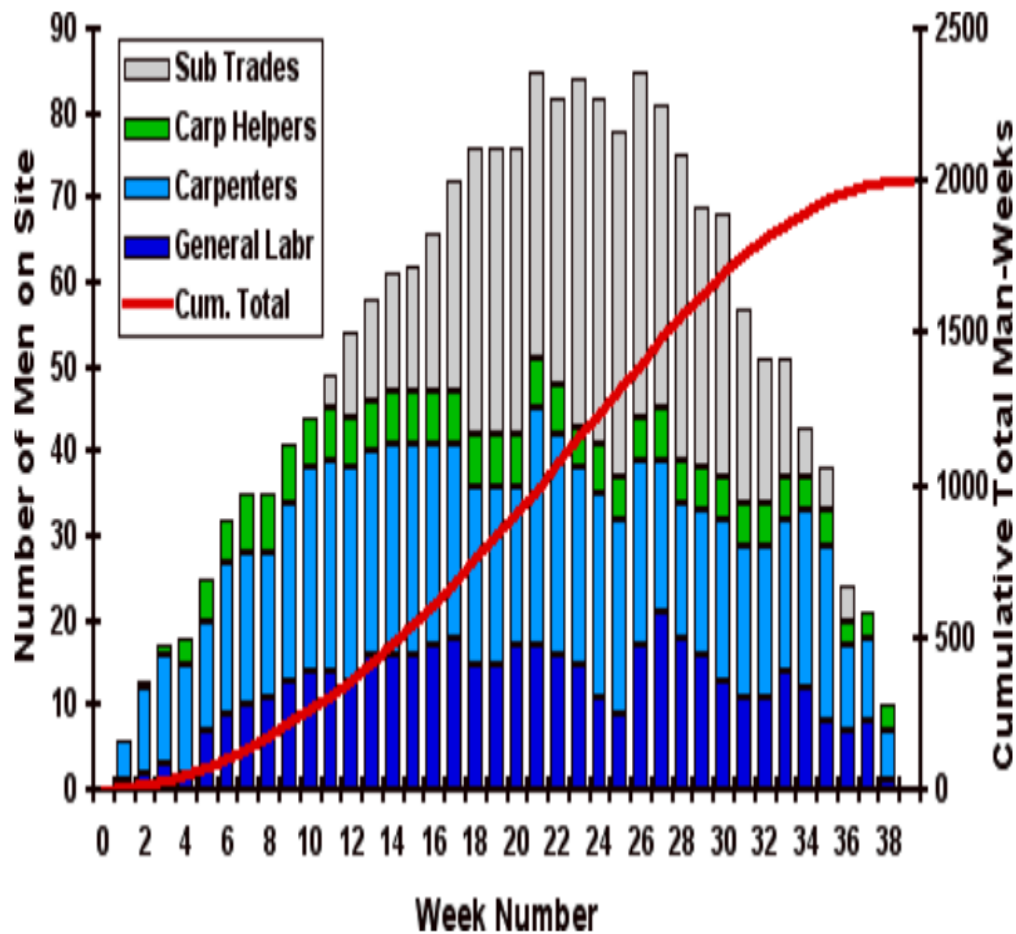
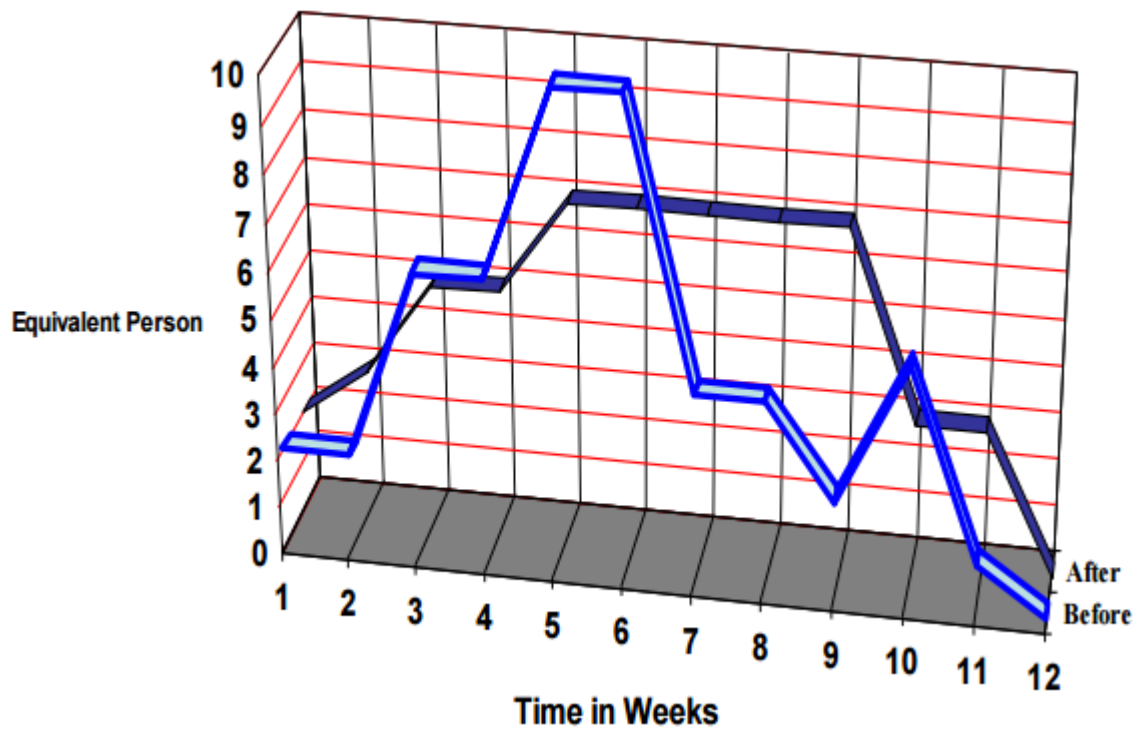


Figure 13 resource demand curve

Source: (Cherf, 2012)

After the resources are loaded, the resource demand curve can be generated. Usually such a curve possesses high peaks and low valleys at different periods. An illustration for resource curve is shown in Figure 13. However, the resources available tend to be more fixed or static. Therefore, resource leveling which smoothen the spikes in resource demand curve, is often needed to match demand and supply. (Meredith & Mantel, 2009) states that resource leveling “aims to minimize the period-by-period variations in resource loading by shifting tasks within their slack allowances. The purpose is to create a smoother distribution of resource usage”. An illustration for leveling is shown in Figure 14. The “resource profile” in Figure 14 refers to the demand for a resource type over each period.



**Figure 14 an illustration for resource leveling: Resource Profile Before & After Leveling**

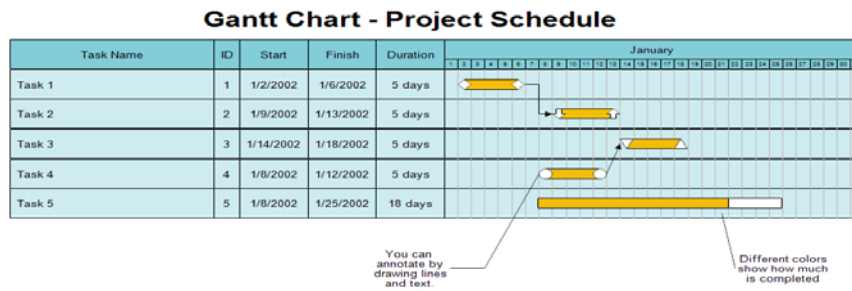
Source: (Cherf, 2012)

Within a project portfolio context, especially when the portfolio adds or delete projects based on the Stage-gate mechanism, the planners cannot tell for sure in future how many projects will come. Such an uncertainty in project selection leads to uncertainty in predicting the demand for resources. Therefore, resource allocation under a dynamic portfolio is a gap that is worth investigating.

### 3.1.1.4.Scheduling

#### *Gantt chart*

Gantt chart is a diagram format in which “the project’s activities are shown on a horizontal bar chart with the horizontal bar lengths proportional to the activity durations. The activity bars are connected to predecessor and successor activities with arrows” (Meredith & Mantel, 2009).



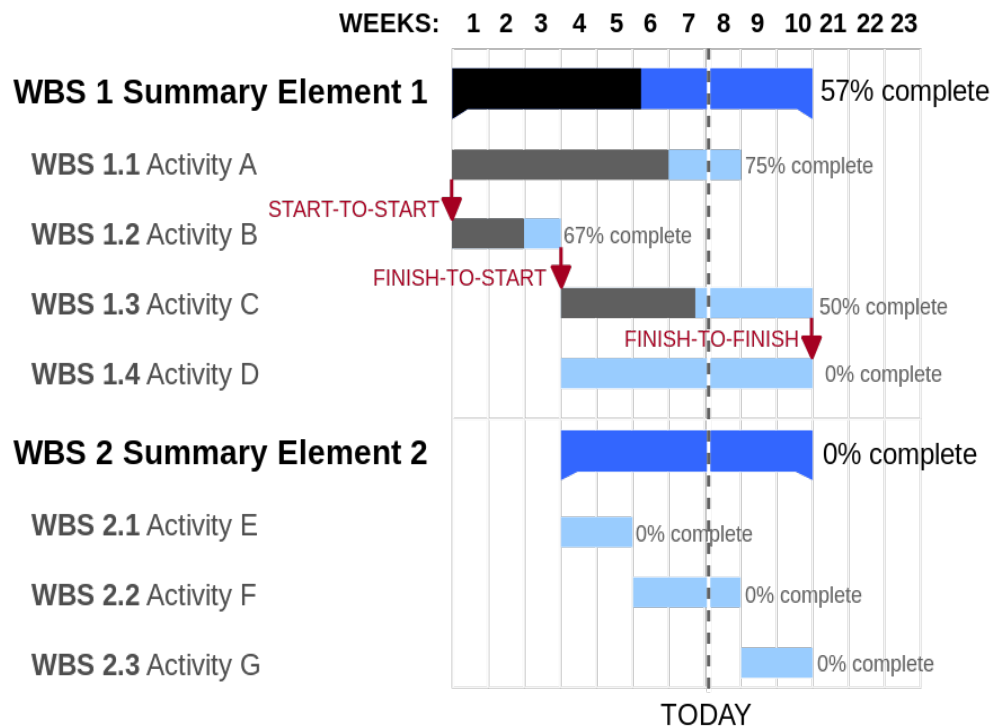
**Figure 15 an instance of Gantt chart**

**Source:** (RFF Electronics, 2010)

Scheduling concerns about the speed at which a project progresses, how long the project take, when should each task start and finish, etc. “A schedule is the conversion of a project action plan into an operating timetable” (Meredith & Mantel, 2009). Schedules are used as “the basis for monitoring and controlling project activity” (Meredith & Mantel, 2009).

### ***The order in which tasks are carried out***

The tasks in the same project need to be carried out in a certain sequence. The order, in which the tasks are carried out, is called “task dependency” or precedence. There are several types of dependencies. “Finish to start” dependency refers to the order that one task must finish before another task can start (Meredith & Mantel, 2009). “Start to start” refers to one task’s start needs to wait for another task has started, often there is a certain time lag between the two tasks (Meredith & Mantel, 2009). “Finish to finish” means one task must have been finished before another task can finish (Meredith & Mantel, 2009). “Start to finish” refers to that one task is not able to finish until another task has started for a certain period (Meredith & Mantel, 2009). A visual illustration for several dependencies is shown in Figure 16.

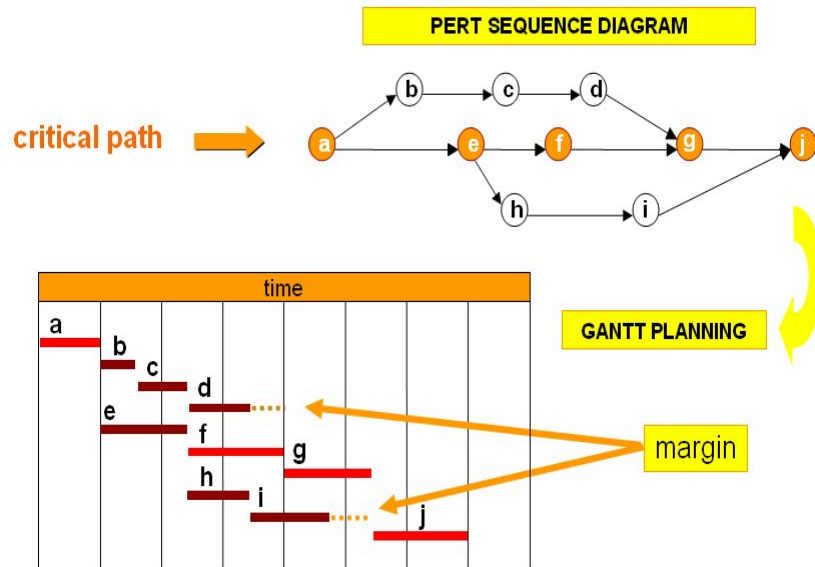


**Figure 16 A Gantt chart showing three kinds of schedule dependencies (in red) and percent complete indications**

Source: (Wikipedia, 2015)

### Critical path

For each project, when the sequence in which tasks are carried out is clear, project managers need to figure out how to schedule the tasks in order to finish the project as quickly as possible. The shortest duration for a project is dictated by the project's critical path (Larson & Gray, 2011). Critical path consist of a queue of tasks and it is the longest queue in the project to which it belong. If a delay in any task along the critical path of a project, the project's duration has to be prolonged. In other words, there is no slack in the critical path for each project, as is shown in Figure 17. The dotted lines in Figure 17 represent slacks for their owner task. A task containing a slack implies that the task's completion date could be postponed to the length of its slack.



**Figure 17 a project's critical path displayed on a Gantt chart**

Source: (Business IT, 2009)

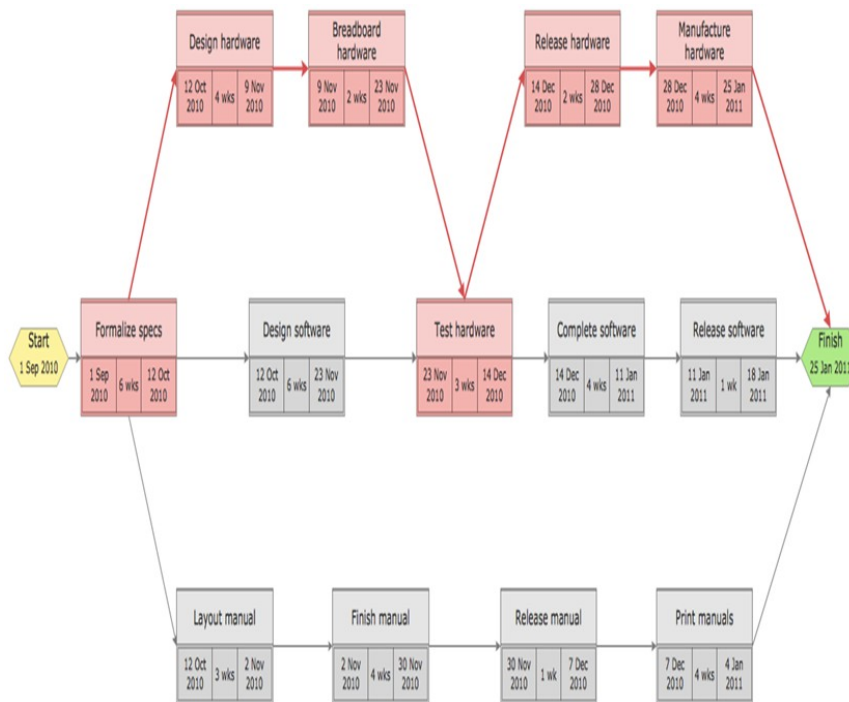
### Program evaluation and review technique (PERT)

PERT is similar to critical path except that PERT view each task's duration as a continuous variable (Larson & Gray, 2011). And PERT use three estimates for each task's duration: the optimistic estimate, the pessimistic estimate and the most likely estimate. Figure 18 shows the presentation node for when each task is likely to start or finish. Figure 19 illustrate how PERT is used in scheduling a project's tasks using the tasks' node representation.

Early Start	Duration	Early Finish
Task Name		
Late Start	Slack	Late Finish

**Figure 18 a task node in PERT**

Source: (ConceptDraw PRO, 2015)



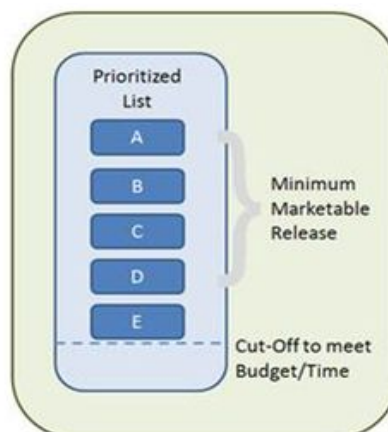
**Figure 19 using PERT to determine the critical path in task network**

Source: (ConceptDraw PRO, 2015)

### 3.1.2. The decisions in a portfolio level

The decisions in a project portfolio include: the project selection—which project enter or leave the portfolio; project ranking—which project should be handled before other projects; resource allocation—how many man hours should be supplied to a portfolio, how to allocate resources onto different projects or different portfolios.

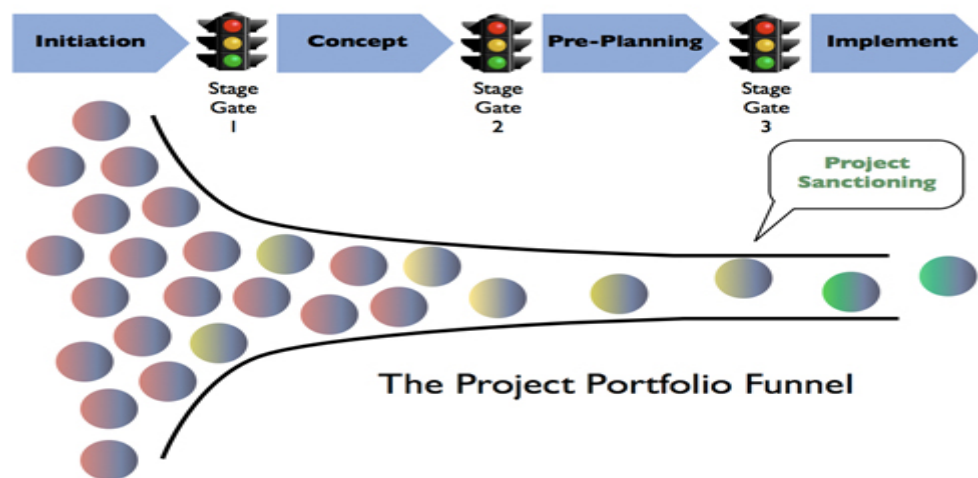
#### 3.1.2.1. Decision on project selection



**Figure 20 limited resources filter out some candidate projects**

**Source:**(Griffiths, 2011)

How many projects should be included in a portfolio, has been discussed in many studies. (Cohen & Englund, 2005) pointed out that the project staff member he interviewed complained about the overwhelming amount of projects. (Larson & Gray, 2011) also mentioned that too many projects, together with multitasking and changing priorities lead to lower efficiency. (Cooper & Edgett, 2003) claimed that too many projects caused “pipeline gridlock” in which pipeline refers to all projects that need to be processed. Similar comments appear in the company we investigated.



**Figure 21** the number of projects decreases when passing through gates

**Source:** (Holland & Holland Enterprises Ltd, 2010)

The decision whether to continue a project changes as more knowledge is gained. Funnel Model is adopted in our case company and other industries. As is shown in Figure 21, the main idea for Funnel model is that, not all projects will continue till completion. Some projects will be filtered out, as more knowledge about the projects is gained. Whether to continue a project or not, depends on the comparing the project with other candidates. For each project, there are several Gates. Each gate is the evaluation time point to reconsider the project approval decision.

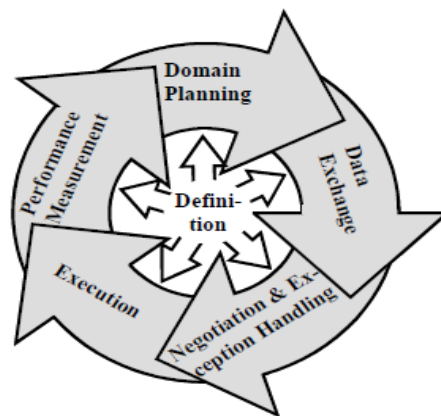
### **3.1.2.2.Prioritizing different projects**

How the projects should be prioritized usually refers to the criteria used in ranking the projects. However, our study focus more about whether there exist some general rules that prioritize projects without disputes, and whether the priority ranking for projects are clear and stable in

order to tell task-performers what should be done first. It is out of our scope to pay attention what the rules are to prioritize projects, and why the rules are like that. Studies pointed out that in many firms don't prioritize projects. (Pennypacker & Dye, 2002) pointed out that the need to prioritize projects is often neglected in practice. (Simpson & Lynch, 2000) blamed the unclear and unstable priorities as the cause for many symptoms of losing project control.

### 3.1.3. The process for updating a portfolio plan

To begin with, it is worth pointing out that each plan-updating process is not categorized by decisions, but by the type of activities. In literature about planning process in other fields, especially for a plan that need the consensus of multiple stakeholders, the process of planning is categorized in a similar approach. For instance, (Dudek, 2009) categorized the process to reach a supply chain plan into several steps, which is shown in Figure 22. Some steps are similar to the steps in project portfolio planning process, such as: data exchange, negotiation. By the way, the "performance measurement" step in Figure 22 is similar to the step that evaluates whether a portfolio plan needs to be revised. The evaluation step is an essential step in the portfolio planning cycle.



**Figure 22 Collaborative planning cycle**

**Source:** (Dudek, 2009)

The steps for updating a portfolio plan coincide with the plan-monitoring process in Assumption-Based Planning (ABP). Since each decision is made basing on certain assumptions, as some assumptions do not hold, the decisions need to be updated(Dewar, 2004). In ABP, monitoring whether each assumption holds(Dewar, 2004), is similar to the information collection step in our plan-updating process. In ABP, the step to evaluate whether some decision still hold



when its underlying assumptions do not hold (Dewar, 2004), corresponds to the step of updating the predicted future in the plan-updating process.

### **3.1.3.1. Information exchange**

The information refers to the input that affects the decisions in a plan, such as whether some project is approved by the client or not, the wished deadline for each project, the requirement towards each project, the design that is selected for a project, the actual progress of projects or tasks, the availability of resources. The importance of information is illustrated by literature which attributes the amount and quality of information as a determinant for the quality of decisions (Nemeth, 2012).

#### **Why information is needed**

(Dobson, 1999) viewed gathering all relevant information into a single place as a prerequisite to prioritize work, and other arrangements. How information affects decisions is illustrated in Goldratt's definition "(information is) the answer to the question asked" (Leach, 2005b). The question is the decision to be made, while the information refers to the relevant factors that influence the decision.

An example of the importance of the clear specifications towards to engineers/designers is best illustrated by the interviews carried out in (Ford & Sterman, 2003):

"two 'upstream' people (the marketing representative and the product architect) believed the 'downstream' people (the design manager and designer) could, and presumably should, begin their work quite early, when few product specifications have been released, while those downstream believed their work could only progress when a majority of the specifications were available. These differences in mental models had led to conflict and delay in prior development projects."

Although information is important for updating a portfolio schedule, often the information needed is missing. One such information is the scope or design for a project. Many studies mentioned that the scope or design is not specified in detail and thus contains uncertainty. Since the workload is uncertain, the schedule could be estimated accurately. (Hassanzadeh, 2012) investigated why clients tend to hesitate over whether a project should be continued or not. When such input is unavailable, the schedule's accuracy is doubtful.

**Project information is scattered:** Even when the information is available, the information about a project or portfolio is usually scattered around in different places. One reason for scattered information is the conflict between the division of work among specialized professional and a project usually involves multiple disciplines and professions. Another reason is the division of responsibility among different parties: the client takes care of budget; the engineers are responsible for quality; etc.

**Information is confined within certain locations:** It is not easy to share information barrier-freely even within the same organization. (Leach, 2005a) mentioned that “Information gets distorted as it passes up the chain (of reporting)” and he cited a manager’s comment that “nothing (no information) important got through two layers of management”. When a team consists of members from different departments and faces a dynamic project portfolio, the need in the speed of information exchange becomes more apparent.

**Misinterpretations appear during interdisciplinary communications:** The meaning of a design is often communicated between people from different disciplines. (Torrissi & Hall, 2013) provided evidence that miscommunications easily arise in multi-disciplinary group and such misinterpretations endanger exploration for new solutions.

To sum up, the information that needs to be collected represents the most updated status of a project portfolio. Such information dictates whether the current plan is feasible or satisfactory. Although the information is essential for updating the decisions in a plan, it is not easy for planners to pool information together. The obstacles for information sharing include: the information is scattered around different places; some information is ambiguous at certain stages; and the information is not easily understandable by recipients. There are some information systems available for sharing information.

### **3.1.3.2. Estimating the feasibility of each decision**

Many decisions in a portfolio schedule need to be feasible. For instance, if some project manager sets an early deadline for a project, he/she usually faces a high risk that the project may not be able to finish on the due date. Therefore, before making a decision, it is usually necessary to evaluate the chance for the decision to be carried out as planned. Such a feasibility check is in essence a prediction or estimation process.

It is worthwhile to point out a subtle but important distinction between a goal and a likely forecast (Finney & Joseph, 2009). A goal is the desired level of a variable of interest, while a forecast is the likely value or predicted value for a variable. Attainment of goals usually entails efforts to be taken, while the forecast value of the variable could be reached under certain external conditions. Such conditions could happen naturally or be generated by actions.



**Figure 23 Plan making starts with forecasting**

**Source:** (Finney & Joseph, 2009)

### **The quality of the estimates**

During the estimation step, the risks of inaccurate estimates would be rooted. Many studies in both project planning and in personal task estimation shows that more often than not the estimates turned out to be too optimistic. Such a bias is called “planning fallacy” (Virine & Trumper, 2008) or optimism bias. In our case study, some project managers also believe such an optimistic bias exists. Such biases are to blame for the reason of unfulfilled goals.

To remedy such a bias, (Flyvbjerg, 2006) proposed “using distributional information from previous, similar ventures” as reference in predicting the duration for a future project. Whether such a method works in our case is worth investigating. Further analysis of the discrepancies between forecasted figures and their counterparts in reality will be further discussed in Risk analysis section.

Bias during estimation stage may set roots for a plan’s unfeasibility. When estimating how long a task will take, some factors in carrying out project tasks are easily neglected or under-estimated, such as change in design or scope, feedbacks in reviewing the deliverables when the first draft is handled in, possibilities of rework, possibilities in changes in the interface between tasks. Such factors often delay a task more than expected. Some studies use system dynamic modeling to explain the vicious circle that if something goes wrong, a vicious cycle

forms(Ford & Sterman, 2003). Such a vicious circle is usually underestimated. When estimating duration for task, planners may assume the first draft will be satisfactory and the content of work is clear and stable.

### **3.1.3.3.Documenting the decisions in a plan**

Plan-documentation is often shortly mentioned in most literature. The time spent in documenting plans is usually not significant. However, the Assumption-Based Planning theory emphasized the importance to document the assumptions that underlie the decisions in a plan (Dewar, 2004). ABP concerns about the quality of plan-documentation rather than the efficiency. Besides, (Hergunsel, 2011) mentioned the usage of Building Information Modeling (BIM) in construction projects. One function BIM take is to make project schedules and documenting them. (Gibbs, Emmitt, Ruikar, & Lord, 2013) investigated whether the information stored in BIM system could assist identifying responsibility for delays. Therefore, documenting the decisions and the conditions under which the decisions are made, is too important to be skipped.

## **3.2. *The theories***

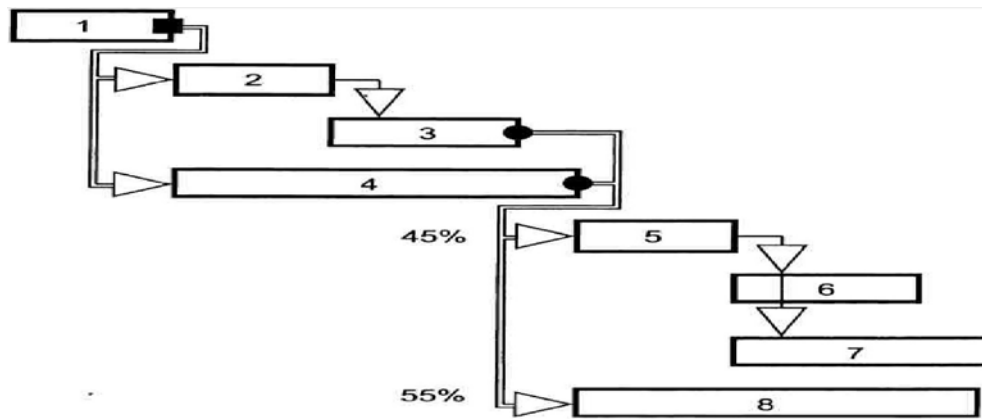
In this section, we list the theories that explain why the problems happen in our field study. The low efficiency of portfolio planning can be categorized into two aspects: the first aspect is the discrepancies between some existing decisions in a portfolio plan and the corresponding actual outcome; the second aspect is the process of updating a portfolio schedule.

When analyzing mismatches, we figure out why the mismatches appear, when the mismatch on a decision appear by locating the stage in the process of making the decision and carrying the decision out. When analyzing the low efficiencies in the process for updating a portfolio schedule, we point out why some decisions are contentious, or why some decisions tend to go wrong.

### **3.2.1. Decision tree diagram usage in presenting decision relations**

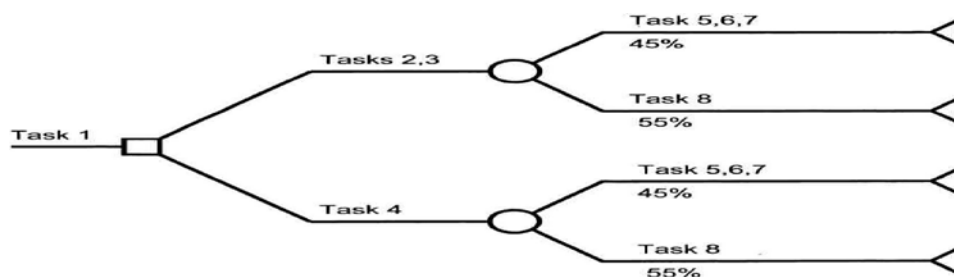
Decision tree diagram is used in project planning/scheduling, highlighting how certain decisions affect other decisions that follow. Such influences disclose that many decisions are conditional to be carried out. A decision is conditional indicates that the decision may not be carried out at a certain chance. (Virine & Trumper, 2008) used decision tree diagram like Figure 24 and Figure 25,

to present the relations between decisions. Such trees show the variability in some decisions in a project plan. When a certain scope could be implemented through different design/solutions, each design/solutions can be decomposed into a different set of tasks. When what tasks to be carried out is uncertain, how long will the tasks will take is also uncertain.



**Figure 24 Project Schedule to Be Converted to a Decision Tree**

Source:(Virine & Trumper, 2008)



**Figure 25 Results of a Schedule-to-Decision Tree Conversion**

Source:(Virine & Trumper, 2008)

Besides, project owners use decision tree diagram in evaluating whether to pursue a project or not. (Loch, Bode-Greuel, & Smuck, 1999) used Figure 26 to illustrate an example for such usage. Besides, in other fields which are characterized by high uncertainty and fast changes, decision tree diagram is also adopted. For instance, some planner in military fields proposes to use decision tree diagram in planning for a dynamic circumstance (Meysam, Raissi, Vahdani, & Hossein, 2011). Project portfolio planning is also a problem which faces multiple uncertain factors and frequent changes in decisions. For example, the arrival of an urgent task may occupy the resources, disrupting some on-going work, or making some projects postponed.

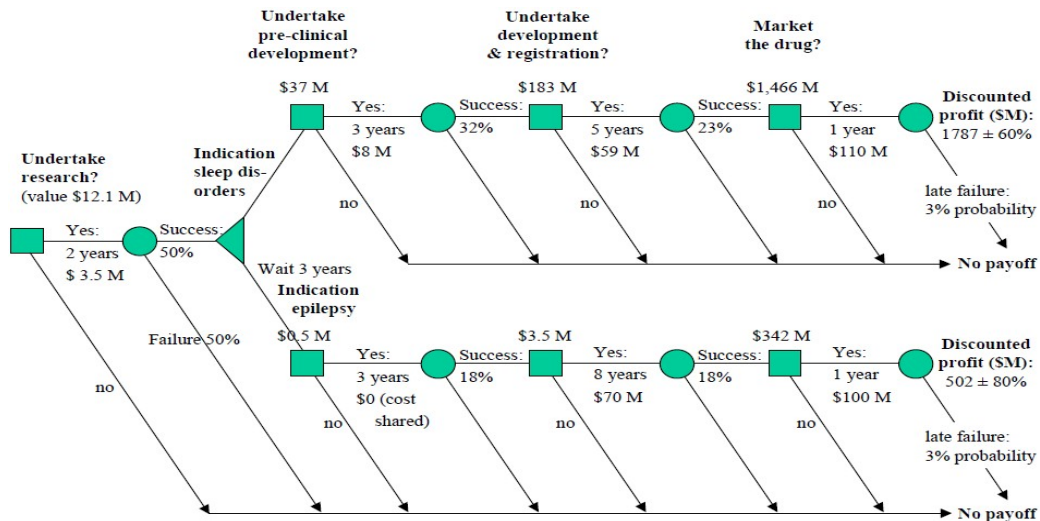


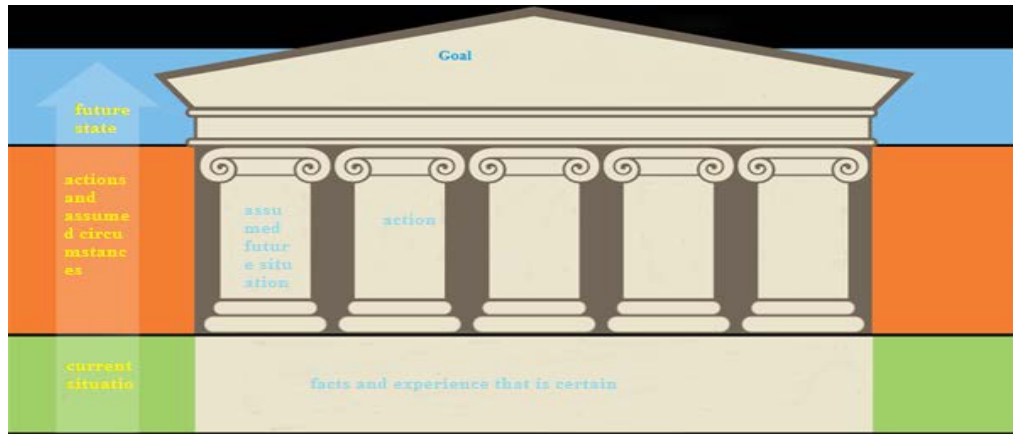
Figure 26 using decision tree to evaluate the prospects for a project in a pharmaceutical company

Source:(Loch et al., 1999)

### 3.2.2. Assumption Based Planning

Assumption-based planning (Dewar, 2004) is an approach used in making long-term strategic plans for military and business organizations. The purpose for ABP is to enhance the robustness of the plans, especially when the environment is uncertain and dynamic. ABP helps us understand why some decisions in a portfolio plan tend to mismatch from reality.

ABP claims that many decisions in a plan are conditional. That means, the fulfillment of a conditional decision requires the existence of certain conditions. Such preconditions for a decision are usually assumed to appear, when the decision is made. However, if some assumed condition fail to appear as expected, the decision that depends on this assumption is likely to fail (Dewar, 2004). Some assumptions are critical for a decision to be carried out as planned, while some assumption's impacts may be less significant. The critical assumptions are called load-bearing, which means the collapse of such assumption pillars would lead to the fall of the decision the assumptions support.



**Figure 27 the desired future status is supported by pillars of assumptions and actions**

ABP also label the assumptions whose chance of incidence is low, as vulnerable assumptions (Dewar, 2004). Identifying the assumptions that support a decision's fulfillment, figuring out the vulnerability of each assumption, and checking how significantly each assumption would impact the decision it support, helps the planners to notice which decisions are vulnerable and why.

### 3.2.3. Critical Chain theory

Critical Chain theory proposes an approach for managing a project or a group of projects. The grounds for such a project management approach, also stated in the theory, are that(Leach, 2005a):

- 1) Many projects did not finish as scheduled, due to contention for resources. That is, multiple tasks compete to gain the attention of task performers in the project team. Therefore, before deciding the deadlines, the resource supply should be checked.
- 2) Guaranteeing each single task to finish on schedule, is much harder than guaranteeing a queue of tasks. Tasks finish around deadline. Such fluctuations of completion dates around deadline will be more effectively controlled collectively.
- 3) Tasks finish around their deadlines, due to procrastination, student syndrome, Parkinson's Law, perfectionism, multi-tasking, cherry-picking and etc. Such a deadline effect should be exploited. And task performers should be motivated to progress faster with an earlier deadline setting. And to prevent task performers protecting themselves by setting late deadlines, the managers should tolerate a certain proportion of delays when the deadlines are set aggressively.
- 4) The resources which are busiest in the project team, dictates the progress speed of the

whole team. Therefore, project managers should know the upper limit for project progress speed by identifying the busiest resources. Feeding the project team workbench with excessive work will not boost the project progress speed.

- 5) Project managers should guarantee that the busiest resources are protected with buffers around the bottleneck.
- 6) Multi-tasking usually disturbs the attention of project team. Fragmenting the working hours among multiple tasks, probably lowers the efficiency of task progress.

The project management approach Critical Chain theory recommends, includes that:

- 1) Figuring out the bottleneck resources and calculate the maximum progress speed based on the bottleneck;
- 2) Reducing multi-tasking;
- 3) Extracting buffers from each task, and pooling buffers together. Coordinating tasks in a relay race style;
- 4) After extracting buffers, each task's duration becomes shorter. Using a shorter duration, and scheduling tasks at their latest starting date, to alleviate procrastination;
- 5) Do not blame task performers for delays when tasks' duration allowance is skimmed.

(H. W. Dettmer, 2000) illustrated how Critical Chain and Critical Path schedule the same project differently using Figure 28. Figure 28 shows that in Critical Chain, task durations are shortened; the buffers are pooled after the tasks; and the usage of each resource is staggered to avoid the schedules to be non-executable.



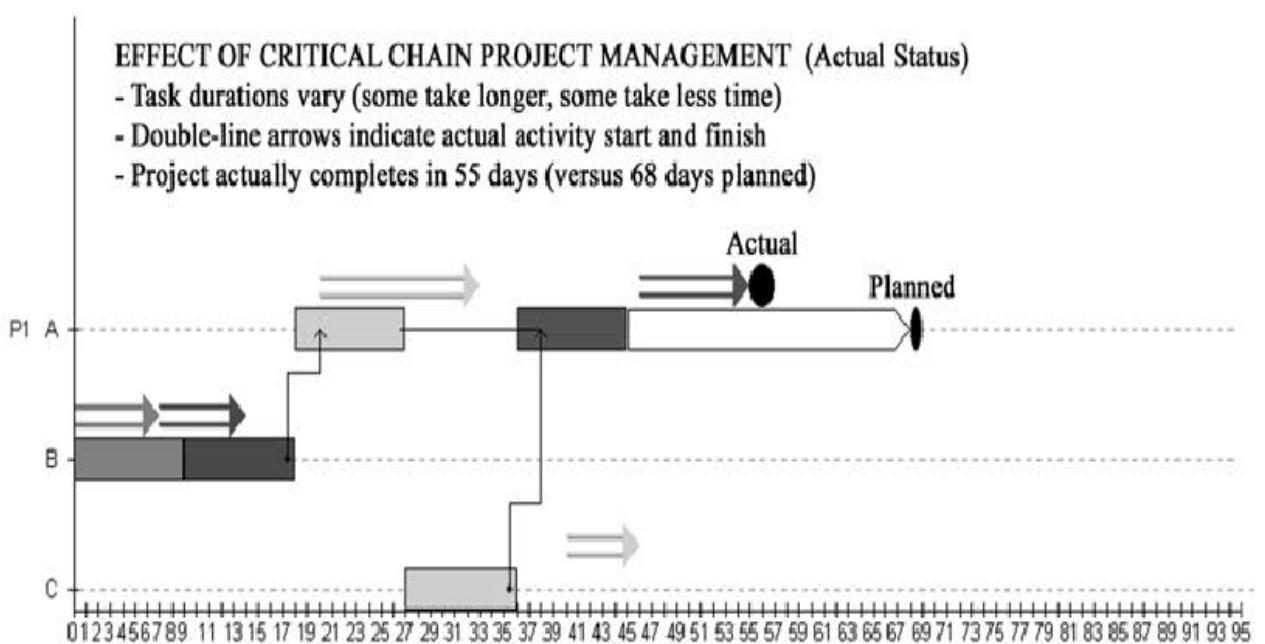
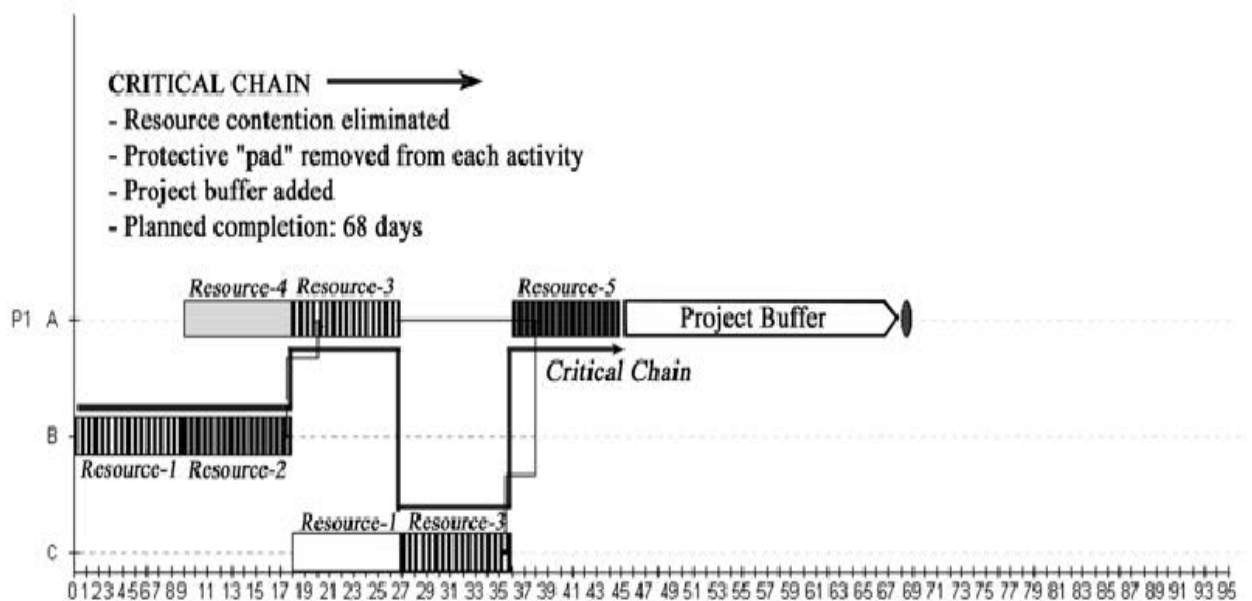
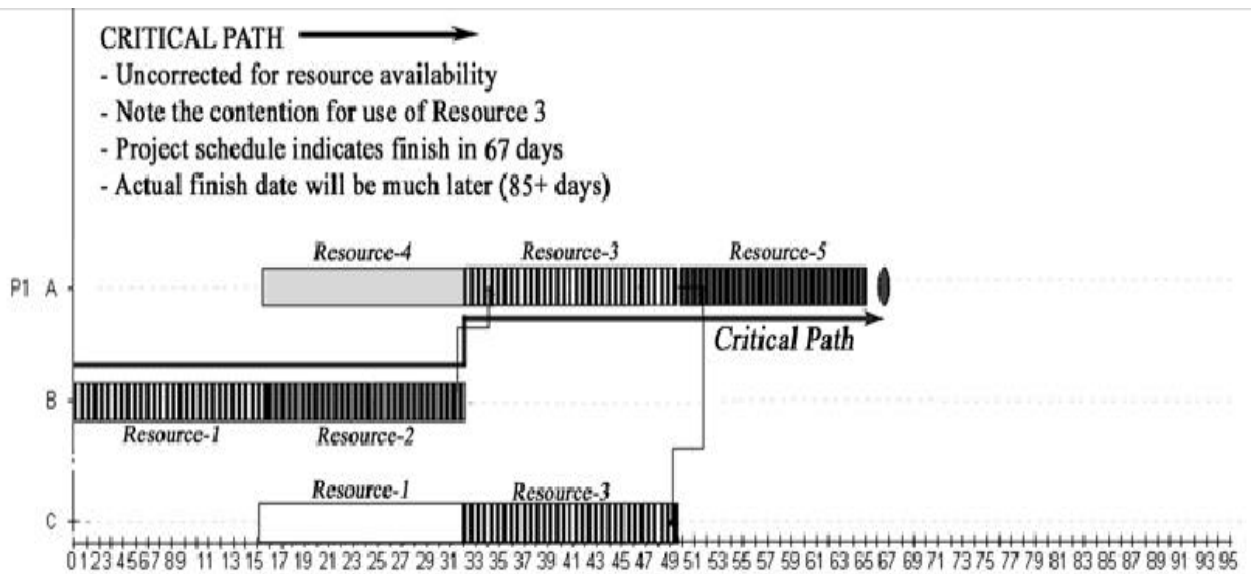
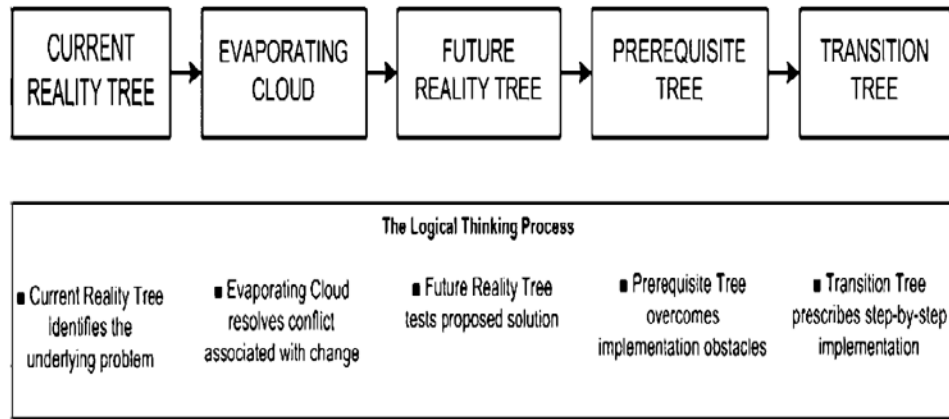


Figure 28 the contrast between critical path and critical chain scheduling

### 3.2.4. Theory of Constraints (TOC)

TOC is a framework for solving problems (Goldratt, 1999). There are various tools within TOC used for problem analysis and solution design. The order in which those tools are used, is shown in Figure 29. In Figure 29, a brief introduction of the function of each tool in a problem-solving process is also provided.



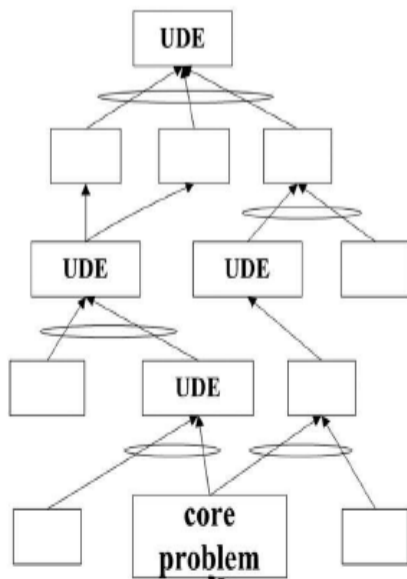
**Figure 29 the steps in a TOC process**

**Source:**(Cox & John G. Schleier, 2010)

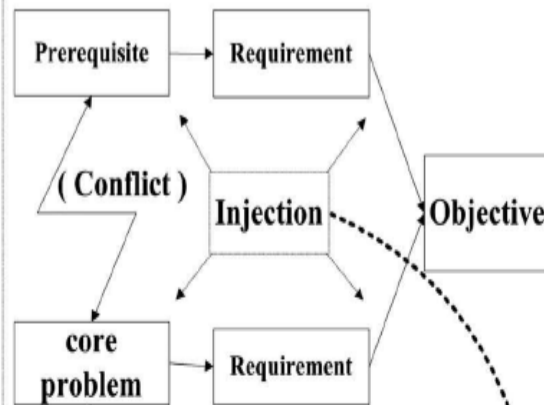
Briefly put, TOC first uses Current Reality Tree (CRT) to pinpoint the deep causes for the problems/symptoms. The causes converge in CRT into a smaller amount of core problems. Second, TOC analyze the core problems through surfacing the conflicts in Evaporating Cloud. Evaporating Cloud is also called Conflict Resolution Diagram (CRD), because changes/measures will be proposed to tackle the conflicts identified. Third, Future Reality Tree diagrams will be used to project the effects when the suggested measures are adopted. After the evaluation, obstacles for adopting such changes will be pointed out, and the actions to overcome the obstacles will be devised. Last, the implementation of the proposed changes will be detailed into a step-by-step roadmap (Cox & John G. Schleier, 2010). (Watson, Blackstone, & Gardiner, 2007) illustrated the relations between the five tools in TOC using Figure 30.

## What to Change ?

### a. Current Reality Tree



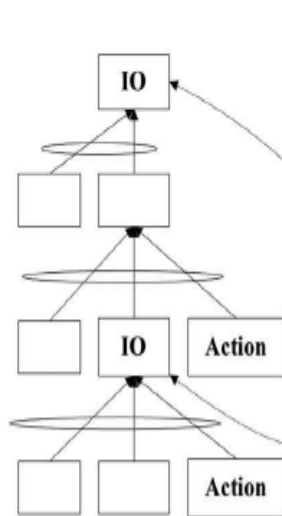
### b. Evaporating Cloud



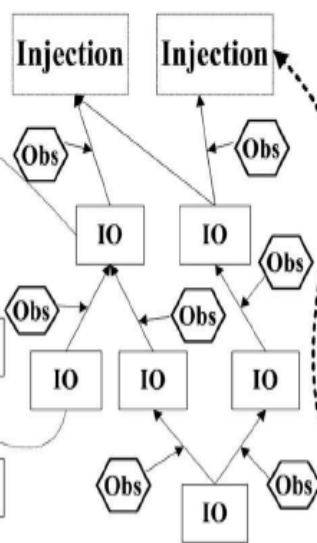
## What to Change to ?

## How to Cause the Change?

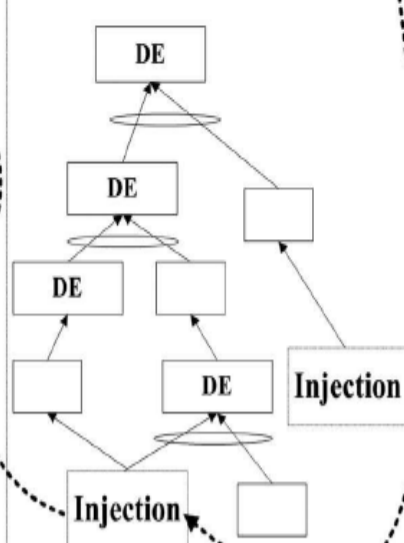
### f. Transition Tree



### e. Prerequisite Tree



### c. Future Reality Tree



UDE = Undesirable effect  
 DE = Desirable effect  
 IO = Intermediate objective  
 Obs = Obstacle  
 Injection = Proposed solution

Figure 30 the relations between different tools in TOC

Source: (Sanjika, 2010)

### **3.3. *Summary***

The academic literature provides the tools and perspectives through which we interpret what we observe in our case company. The literature chapter serves as a glossary of the theories and concepts we used in analyzing the problems. In the analysis chapter and the suggestion chapter, we also quote some literature, and the literature in those chapters will be organized by the theme/problem the literature topics address.

## 4. The analysis on portfolio scheduling

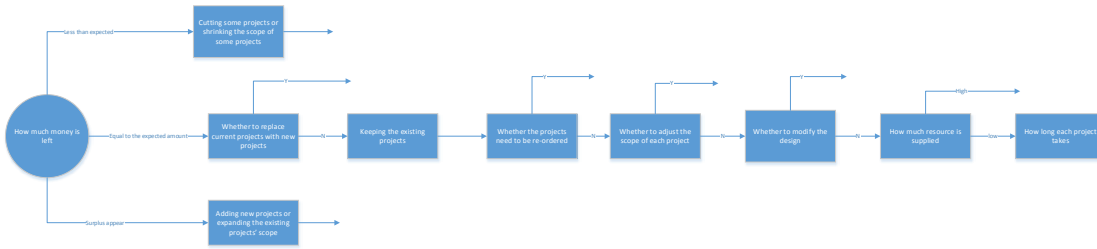
This section applies the theories and causal links found in literature to explain the phenomena we observed in our case company. The analysis is structured as follows. First, we show that in a portfolio schedule, some decisions' choice depend on some other decisions or external factors. The decisions form a decision tree. Along each branch of the decision tree, the chance for each decision's choice/content to be realized gets lower and lower. Therefore, to some point/node in the decision tree, the last decision's chance is so low that the portfolio plan had better exclude the last decision from the plan to avoid mismatches to arise. The decision whose chance to be realized is lowest in a plan, determines how likely the plan will encounter mismatches. Presenting the decisions in a plan, and highlighting the trend of declining likelihood along each decision tree branch, provide the readers an impression of what are the decisions, which decisions are more likely to mismatch.

Second, we make an abstract summary for the process for updating a portfolio schedule. We point out some activities in the plan-revision process easily get stuck, or some activities easily go wrong—producing a biased or defected decision. We point out the inefficiencies within the plan-updating processes.

Third, we discuss how to cope with mismatches. We evaluate the impacts of each mismatch to determine whether the mismatch bother to be eliminated in a plan-revision process. And to lower the chance for each decision to mismatch with its actual status, or to limit the impact of each mismatch, we trace back where/when the mismatch is rooted. We trace the root cause for a decision's mismatch along the process: from making the decision to executing the decision. We point out the exact phase where/when the decision encounter mismatches. Such a disclosure suggests which stage we should take measures to fix the mismatch.

### ***4.1. Using Assumption-based planning to explain symptom 1***

The decisions in a portfolio schedule are interrelated. Those decisions form a decision tree. If we proceed from one decision to the next along each branch of the decision tree, each succeeding decision's choice or content depends on the preceding decision's content or choice. According to the probability theory, each conditional event happen with a lower chance than the chance of its preconditions. Therefore, along each branch, the chance for each decision to be carried out gets lower and lower. When we continue proceeding along a branch of the tree, sooner or later we will arrive at a decision whose chance is low enough that the planner had better consider whether specifying this decision is worthwhile. By “worthwhile” we mean if a decision is too likely to mismatch from the future status, the plan's robustness will be harmed by the risky decision.



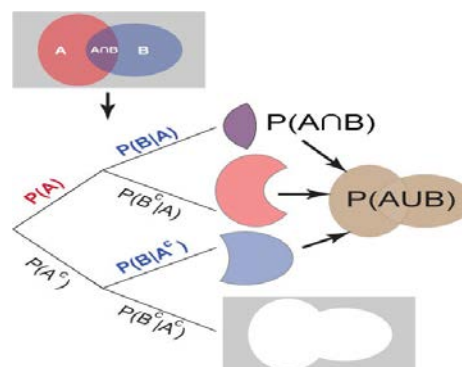
**Figure 31 an illustration for how the decisions form a tree**

### **The decreasing chance for each decision to be carried out along each branch**

Most decisions in a portfolio schedule are conditional. That is, the execution of a decision depends on some preconditions. For instance, a project's starting time is affected by how high the project's priority is, compared with other projects in the portfolio. The relationship that some decision's content affects some other decision's content, inspires the researcher to use decision tree diagram to depict the interrelations between decisions. And using the decision tree diagram we can discover why some decision's chance to be carried out is low.

When you observe a decision tree from the tree's root to its branches and sub-branches, you would see how each decision in the tree affects its succeeding decisions. For instance, in Figure 24, if one design is chosen and the other design is abandoned, the tasks in the abandoned design would become obsolete. Therefore, the chance at which task 6 in Figure 24 will be carried out, is no greater than, often lower than the decision that the design including task 6 is chosen. The further behind a decision lies in a decision tree, the lower the chance the decision will be carried out.

Figure 32 visually illustrates how two variables create four scenarios through a decision tree diagram. There are two variables in Figure 32, each variable taking on two values/levels. When we divide the future situations into different scenarios according to the two variables' values, we generate four scenarios. Usually our decisions under different scenarios would be different, each decision fitting best with one specific scenario. Which decision we will carry out, depends on the specific scenario that actually appears. In this sense, the chance at which each decision will be carried out, depends on the chance at which its preconditions will appear.

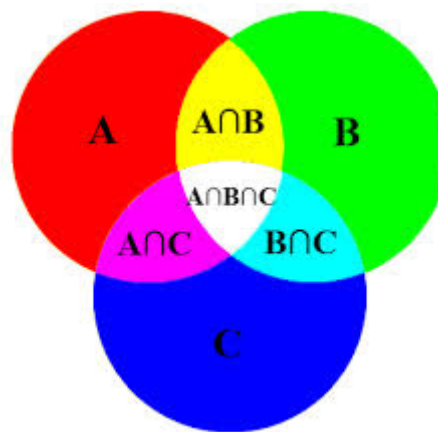


**Figure 32 a visual display of how multiple scenarios are caused by multiple variables**

What ABP did not mention explicitly, is the likelihood at which each decision will be realized, although we can infer it when combining ABP theory with probability theory. The vulnerability of a decision can be measured through the chance at

which the decision may be carried out as planned. Since a decision's incidence depends on the incidence of its underlying assumptions, the chance at which the decision is carried out, would be no greater than the chance at which all its underlying assumptions will hold. Suppose a decision depends on three assumptions, that is, if decision D needs to be realized, the three assumptions underlying decision D have to hold. We use a circle to represent each assumption to hold. Decision D will happen only within the overlapping area of its three assumptions.

If we discover an extra assumption that underlies decision D, an extra circle needs to be added to the Venn diagram. And the overlapping area would be further segmented by the newly introduced circle. As a decision depends on more and more assumptions, the chance at which it will be carried out, will probably decrease with the addition of each extra assumption. Since the decisions that lie further away from the root of a decision tree depend on each of its preceding decisions, the chance at which each dependent decision will be carried out, is usually lower than the chance at which the decision it depends on will be realized.



**Figure 33** a decision depending on more preconditions will be carried out with smaller chance

## **When the preconditions hold, finer grain size is more effective in controlling project progress**

As explained in decision tree representation and Assumption-based Planning, the chance at which a decision will be realized, is lower than the chance for its dependent assumptions to occur. Based on this principle, if some task is divided into several sub-tasks, each sub-task's timing is more likely to mismatch from the actual progress compared with the bulk task from which it is divided. If some issue impacts the timing of a sub-task, the impact of the issue on the bulk task is usually smaller than on the sub-task. For instance, an unexpected phone call may disturb a task performer's work for a specific hour, but the phone call is less likely to disturb the person's progress on that day.

However, there are benefits for dividing a schedule to be smaller grain size or specifying the plan with more detailed decisions. One reason for such divisions is for preventing the tendency of procrastination. Procrastination is also called "student syndrome" (Yeung, 2013). (Yeung, 2013) used Figure 34 to illustrate how a smaller grain size help in preventing procrastination. Studies in psychology like (Gollwitzer, Parks-Stamm, Jaudas, & Sheeran, 2008) show that, a detailed plan

boost the chance to accomplish goals.

# Project Time Management

## Removing 'Student Syndrome'

➔ Milestones!

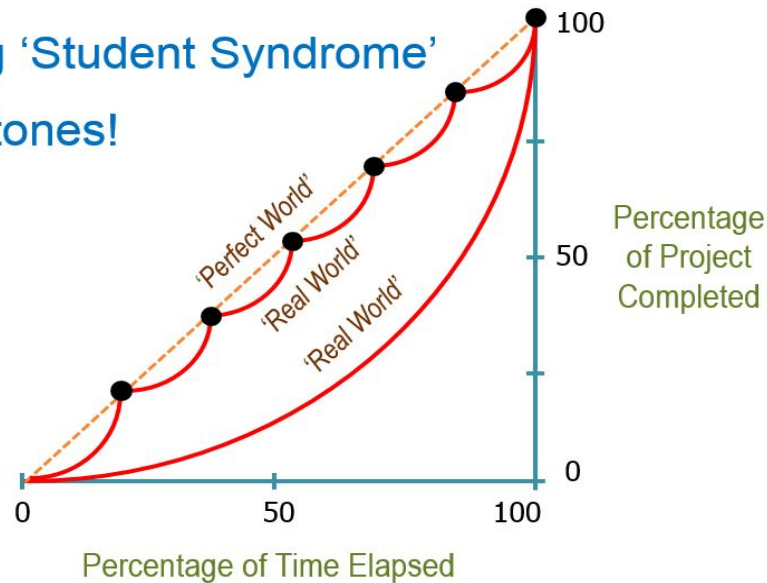


Figure 34 using milestones to alleviate student syndrome

Source: (Yeung, 2013)

## 4.2. Using the prediction theories in prediction to explain symptom 2

When project stakeholders try to predict how much each project will cost, they need to specify the project scope, the choice of design, the detailed specifications in a design diagram, whether to outsource some work, etc. Such factors or choices affect the value of cost estimate. When each project is proposed, the scope is not specified with clear boundaries; the design is not chosen and specified in detail; the outsourcing strategy is not decided, therefore, the cost estimates are potentially deviating from actual cost. The variability of the factors' value would lead to the variability in the cost estimate. A visual illustration is shown in Figure 35.

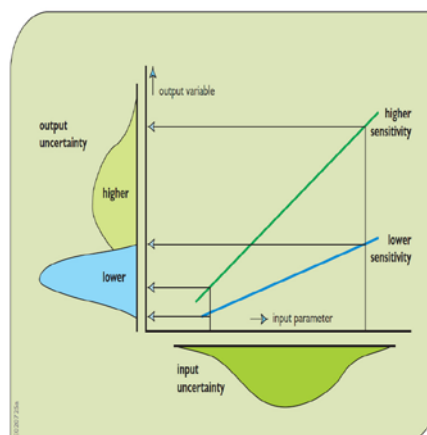
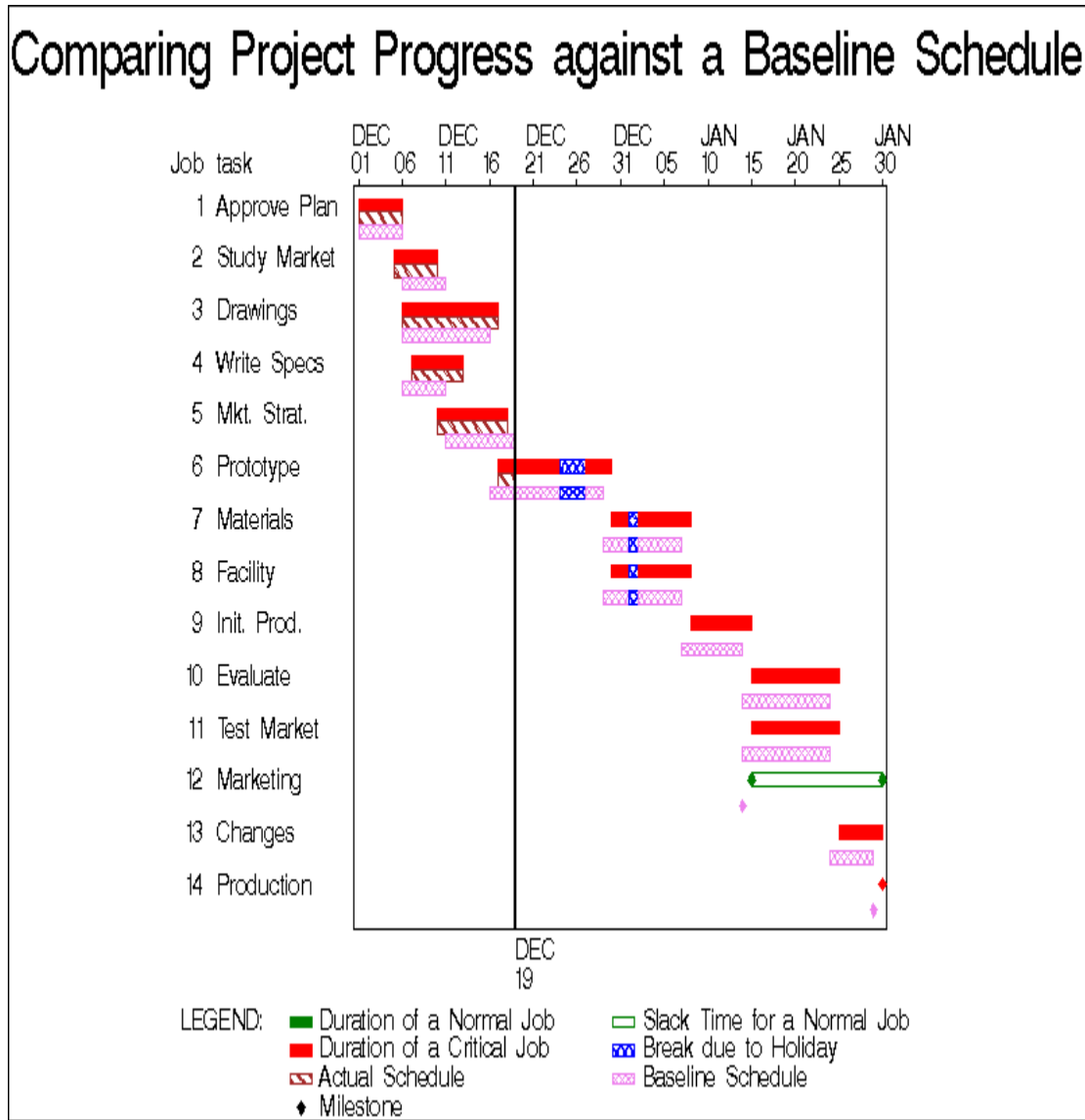


Figure 35 the uncertainty in factors is passed on to the dependent variable



**Source:** (Loucks, van Beek, Stedinger, Dijkman, & Villars, 2005)

As mentioned in an internal document in the case company, “Developing a Project Scope or Technology Plan is an iterative process to balance cost and benefits - it takes time”. Changes in a project’s scope usually lead to changes in design, in resource demand, and other aspects. Therefore, the wide range of variability of project cost estimate, when few factors have not been determined, is inevitable.



**Figure 36 illustrating the contrast between the actual progress and the baseline schedule**

**Source:** (SAS.com, n.d.)

When the duration of a project or a big task varies with a great range, dividing the work into smaller pieces is risky. The variability of the duration easily leads to the actual duration deviating from the baseline schedule, as shown in Figure 36. Figure 37 illustrates how a big chunk of work can be divided into smaller pieces. As (Goldratt, 1997) expressed, “it is a mistake to strive for accurate answers when the data is not accurate. Answers that pretend to be more accurate than the uncertainty embedded in the problem are not better answers.”

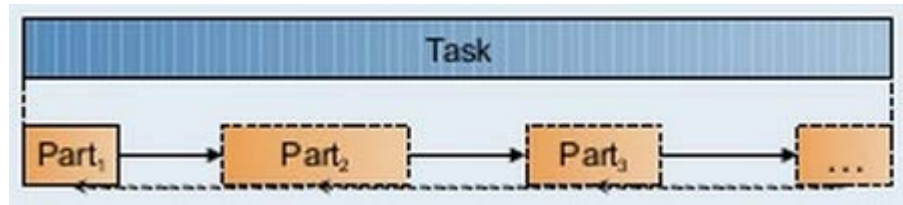


Figure 37 when a task is divided, the uncertain items increase

Source: (Laborie, 2009)

### 4.3. Using stakeholder analysis to explain symptom 3,4 and 5

There are several reasons that cause the plan-updating process inefficient. First, some information tends to be unavailable when it is needed to update the plan. Second, some decisions encounter a deadlock in discussion and thus hinder the plan-making process. Third, some decisions that are hastily made, contains defects which will trigger project design rework in future.

#### 4.3.1. Information dispersion

Although the parties in our case often belong to the same corporation, or they form a long term cooperation relationship and trust with each other, the information about project selection, about project progress, about available resources is still segmented and scattered around different departments or different roles.

Such information dispersion leads to the need for information integration when all parties cooperate in making a feasible and agreed plan. For instance, the figure out how long a project will take, the client need to express the desired scope, and then the engineers need to come up with a solution/design as basis for cost estimate. And the engineering department needs to compare the workload indicated by the design, with the current resource availability, to estimate the speed of progress for the project. The information about project scope, design, workload, resource supply, need to be pooled together in generating a feasible solution.

Task managers often complain that when they are asked to estimate how long the tasks will take, the task managers have not got the relevant input for such tasks: what is the current status of a facility, what work will be needed, whether the design is clear enough, etc. When the task duration is estimated based on ambiguity of the input, the risk that the tasks will take longer or shorter than expected is high.

Apart from the quality of the scheduling decisions—whether the timing is feasible or not, how long it takes to reach such decisions is also hindered by information unavailability. Some task managers mentioned that they cannot produce a duration estimate when the design is in dispute, or the client has not provided the input in for tasks. Some task managers mentioned that the information they acquired from different sources is inconsistent, such as the requirements towards the design. Task managers need to spend extra efforts in checking the most updated status of the task input.

### 4.3.2. Contentious decisions

Multilateral decisions in project management include the choice of design, whether to outsource some work, the priority setting for projects, etc. Such decisions affect multiple parties and thus a consensus is needed before a workable plan is reached, otherwise a temporary plan is likely to be revised soon. Although agreement is a must, disputes usually happen, prolonging the plan-making process.

#### Theories

Theoretical studies point out the determinants for the final decision and the stages that lead to a decision.(Beresford & Sloper, 2008) uses the framework in Figure 38 to show how a decision is influenced by information about the problem, mental image of the problem, and personal preference/difference.

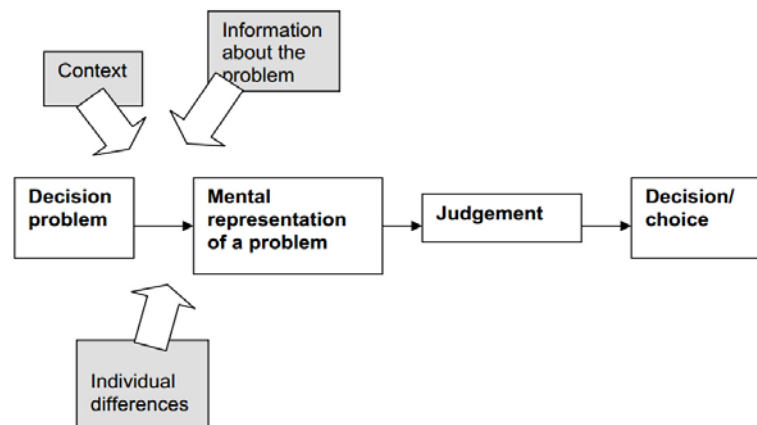


Figure 38 decision making model

Source: (Beresford & Sloper, 2008)

Disputes happen when coordinating efforts from various parties who possess differences in various aspects: perception, interest, and knowledge/specialization. In our case, different perception refers to the disputes like which design to be chosen. Different specialization refers to the communication barrier in technical stuff. Misalignment of interest refers to the disputes in which different parties pursue different goals. (Oliva & Watson, 2011) also mentioned the role that perception and misaligned incentives play in the joint planning process, as is shown in Figure 39.

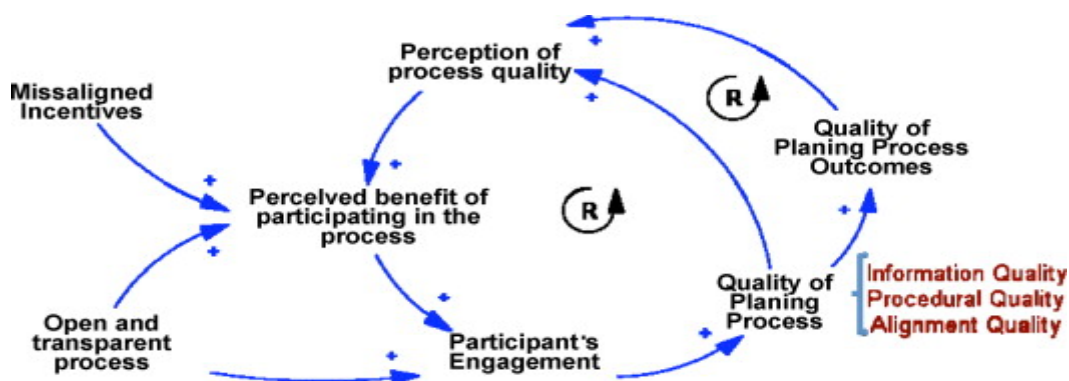


Figure 39 Structural determinants of a planning process' quality and outcomes

Source:(Oliva & Watson, 2011)

## Trade-off between different goals

A project has multiple aspects: scope, quality, speed/schedule, cost, and etc. Arrangements for a project need to cater to different aspects and make trade-offs between them. Different aspects are concerned by different stakeholders. Usually, when trade-offs between different aspects are needed, and each stakeholder urges to gear the project goals towards the aspect he/she favors, disputes arise which prolong how long a planning cycle takes. (Kerzner, 2009) illustrates different orientation in arranging a project using Figure 40. (Tonchia, 2008) uses Figure 41 to show the trade-off between different goals.

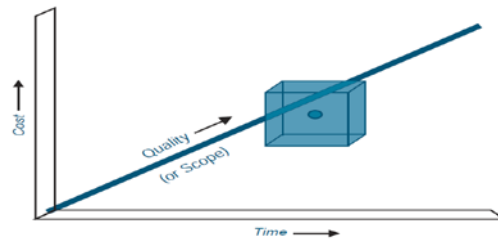


Figure 40 a project can be steered towards different directions

Source: (Kerzner, 2009)

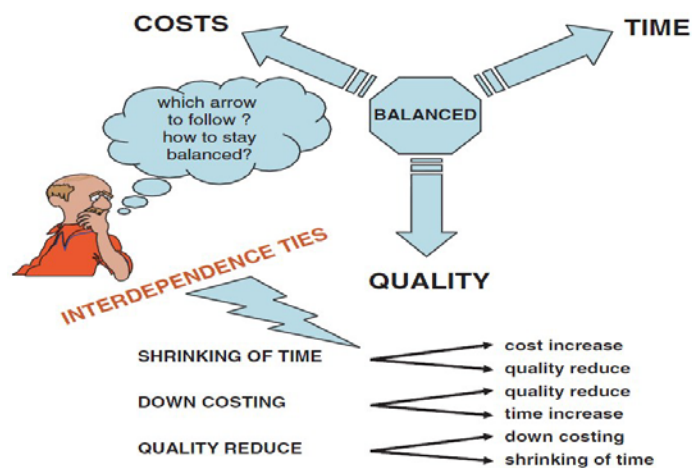
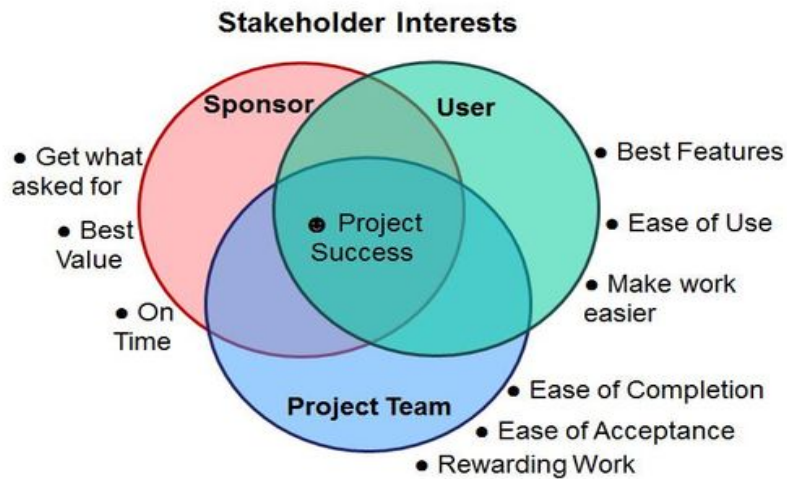


Figure 41 the trade-off between different goals

Source: (Tonchia, 2008)

## Difference between stakeholders

A project portfolio plan concerns multiple stakeholders: the user of a project, engineer/designer, constructor, maintenance. Each want have a say in the final plan. Different stakeholders possess different power or authority in influencing the decisions, but usually the decisions are reached through negotiations.



**Figure 42 different stakeholders' preference**

**Source:** (Griffiths, 2012)

Such disputes about the goals partly originate from the fact that responsibilities are partitioned and assigned on different functional groups. Another reason is that different stakeholder specializes in a different field. For example, engineers often complain that their clients are too optimistic in urging the progress of a project while underestimating the challenges. Different stakeholders pay attention to different aspects of a project.

Although it is desirable to promote a project performance towards every dimension/direction, the available resources are limited and thus the feasible zone for a project to move is limited. It is hard for the client to sense the technical challenges that brought by extra quality or faster completion. And engineering side usually trade-off between catering to client's wish and the feasibility. (Griffiths, 2012) used Figure 42 to show the difference in the goals of different stakeholders.

### **Observation from our case company**

The engineers in our case company often complain that the clients tend to be more eager to urge a higher speed in project completion. The engineers believe that the client/user usually underestimated the difficulty of some project's technical solution. Some engineers said that the client often suggest a simplistic solution that is actually not technically feasible. Or the solution recommended by the client does not comply with the regulations from the corporation policy or government. Therefore, we can infer that the difficulty perceived by clients is smaller than the difficulty estimated by the engineers. Different perceptions cause the dispute.

Another reason for disputes is different orientation or preference, clients often steer the direction in choosing a design towards a design that is of lower cost, or of higher speed, because the clients' performance is usually evaluated with criteria such as profitability, speed. The engineers concern more about the quality or safety, because the engineering side is usually held responsible for the quality issues.

### 4.3.3. Defected decisions lead to rework

When different stakeholders discuss a project's design, they sometimes agree on the design without enough consideration. Some readers of the design diagram misinterpreted what the design means exactly. Some readers have not fully read the design and description carefully because they receive the design report so late. Some participants come to the meeting without receiving the report. When such discussions approve some design immaturely, some design turned out to be defected or not satisfactory in certain details.

If a design turns out to be defected in the late stage of a project, the rework usually take more time since the engineers have detailed the design into a more elaborate version. The modifications at the highest system level would trigger the modifications in multiple modules and sub-modules.

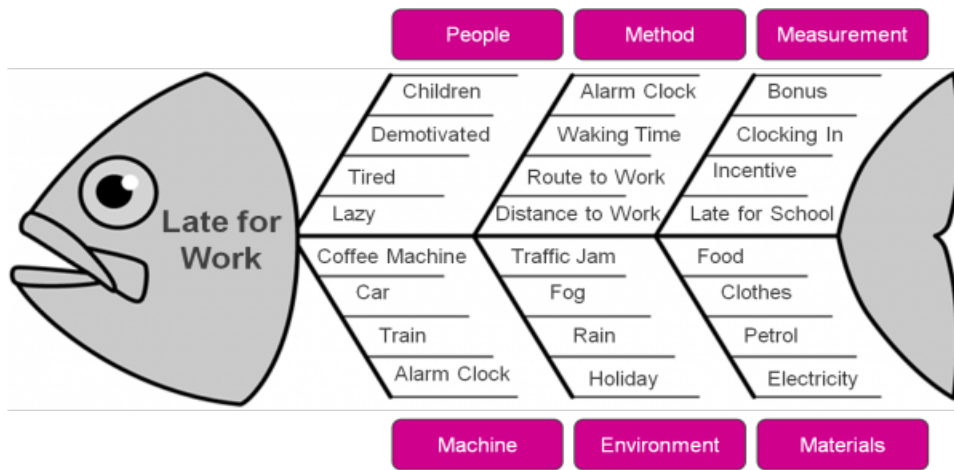
### 4.3.4. Survey of time usage and factor ranking

The reasons for low efficiency of a portfolio-schedule-updating process mentioned above are extracted from the interview records. During the interviews, the planners mentioned various phenomena of inefficiency. And to measure the efficiency quantitatively, we designed a small survey to measure how many hours the planners spend on updating plans; what are the major activities in a plan-updating process; how big is the proportion of each activity; and ranking what are the major reasons that the planning activities are time-consuming. For instance, if some meetings take too long, are the meetings spent on exchanging information, or spent on disputing about some issues. The results are displayed in the appendix of my thesis.

## 4.4. *Using critical chain theory to explain symptom 6 and 7*

**Why analyzing task delays:** We choose one type of mismatches that arise frequently—task delays—for mismatch cause analysis. We are not able to discuss every type of discrepancies in a portfolio plan. The reason for selecting task duration discrepancy for analysis is that, task discrepancy is a commonly mentioned and unsolved discrepancy for years in project management fields. And Critical Chain theory claims the task discrepancy as the biggest constraint for the performance of project management(Leach, 2005a).

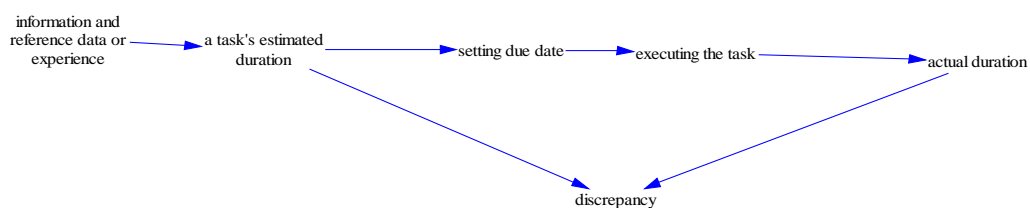
**How we dig out the cause for task delays:** We adopt the fish-bone **method** to find out the causes for task delays. The basic principle that underlies the Fish Bone method is to group various specific causes of a problem/symptom of interest to several major independent categories (Koripadu & Subbaiah, 2014). Fish Bone method displays the causes in a clear and concise way.



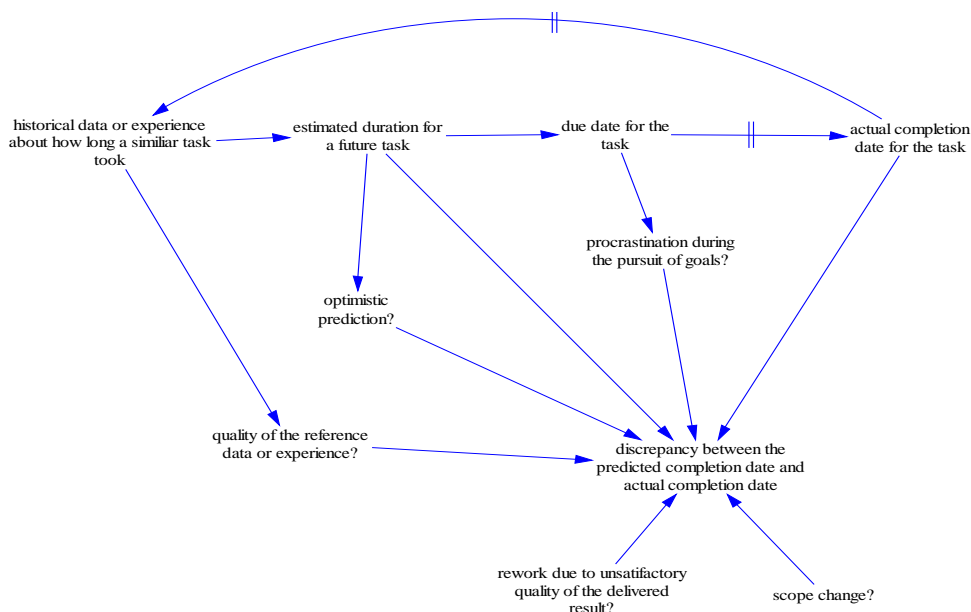
**Figure 43** an illustration of using fishbone method to group the reason for a certain result

Source: (Lawther, 2012)

**What are the specific groups of delay causes:** the delay is the difference between the estimated completion date and the actual completion date. It appears when the task actually finishes. From the actual completion date, we trace back at which stage do the delay causes lie. The tracing back approach is illustrated by Figure 44 and Figure 45.



**Figure 44** the definition of a discrepancy in task duration



**Figure 45** why a discrepancy between a task's predicted duration and actual duration appear

When a task encounter delay, is the delay caused by factors appeared at the task execution stage, like procrastination? Or does the cause lie in the estimation stage, for instance, the original estimated completion date is unrealistic?

We can proceed this search for cause path even further. For example, if the deadline is unrealistic, is the unrealistic deadline caused by an optimistic estimated completion date? If the estimated completion date is optimistic, is the optimism caused by unclear input about the task? For instance, we can easily tell how long it takes for a trip we travelled a lot of times, but we cannot tell the duration for a new exploration trip.

**How the causes are organized:** In this section we will explore group of delay causes. We will check what is claimed in literature, with what the task managers say during interviews. For example, if we suspect the estimation stage for task duration is defected, we will check whether some literature mentioned optimism bias in estimation, and then provide the descriptions of the task managers.

#### 4.4.1. The causes for delay located in the estimation stage

Each task's actual duration is a continuous variable, which possesses a certain range, as is shown by Figure 46. The author of this thesis mapped various delay reasons into the distribution of a task's actual duration, as illustrated by Figure 47.

##### 4.4.1.1. The estimate is too optimistic to be feasible

The first explanation for delay, is that: (Flyvbjerg, 2007) mentioned that the estimated task duration is often so optimistically short that the estimate falls below the lower limit of the distribution for the task's actual duration. (McConnell, 2006) provide evidence that the "impossible zone" exist for task duration estimation, as is shown in Figure 48.

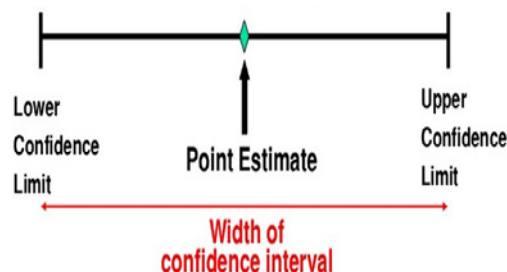


Figure 46 range estimate vs. point estimate

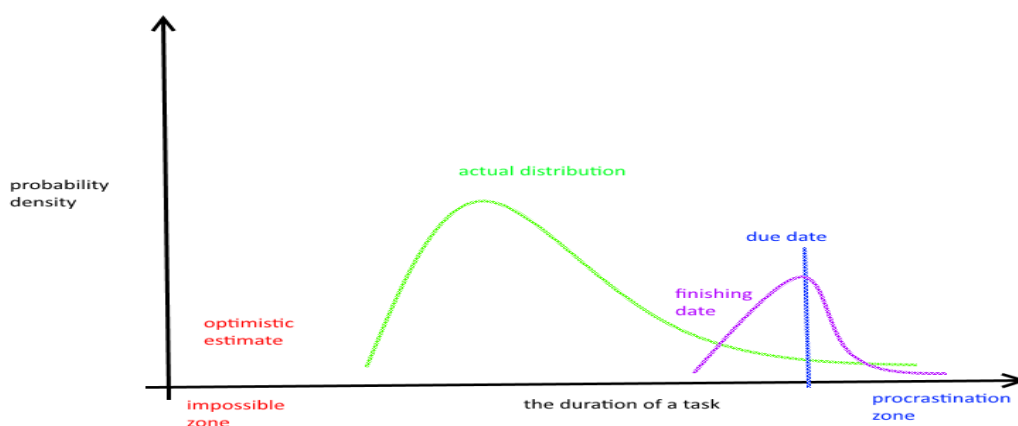
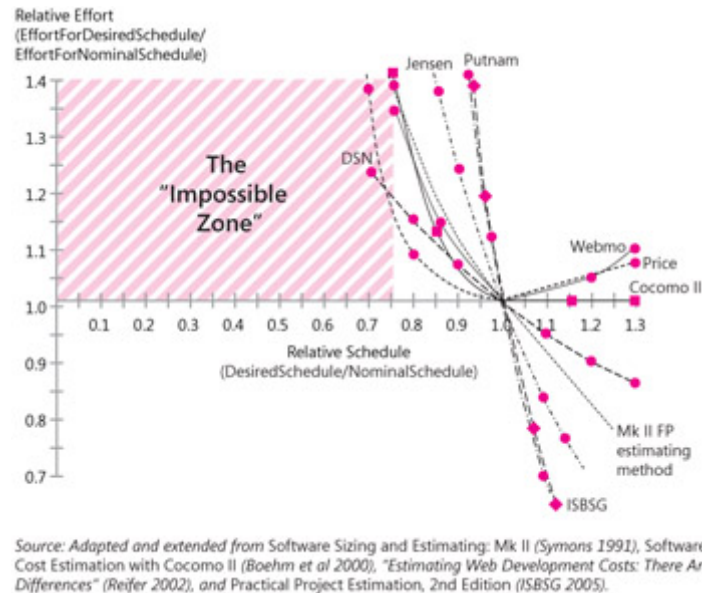


Figure 47 possible reasons why the actual completion date of a task exceeds its due date





**Figure 48 the existence of the impossible zone.**

**Source:** (McConnell, 2006)

### ***The reasons for generating an optimistic estimate***

As (Buehler, Griffin, & Ross, 1994) point out, when people estimate how long a future task will take, he/she may adopt one option from two alternative types of estimation method. The first type of estimation method is to estimate based on the characteristics of the future task itself. Such traits include the content/difficulty of the task, the volume of the task, etc. For instance, if a task is considerably difficult, the planner will estimate the duration to be longer. Another type of estimation method refers to similar historical tasks to estimate the duration of the future tasks. The future task is viewed as one instance of the statistical distribution formed by historical tasks. Referencing historical tasks possess potential risks that are stated below.

#### **Referencing history**

When referring to similar tasks, human beings tend to hold deeper impression of certain tasks than others, and may have an erroneous memory in the value of the events (Project Implicit, n.d.). For instance, the most impressive reference task may be too easy and thus the estimated task duration range will be shorter than it should be. The reference data could be located in the low probability zone of the distribution. The data that the estimate figures are based on, are biased, leading to biased estimate figures.

When discussing the optimism bias in estimating the duration for a future task, (Buehler et al., 1994) pointed out that planners usually attribute the delay in historical tasks to some temporary factors that will not appear in future task's execution, therefore the estimated duration for a future task remain optimistic. In other words, it is easy to neglect some factors that prolong the duration of a future task.

**Projecting the future:** If planners only refer to the future task's characteristics, they may neglect some risks or

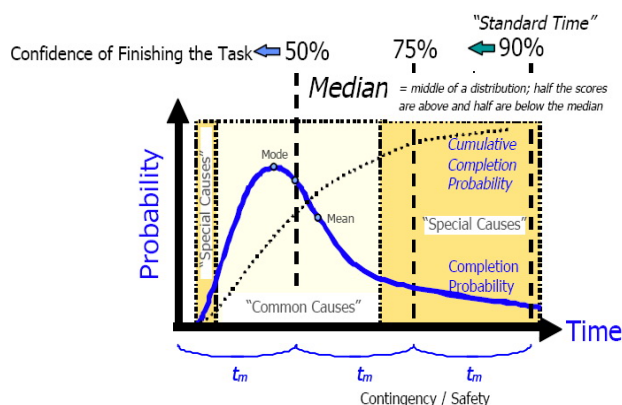
underestimate the impact that some small events will cause big delays. Therefore the estimate based on projecting the future task's traits is optimistic, leading to unrealistic due date setting. If the value of a variable to be predicted, is sensitively affected by the error in assumptions, the error in target variable prediction could be more than expected. For example when estimating how long task T will take, the assumptions needed includes how difficult task T is, and who will do the task. In the example for estimating task T's lead-time, if task T will be a bit more difficult than expected, and the task duration would is sensitive to the changes in such parameters, the error in predicted task duration could be higher than expected.

#### 4.4.1.2. The estimate falls into the possible zone

The second reason claims that, the due date falls into the possible range of the actual completion date, meaning that the task may finish within a certain estimated duration. However, since a task's actual duration possesses a long right tail, there is chance that the task duration exceed the estimated duration, no matter how conservative the estimate is. Even when the due date is set to be very safe, the actual completion date usually fluctuates around the due date. A task still delay under a conservative due date, is that, the task performer procrastinate in working (Leach, 2005a).

### *The factors affecting the range of a task's duration's distribution*

When the estimated duration lies in the possible range of the distribution, the narrower the distribution range, the smaller the chance that the estimated duration will deviate greatly from the actual duration. Therefore, we need to figure out what causes account for the wide distribution of a task's duration, if we want to make the distribution range narrower. (Martinello, 2014) used Figure 49 to group the factors that affect a task's duration's distribution. The causes are grouped into common causes and special causes, in a similar approach for statistical quality control in production management(Oakland, 2008). The causes that prolong a task's duration distribution's right tail, are called special causes. Special causes often consist of special events that do not arise every time when the task is carried out. For example, sick-leave of task-performers is one special cause that does not happen often. But if some special causes do appear, the task's duration would be greatly prolonged(Leach, 2005a).



### Figure 49 task duration distribution and causes

The variability of the independent factors, and their impact on the target variable—the task’s duration, is illustrated by Figure 50. Figure 50 is based on statistical correlation/prediction theory (Loucks et al., 2005). (Intaver Institute Inc, 2013b) measured how significantly a task’s duration is affected by the changes in its determinants. And the results are shown in Figure 51.

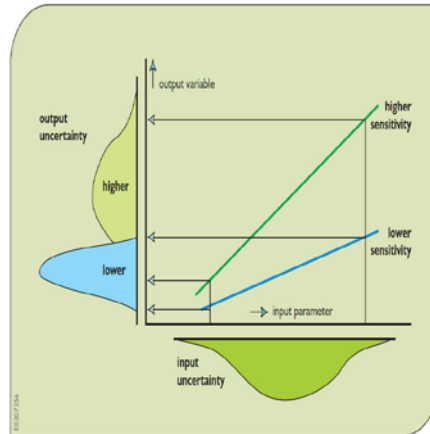


Figure 50 the uncertainty in factors is passed on to the dependent variable

Source: (Loucks et al., 2005)

Event or event chain	Coeff.	Chart
Software performance not acceptable	0.561	
Wrong selection of development tools	0.451	
Early requirements changes	0.203	
Later requirements changes	0.199	
Limited user interface experience	0.123	
Management changes	0.103	

Figure 51 how sensitive a project’s duration is affected by the factors listed

Source: (Intaver Institute Inc, 2013b)

Changes in the factors that lead to the dependent variable to vary, are not hard to find. In many projects changes in scope or design happen very often, and such changes could prolong the duration of a task. Scope changes often bring benefits to the client of the project(Tyson, 2011), and clients possess more power to request scope changes. The variability in scope or design leads to the variability of the task duration. And the scope change is nearly inevitable, especially during the front-end phases.

#### 4.4.1.3.Selecting a point estimate

After figuring out the possible range for a task’s duration, the planners need to select a point estimate as the basis for

setting the deadline for the task. A single point estimate is usually used to hide the range of variability. There have been several attempts for selecting a value that better represent the range. For example, in a approach named “*Program Evaluation and Review Technique*”(Virine & Trumper, 2008), the expected task duration is calculated as the weighted average of the most optimistic, the most pessimistic, and the most likely time estimates In practice, task managers usually set a conservative/safe due date to accommodate potential contingencies(Leach, 2005a). For example, when the estimated duration for a task T is a range [10,20], the upper limit 20 is selected as the basis for setting the due date.

### ***Setting a conservative deadline***

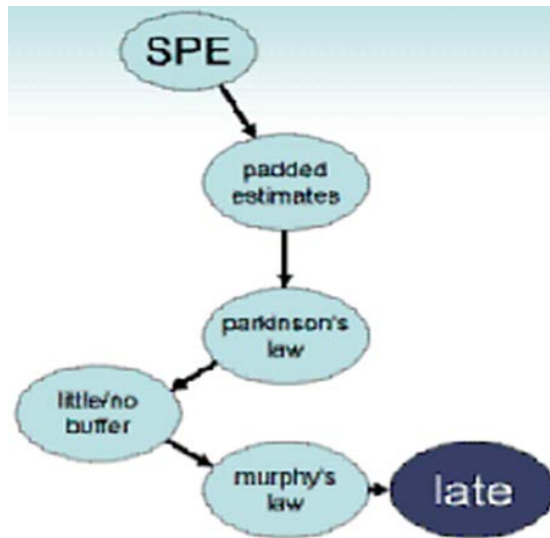
If a task duration distribution possesses a long right tail, it seems that the planners can cope with the risk for task delay simply by making the estimated duration bigger, or setting a safer deadline. However, adopting a conservative duration estimate causes other side effects. Some studies believed that if a task’s duration is overestimated, it leads to some side-effects such as Parkinson's Law (Concurre, 2011). The downsides of being too optimistic or too conservative in estimating how long a task will take, are shown in Figure 52. (McConnell, 2006) express similar ideas using Figure 48. The following words are explanations for Figure 48.



**Figure 52 the harms brought by underestimation or overestimation**

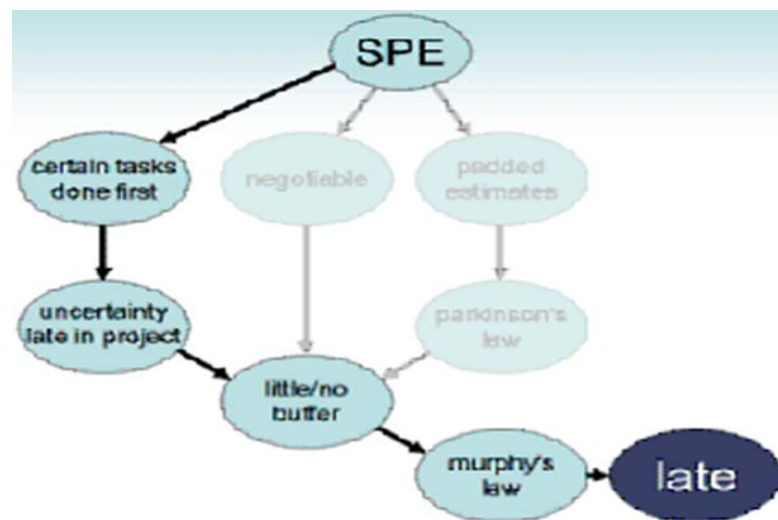
**Source:** (Concurre, 2011)

“The horizontal axis on the graph represents the relationship between the nominal schedule and the compressed schedule. A figure of 0.9 on that axis indicates a compressed schedule that takes 0.9 times as much time as the nominal schedule (that is, 90% of the nominal). The vertical axis represents the total effort required when the schedule is compressed or expanded compared to the effort required when the nominal schedule is used. A value of 1.3 on the vertical axis indicates that the compressed schedule requires 1.3 times as much total effort as the nominal schedule would require.”



**Figure 53 a conservative single point estimate promotes delayed task completion**

Source:(Henry, 2009)



**Figure 54 How multi-tasking lead to procrastination in uncertain tasks**

Source:(Henry, 2009)

(Henry, 2009) uses Figure 53 to illustrate how a conservative single point estimate could prolong the actual duration of a task. Figure 53 mainly discusses the scenario in which the task performer faces only one task. When a task performer faces multiple tasks, the procrastination is aggravated. The reason is that the task performer tends to handle certain tasks before uncertain tasks, leading to the buffers within the estimated finishing date for the uncertain tasks diminished (Henry, 2009). The illustration for the mechanism is shown in Figure 54.

**Setting an aggressive deadline:** Although a conservative estimated duration bring harmful effects, the estimated duration should not falls into the impossible zone either. If an underestimation lead to a tight due date, the affected task performers' motivation could be hurt, because the task performer does not believe they can accomplish the tasks within the due date. As is suggested by self-determination theory, the intrinsic motivation is inspired when the challenge level is appropriate(Deci & Ryan, 2000).

#### **4.4.1.4.Evidence from our case company**

Some project managers believe that task managers often provide over-optimistic task duration estimates. Those task duration estimates are too optimistic to be achievable. Therefore, the task duration estimate should be more conservative in order to reduce delays.

Some task managers admit the optimism bias in estimating task duration. The optimism bias is attributable to the lack of knowledge towards the future tasks. Each project task is new, and the historical tasks are not so similar to the future task. Therefore, the future task's duration can hardly be predicted by referencing history.

Some scheduler who coordinate tasks between disciplines, point out that the workload status of task performers affect the duration for a task. Workload status means how busy the task performer is when working on a task. And how busy the task performer is, can be indicated by how many other tasks are undertaken by the same task performer. Therefore, when referencing historical tasks, the estimator should watch out for the workload status of the task performer when carrying out the tasks.

Some scheduler experimented on the effect of extending/postponing task deadlines. He discover that when task deadline is postponed, the actual completion date shift backwards with the deadline. The actual completion dates are usually around the deadline. Therefore, selecting a conservative deadline did not dissolve delays.

#### **4.4.2. The causes for delays located in task execution stage**

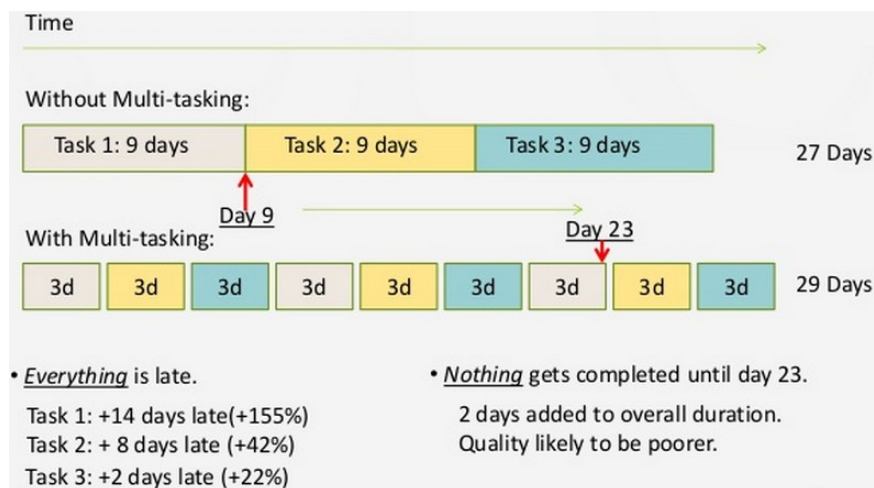
After digging out the causes that lie in the estimation stage, we turn to check the task execution process. That is, what factors affect a task's duration when the task is under processing.

##### **Multi-tasking aggravates procrastination**

Another issue that comes along with multi-tasking is cherry-picking behavior(Simpson & Lynch, 2000). Cherry picking means that when facing multiple tasks, a task performer chooses to work on the easiest tasks before working on unpleasant or uncertain tasks. The unpleasant tasks are those that involve thinking, or talking with others. Such tasks happen to be similar to what a typical task-performer in our case faces: asking the client for clearer specification of technical parameters or designing. Engineers work on the tasks that are easy and with clear specification, while waiting for clients to send information or waiting for inspiration about design. (Henry, 2009) calls such behavior as delayed resolution of uncertainty. Interviewing some task managers in our case also provides similar evidence. The original schedule is made when the input information for some tasks is vague. However, as the time elapse, the uncertainty contained in the ambiguous tasks remains. The responsibility to resolve the uncertainty at task-level is not clear.

Multitasking also make the time spent on each project or each task foggy. For a historical task, if the time that is spent on the task contains some disruption from other tasks, the duration for the historical task is not so qualified to be referenced,

when a future similar task's duration needs to be estimated.



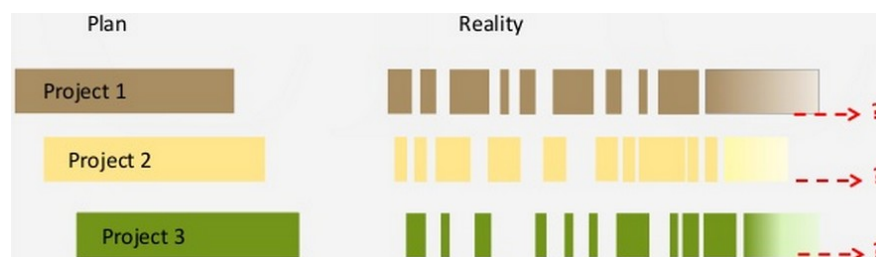
**Figure 55** how multi-tasking prolong the actual duration for each task

Source: (Palmer, 2013b)



**Figure 56** when multiple projects run in parallel, each project progresses intermittently

Source: (Palmer, 2013a)



**Figure 57** multi-taking obscures how long each project takes

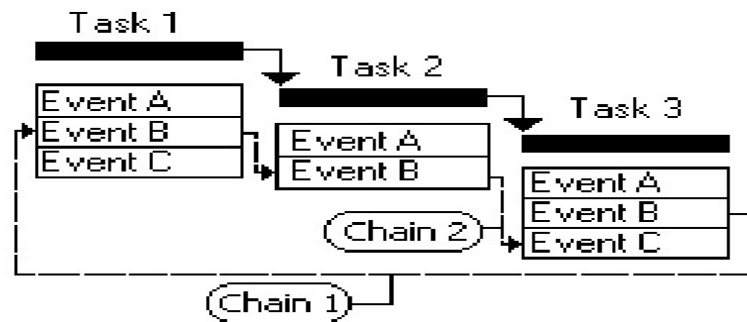
Source: (Palmer, 2013a)

**Scope change or design changes affect the duration:** many empirical studies blame scope creep as one important reason for prolonging task durations (Petit, 2011). Such scope change often happens during the execution of tasks. The scope change are so common in front-end phases of projects that (Williams & Samset, 2010) claims scope changes are inevitable and should be justified since each project should first be checked as the right thing to do, rather than being promoted as fast as possible. Therefore, since scope changes are so common and so significantly impact task durations, they should be listed as

one important factor that account for the variability of task duration.

### ***The changes in design or requirements trigger a chain of reactions***

The rework or modifications on some design tasks trigger knock-on effects on other tasks (Suss et al., 2010). Those tasks are usually inter-dependent: the delay in some tasks would hinder the progress of other tasks (Intaver Institute Inc, 2013b; Marchewka, 2003). Such interrelated parts usually have to be performed by different disciplines, functional departments or organizations, while the overall design should be coherent. Different modules should fit together. When the interfaces between different modules are modified, the design in relevant parts needs to be adjusted to reach a new consistency between different modules. Such adjustments sometimes need to take several iterations. As long as one task is modified, relevant tasks need to be revised too.



**Figure 58 changes in one task trigger chain reactions**

**Source:**(Intaver Institute Inc, 2013b)

When some tasks' deliverables are not satisfactory, they need to be reworked. Such reworks can be explained by Coordination Theory. According to Coordination Theory, a task need to be reworked when the usability of the deliverable of the task is insufficient for other tasks that depend on the defected task (Malone, Crowston, & Herman, 2003). Even if other tasks' content is not affected, the scheduled starting date of the subsequent tasks needs to be shifted backwards, because the preceding task takes longer than scheduled.

**Tackling ripple effects:** Critical Chain theory alleviates such chain reactions through placing buffers between tasks (Leach, 2005a). One severe chain reaction happens on the busiest resource. When a busy resource's work gets delayed, usually multiple dependent tasks are affected. The delays happening on busiest task-performers affect most relevant tasks in the workflow process. By placing a buffer before and after the tasks performed by busy resources (Leach, 2005a). Critical Chain approach reduces the chance of ripple effects from happening.

Scope change, multi-tasking and design changes in dependent tasks are all example for how external factors affect the duration of a task. The term "external" indicates the task performer has little influence in removing those factors. However, (Buehler et al., 1994) claims that task performers often exaggerate the impact of external factors' on causing unfulfilled promises on tasks' completion date. Perhaps such external factors impacts are exaggerated by task performers.



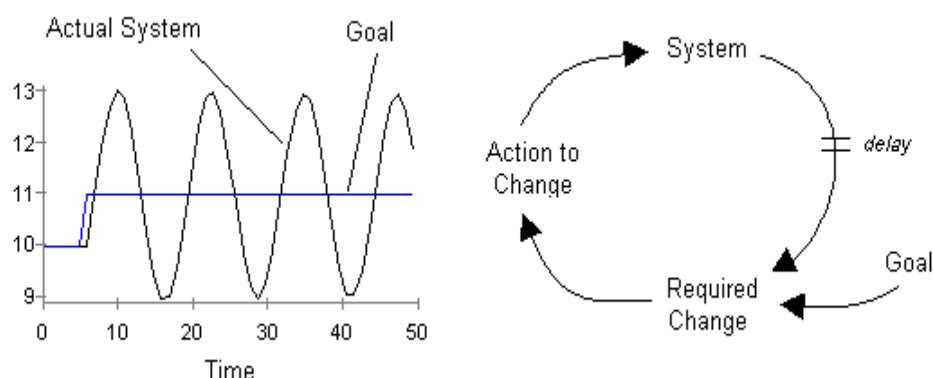
## The deadlines setting affect the actual completion date

**A safe deadline promotes perfectionism.** Another reason for a task takes longer than expected is that “work expands so as to fill the time available for its completion”(Wikipedia, n.d.). A task is kept being worked on until the due date arrives. Such a phenomenon is most apparent in mental tasks which possess no objective criterion as to when to stop. And such a syndrome will do more harm when the task performer has multiple tasks to do, because the task performer will not start working on task X until X becomes the most urgent one.

The decisions set in a plan, such as the due date set for a task, are one type of goal. When a task performer endeavor to finish a task on scheduled due date, he is pursuing a goal. We often observe that the actual level the goal seeker achieve, seldom exactly equal to the target level. The actual level usually fluctuates around the target level. For instance, when performing a task, the scheduled due date in July 1<sup>st</sup> usually leads to the actual completion date to fluctuate around the due date. Such variability is common even for a mechanical task which possesses little uncertainty. Such an error range could be larger in mental tasks which involve more unforeseeable factors. In our case, some interviewee observed that a task’s actual completion date is usually shortly behind the due date, even when the due date is believed to be conservative.

As a psychological study, (Locke, 1996) points out the goal’s difficulty affects motivation. In system dynamic field, why actual performance fluctuates around the target level is explained by the fluctuation in motivation level. The actual result of a goal-pursuit process usually fluctuate around the target level(Michael J. Radzicki & Taylor, 1997), not equal to the target all the time. If such fluctuations exist, the chance at which a due date is missed is still considerably high.

Therefore, as a measure to cope with the fluctuation of a task’s actual completion date, to guarantee that a task finish before the due date, the planners had better set a target completion date for the task. And the target completion date should be earlier than the latest completion date that is acceptable for the boss. For instance, if the latest submission date is on day 5, setting a target completion date earlier than day 5 could be safer in guaranteeing on-schedule completion.



**Figure 59 the actual performance level fluctuates around the target level**

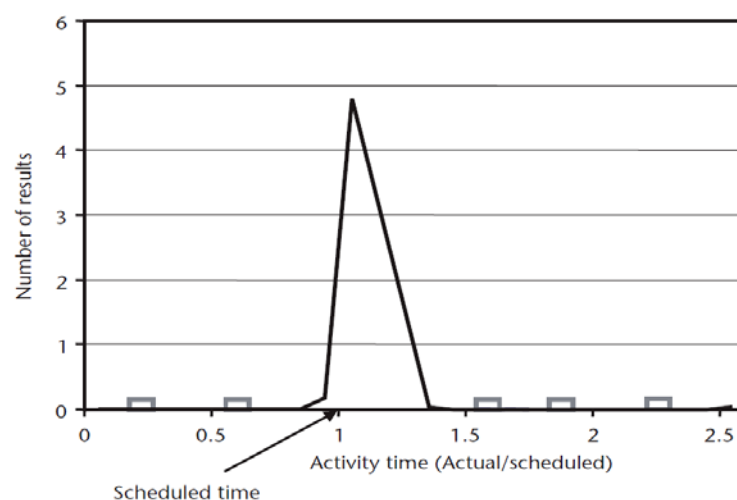
**Source:**(Michael J. Radzicki & Taylor, 1997)

Attributing discrepancies to the goal-pursuit process also applies to cost control for projects. In our case, we discovered

that a client for a project or for a portfolio tends to use up the entire budget that is authorized. However, the budget should be the upper limit for actual spending, but in reality the budget becomes the goal for spending. As a resource-user attempts to use up the entire budget, the actual spending will fluctuates around the budget. When the budget becomes the de-facto average amount of spending, the risk for budget overrun is still considerable.

Another explanation which also falls in the goal-pursuit category is procrastination. Procrastination is also called “student syndrome” since students typically suffer from similar behavior when preparing for exams or assignments. Procrastination means that a task-performer postpones the work until the deadline is approaching. Such postponing gets more apparent when the task-performer faces multi-task at the same time. Difficult tasks are prone to be postponed until they become urgent.

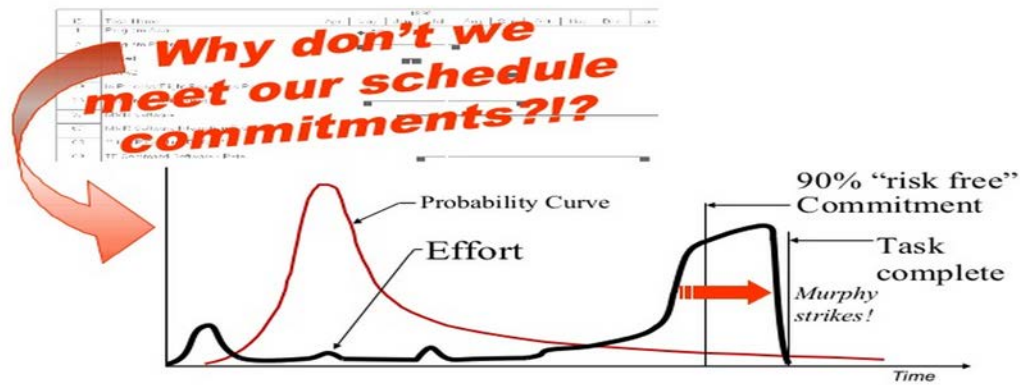
Both academic literature and practitioners mention that, task managers who are responsible for estimating the duration of a task typically anticipate potential risks for delay in tasks. To play safe, he/she would take a conservative estimate and set it as the due date for the task. Many task managers do that. However, the actual completion date often turns out to be late than the conservative due dates. The actual chance for tasks to be delayed turns out to be much higher than the original estimated chance of delay.



**Figure 60 the actual completion date vs. the scheduled due date**

**Source:**(Leach, 2005a)

During estimation of how long a task will take, many task-managers usually reserve some buffer in order to enhance the chance that the tasks could be finished before scheduled due date. Therefore, there is a reasonable chance that the tasks be completed before their due date. However, according to a small survey carried out by (Leach, 2005a), only a very small proportion of tasks are finished before due dates. The result is shown in Figure 60. Similarly, (Oxnam, 2005) used Figure 61 to illustrate why delay happens due to procrastination.



**Figure 61 the expected task duration vs. the actual progress pace**

**Source:** (Oxnam, 2005)

Figure 61 disclosed a big fallacy embedded in schedulers' assumption, that is, tasks will start very early and proceed at a speed which is comparable between an urgent deadline scenario and a safe deadline scenario. On the contrary, task performers typically adjust the starting time of each task according to its deadline, and adjust speed of progress with the remaining time available. Therefore, the way that deadline setting affects the behavior of task performers, carries certain traits of Game Theory. In Game Theory each player adjusts his/her behavior in reaction to the changes in others' strategy (Osborne, 2000). Such dynamic interactions between schedulers' deadline setting and task-performers' reactions aggravate the uncertainty/challenge in setting deadlines.

#### **Evidence from our case company**

A scheduler mentioned that postponing a task's deadline lead to the backward shift in the task's actual completion date. Therefore, the deadline setting probably affects the actual completion date.

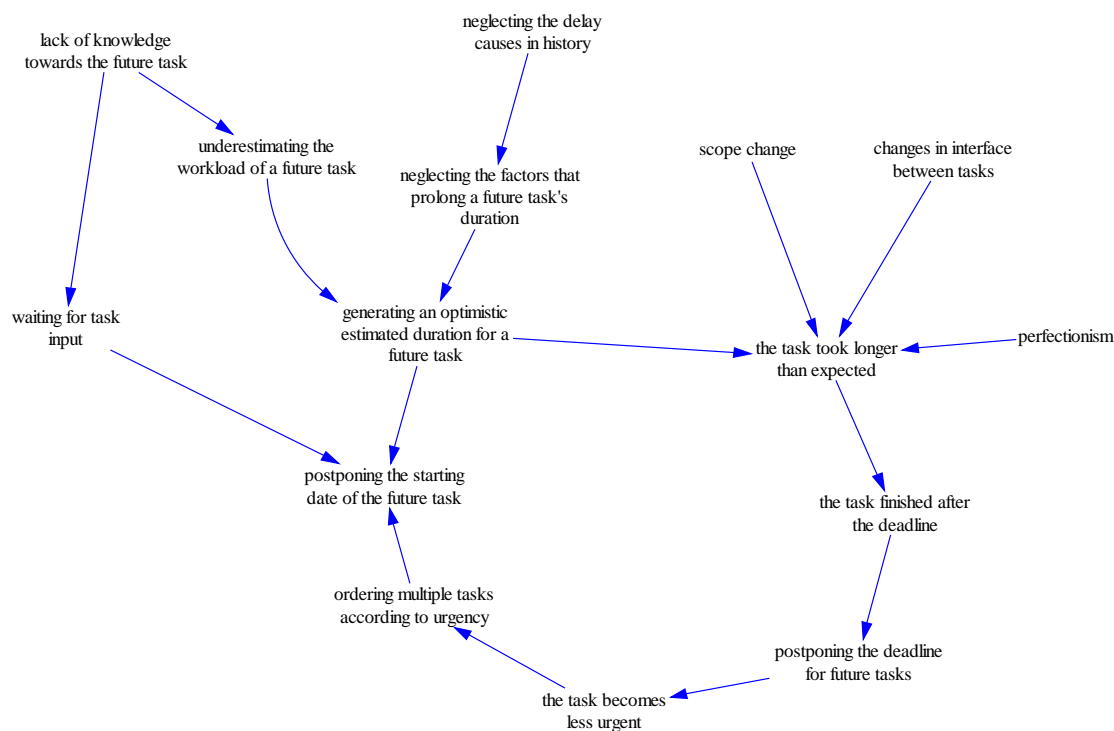
Some task managers and engineers mentioned that scope changes, design changes, or task rework often arise, prolonging the task duration. And the interface between tasks is modified often, and lead to the modification of the multiple relevant tasks. Usually a task often needs to wait for the modification of another task to be finished before its rework can start. Sometimes, the modification of interface takes several rounds and different tasks are coordinated iteratively. In each round, different modules are modified individually. And then the interface is negotiated to make the design seamless.

Some engineers mentioned that the input about tasks is not clear. Such inputs include the specification or technical parameters of the equipment used, the current configuration of the facility when the task is to modify some existing facility. Or sometimes, the engineers feel that they need more time to figure out the solution. Therefore, the engineers process the tasks which seem easier and clearer first, while postponing the ambiguous or challenging tasks. Besides, it is not so clear who is responsible to provide the task inputs or when is the deadline for input provision, therefore, the ambiguous tasks are postponed without progress or input injection.

Some task managers claim that some tasks finish before their scheduled deadline. However, such opportunities to take advantage of the early completions are lost when the next task will not start immediately. And since the engineers are held

accountable for the quality of the deliverables, early completions will not be rewarded. Such a rigid timing/scheduling approach has room to be improved in efficiency aspect. And a remote deadline unintentionally promotes the tendency of postponing or procrastination since the task performers have other tasks to do.

As a summary, we use Figure 62 to show the causal relationship between the issues in task delay.



**Figure 62 how task delays repeat**

### Measuring the proportion of each delay reason

In the case company, some delayed tasks in historical projects are recorded. And we group the delay reasons and calculated the percentage of each delay reason. Only the delayed tasks locating on critical paths are registered roughly. By “roughly” we mean the recorded reasons for a task are usually short and ambiguous. The researcher tried to recover a clearer and authentic description why the tasks could not finished on schedule by asking some managers to recall and infer what happened from the records.

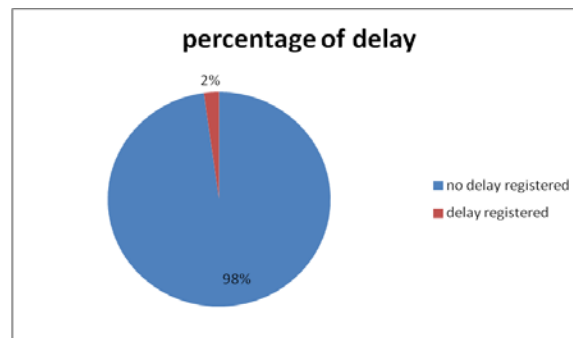
First, one reason for plan revision is the delays in delivering the result of project tasks. When delays appear, the project schedule to which the delays correspond, usually need to be revised.

The first step in measuring the incidence of delays, is that the delays are categorized by the reason that caused the delay. The following pie chart shows the relative frequency in which each type of delay happens.

**Table 3 percentage of delayed tasks**

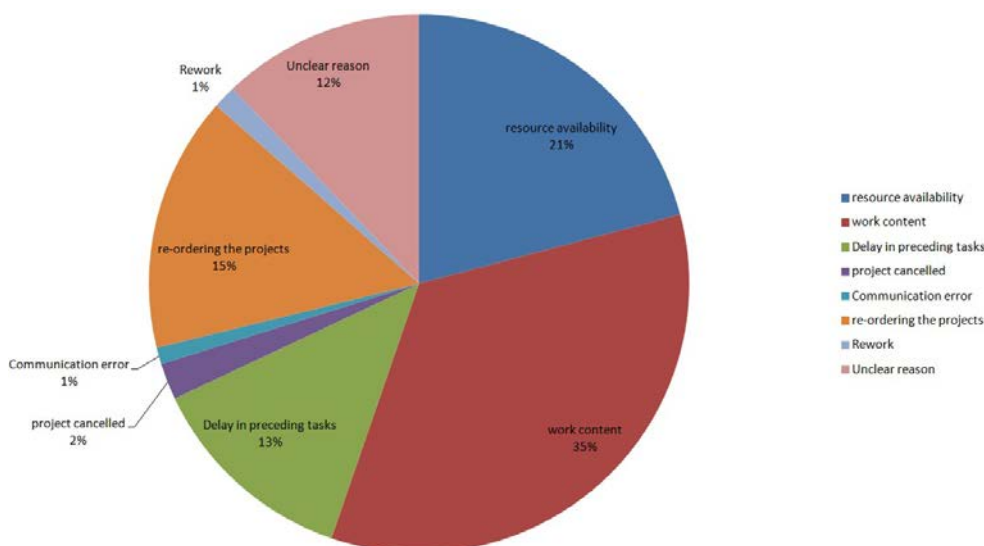
Task group	Count
no delay registered	17552
delay registered	394

At first sight, the percentage of delayed tasks that accounting for all tasks is not significant. However, it is worth noting that, not all delayed tasks were registered. In practice, only the significant delays in tasks which happen to fall in the critical path of their owner projects are recorded. Another reason for highlighting the big impact of delays is that, the traditional critical path control approach is so rigid (which will be explained in more detail later), any delayed task along the critical path would lead to the delay of its owner project. Since the registered tasks are not grouped by their projects, the percentage of delayed projects would far higher than the percentage of delayed tasks. The third reason for the mismatch in perception how high the delayed project proportion is, people remember delayed projects more clearly than on-time projects.



**Figure 63 the proportion of delayed tasks on critical path**

As can be seen from Figure 64, “Human resource inadequacy” accounts for the biggest proportion of the delays. When the tasks were scheduled, some engineers were assigned to those tasks. Therefore, insufficiency in human resources can be interpreted as the fact that the engineers that were reserved for those tasks are borrowed onto other tasks. Similarly, insertion of other tasks is a reason that reduces the availability of the human resources for the scheduled tasks. The second biggest reason is the ambiguity in the content of the tasks. For instance, “waiting for input” falls in this category. Unclear scope is similar to waiting for input. Another synonym is unclear input.



**Figure 64 the categories for delay reasons**

#### 4.5. Using system thinking to understand the relations between symptoms

(Huang & Anderson, 2011) claimed that, planning for complex technical systems is a wicked problem, and suggested using system thinking to understand the problems of technical system design. The meaning of system thinking is explained briefly in next paragraph.

The usual way of thinking in solving a problem is linear - from problem-as-event to solution-as-fix (Ulrich & Reynolds, 2010). Such a way of thinking is displayed in Figure 65. However, it is hard to use a linear thinking style to solve complex problems like project portfolio control. There have been countless efforts to improve project performance, but the achievements are still far from satisfactory. Therefore, it is probable that such a simplistic way of thinking is not appropriate for project control.

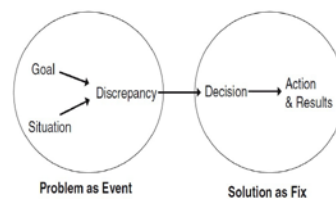


Figure 65 event-oriented world view

Source: (Ulrich & Reynolds, 2010)

Some scholars recommends another way of thinking to solve complex problems. In the proposed new way of thinking, the “problems and solutions are viewed as intertwined” (Ulrich & Reynolds, 2010). And “the typical thinking style here is circular - starting from a problem, moving to a solution and then back to the problem” (Ulrich & Reynolds, 2010). A diagram depicting the characteristic of such a circular way of thinking is displayed in Figure 66. Such a way of thinking is often more effective for solving complex problems.

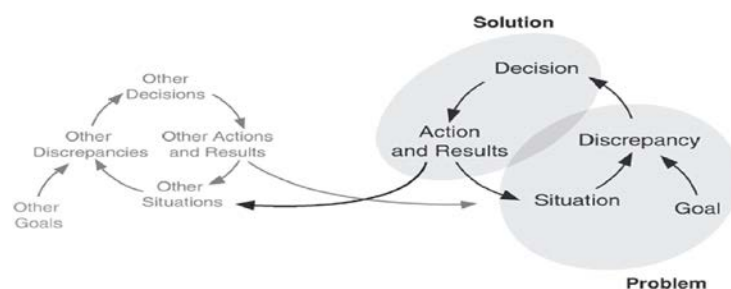


Figure 66 A feedback perspective

Source: (Ulrich & Reynolds, 2010)

#### System thinking applied in project management

In one system thinking approach—the system dynamic field, there have been various attempts to understand project control through the circular thinking style (Lyneisa & Ford, 2007). (Cooper & Lee, 2009) investigated the relationship between quality, resource usage, and speed of progress for project tasks. (Ford

& Sterman, 2003) investigated the reason why the remaining little work took much longer than expected. (Lyneisa & Ford, 2007) provided a review of various models for project behavior patterns—the interactions between quality, workload, haste/pressure, motivation, etc. Such models attempt to explain how the project performance behaves under certain conditions, such relationship network displays the logical relationship between a project plan’s elements and the factors that affect the actual performance of a project.

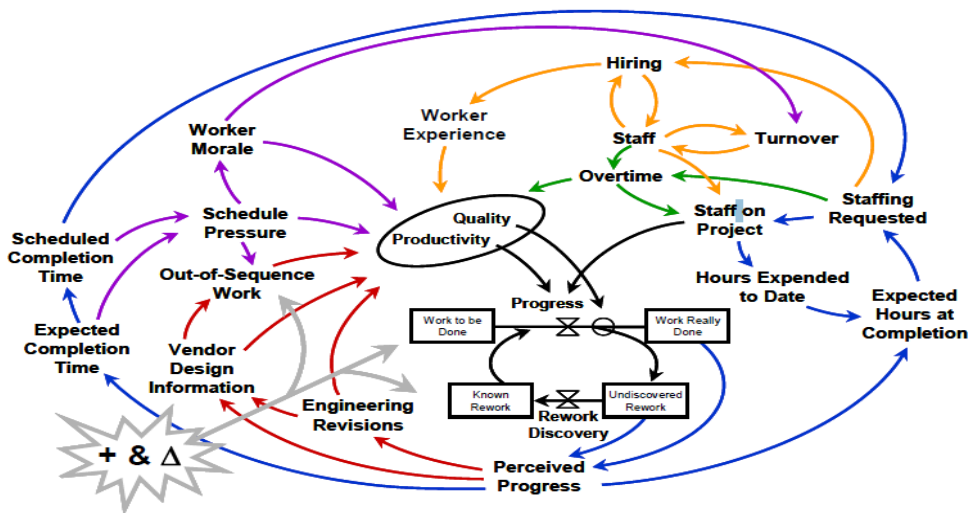


Figure 67 the influences between work speed, quality, morale, deadline, revisions

Source:(Cooper & Lee, 2009)

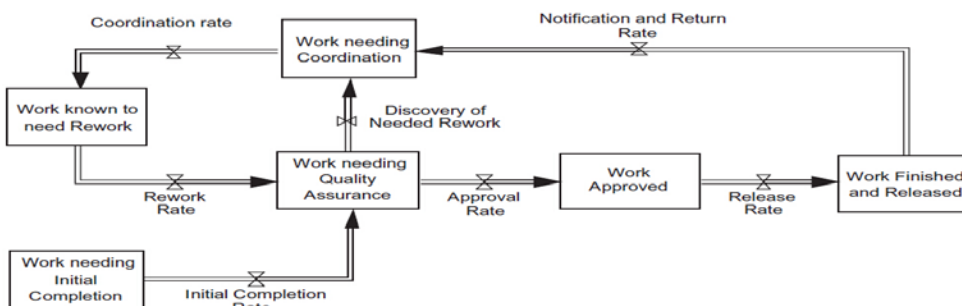


Figure 68 Work flows within a single development phase

Source: (Ford & Sterman, 2003)

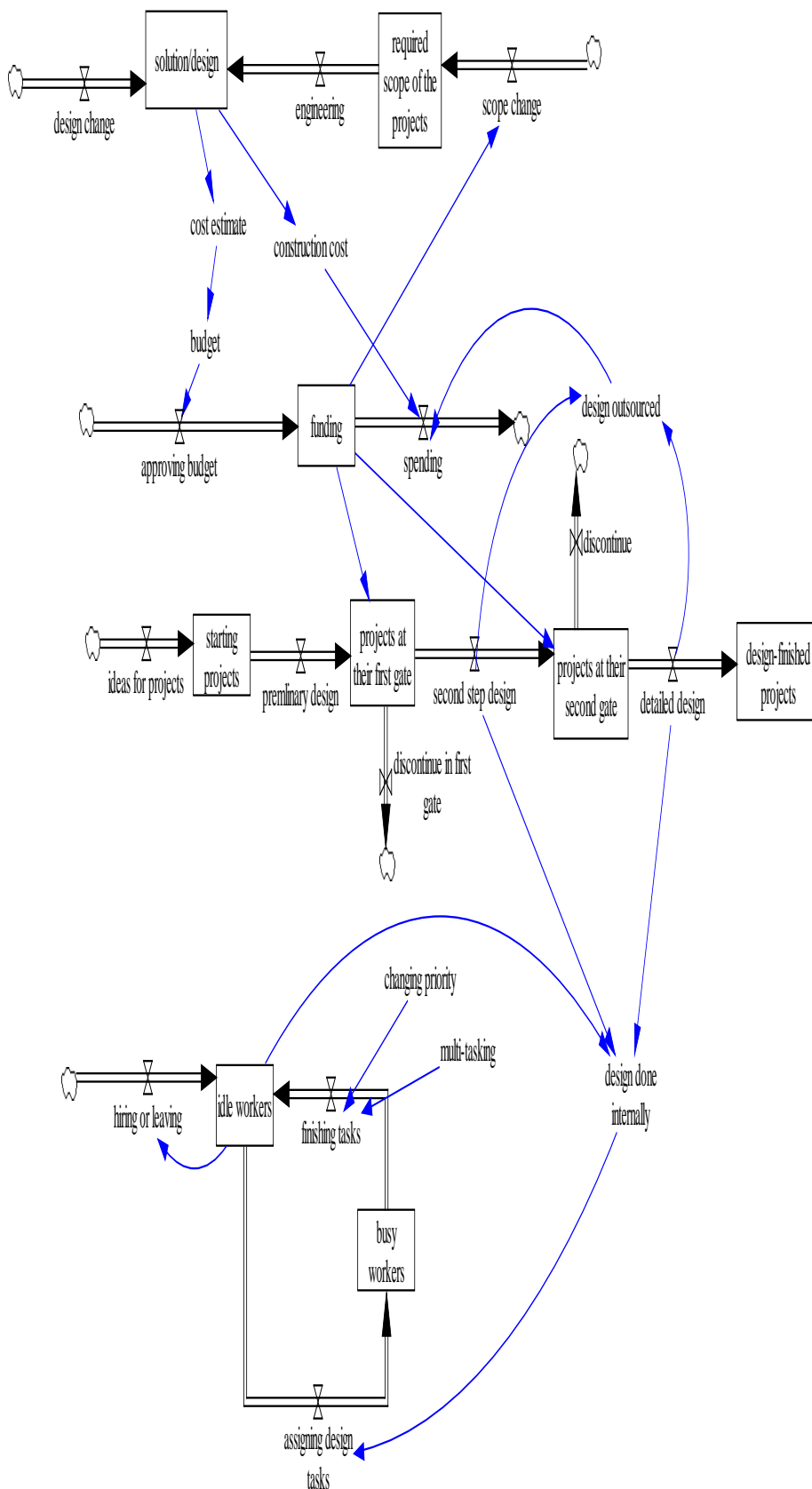
Another reason to adopt such system thinking is some comments from experienced planners in our case. Some causal loops emerge when the interview data is analyzed to link the concepts together. For instance, the estimated duration for a future task affects the deadline set for the task, the deadline set for the task affect the actual completion date of the task, the actual duration or completion date of the task affect the estimated duration for future tasks.

The third reason for adopting system thinking is that one managing approach/theory for managing projects also originates from system thinking(Leach, 2005a). The approach is called Critical Chain project management approach.

Critical Chain theory is proved as effective in reducing task delays in many companies(Leach, 2005a)(Palmer, 2013a).

**Why Dow Company also needs a system approach:** Under the project portfolio management mechanism in the case company, the decisions or factors in a portfolio schedule forms a system. The system consists of interactions between the decisions. As shown in Figure 69, the funding level increases with the inflow of approved budget, and lowers down as expenditure on the construction costs and outsourced design/engineering work. The funding level affects the project client's decision on whether to add or reduce the amount of projects, or whether to expand or shrink the scope of existing projects. Some projects are not approved when they are evaluated in Gates based on their cost figures, and thus they get no budget. Each project's cost is estimated based on its design. As the amount of projects and project scope change, the technical design has to be adjusted and the workload also changes. The engineering department possesses a certain amount of internal resources. When the workload is too heavy, the engineering department needs to negotiate with the client on whether to postpone some work or outsource it. The outsourcing decision need to be agreed by the client, who actually pays for outsourced work. If some work is outsourced, some funding is spent on it. Some work is assigned to internal engineers, making them occupied. When tasks finish, engineers' status returns to be idle.





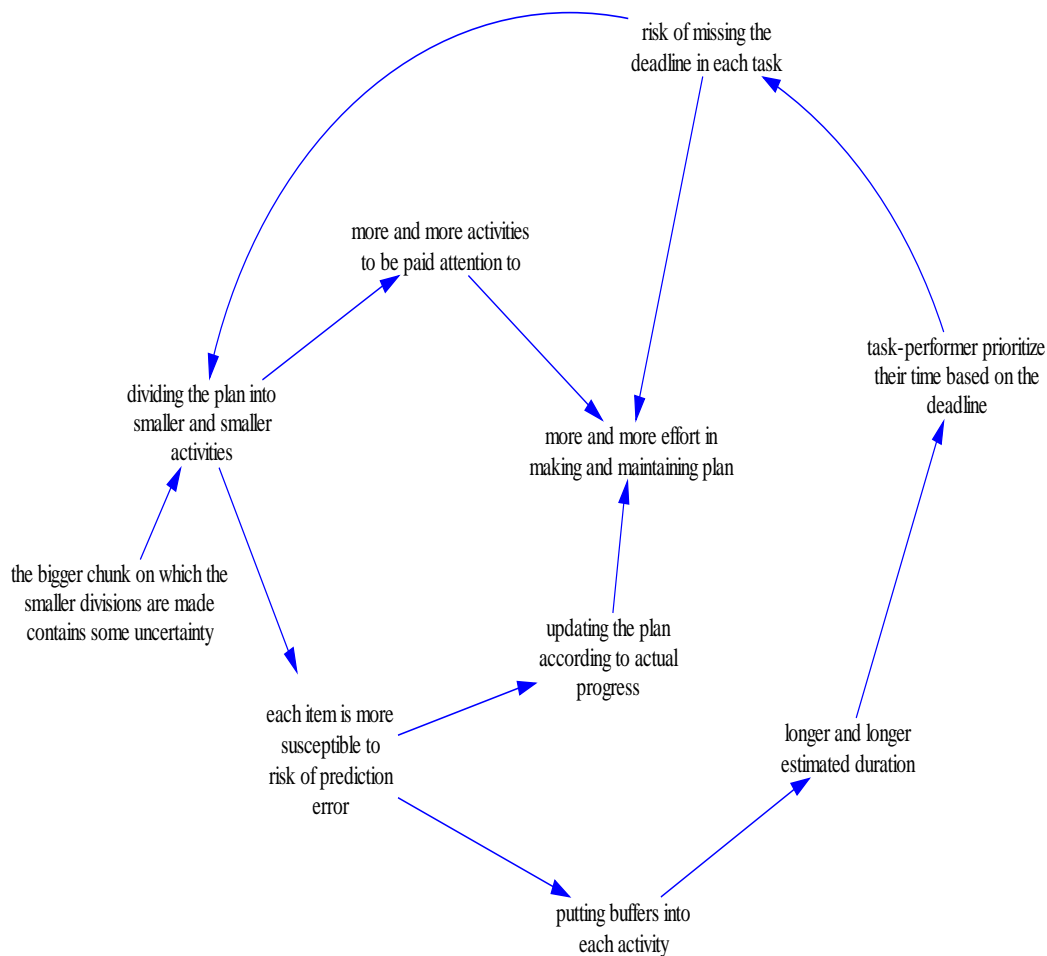
**Figure 69** how the decisions evolve when impacted by other factors

### 4.5.1. Explaining symptom 1

To avoid task delays, the planners usually break down the work into smaller and smaller pieces. Dividing tasks into smaller pieces did not actually lead to a robust plan. On the contrary, since the amount of unit tasks grows, more items need attention, and more frequently discrepancies arise. Every time when a discrepancy appears, it needs to be rectified. Therefore, making a plan more detailed and taking care of every discrepancy, drives planners into a vicious cycle, as is shown in Figure 70.

One reason why mismatches appear more frequently when the planning time interval is set smaller, is that disturbances impact the schedule for a shorter period more greatly than they impact the longer period schedule. For example, when an emergent task arrive unexpectedly at an engineer’s desk and such a task takes a day to finish, if the planning interval is at the monthly level, such a disturbance would not cause much deviation in work progress as scheduled, but if the planning time interval is at the daily level, several days’ schedule need to be adjusted to absorb the emergent task’s impact.

Here we provide an evidence for the increased planning burden brought by more detailed planning. the schedules used to be made at monthly basis, later the interval is sliced into weekly basis, the task managers discover that they need to spend more time on eliminating the mismatches in work progress for 4 weeks instead of updating the progress for one month.

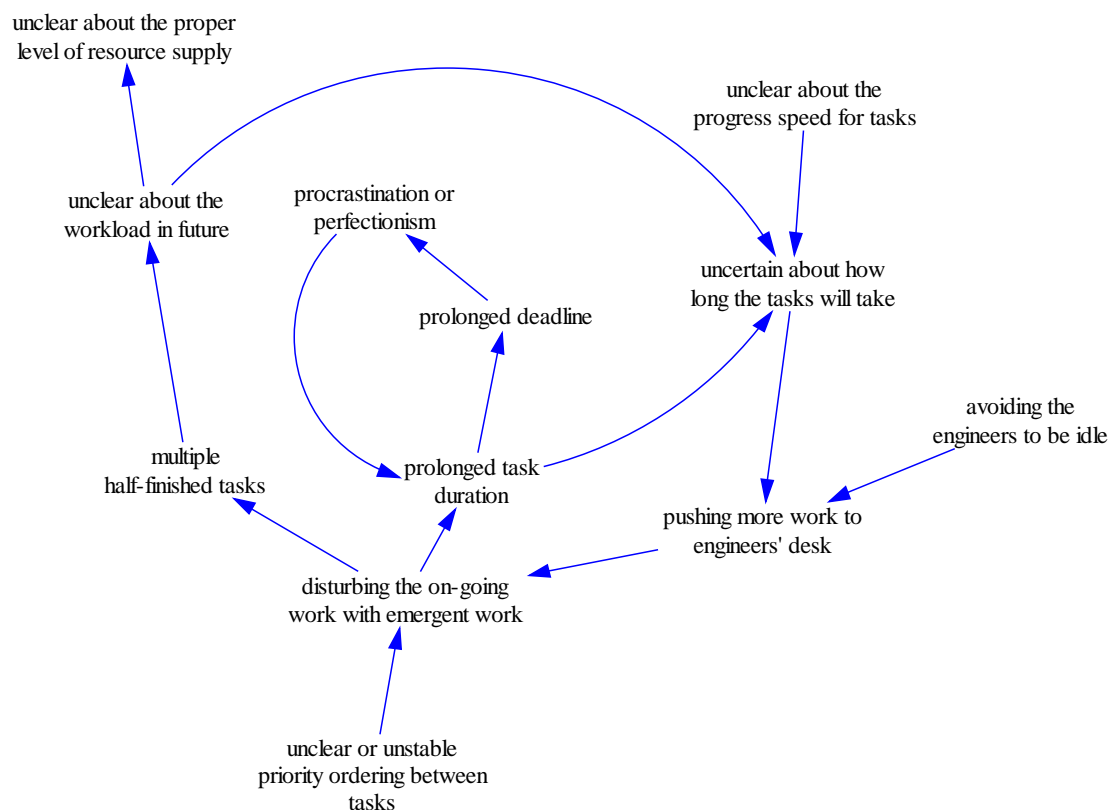


**Figure 70 the vicious cycle of over-detailed planning in an uncertain circumstance**

### 4.5.2. Explaining symptom 7

Another example that a solution to solve delay problems actually invokes other problems is that, when the schedulers encounter delays, they prolong the deadline setting when scheduling future tasks. However, schedulers soon discover that the extended deadline does not resolve delays. Delays still arise, and the actual duration increases with the deadline.

As shown in Figure 71, there are circular cause-effect relationships between task delays, multi-tasking, and extending deadlines. When task delays appear, the schedulers tend to set a safer deadline for future tasks. Tasks with later deadlines are less urgent compared with other tasks. Therefore, task performers tend to postpone the start of such non-urgent tasks, or slowing down the progress of such tasks to make the tasks of higher quality—perfectionism. Task performers are usually evaluated by quality of their work rather than the speed—early completion is not rewarded. The buffer placed in a task's allowed duration, which is intended to be used in contingencies, is not used on promoting the progress of such tasks. Therefore, the chance at which such buffered tasks may delay, is not lowered. When task delays remain, schedulers become more conservative by prolonging the allowed duration for future tasks even further. The average task duration increases. It is ambiguous how fast the task performers progress on tasks. To avoid task performers to be idle, managers pushing more work into task performers' desk. Multi-tasking lowers the efficiency of progress by creating multiple half-worked tasks. The half-finished tasks pile up. Projects' progress slows down.



**Figure 71 how task delays persist**

## ***4.6. Explaining the symptoms using Theory of Constraints (TOC)***

TOC takes a system view when observing a problem and interpreting it. System view pays attention to how the components that are interrelated affect each other rather than isolating a small part of a system and narrow down the attention. In TOC there are various tools for exposing the causes for a problem (W. H. Dettmer, 1997).

### **4.6.1. Using Current Reality Tree (CRT) diagram to find the causes**

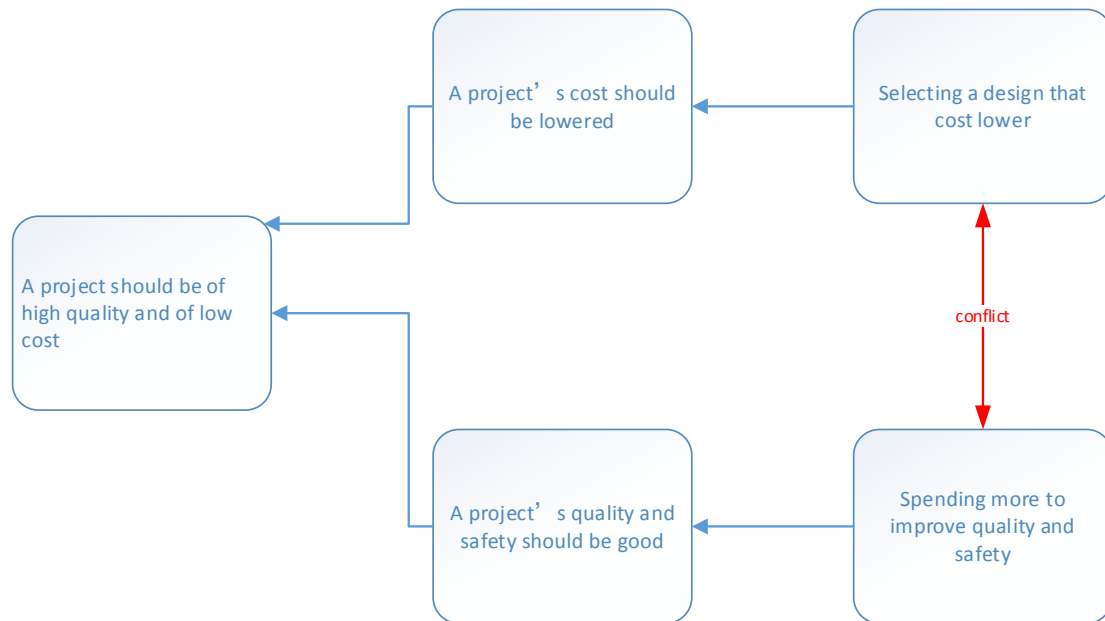
CRT is a tool used to seek the root causes for problems. The basic reasoning in CRT-led analysis is to find the causal links or influences between different issues and finally many issues' causes converge to a smaller amount of causes. Figure 72 illustrates how CRT is used to analyze the causes for the instability of detailed schedules.



#### **4.6.2. Using Conflict Resolution Diagram (CRD) to identify the conflicts**

Another tool in TOC for analyzing problems is called Conflict Resolution Diagram (CRD) or Evaporating Cloud (W. H. Dettmer, 1997). CRD is used to surface some conflicts which may be hidden (W. H. Dettmer, 1997). According to the theory of constraints, the root causes which lead to the most problems, are usually caused by perpetuating conflicts. Another reason why CRD is adopted, is that there are several signs in the case company that indicates some conflicts. As indicated from interview records Line 370 to Line 373, the issues in portfolio planning perpetuate for a long term (more than 20 years). Such a perpetuating syndrome is probably not caused by some local issues alone. There are many smart and hardworking employees in Dow, but the problem still persists. (W. H. Dettmer, 1997) point out such signs of a perpetuating problem often indicates some hidden conflicts. Therefore, CRD is used to check whether conflicts exist and what they are.

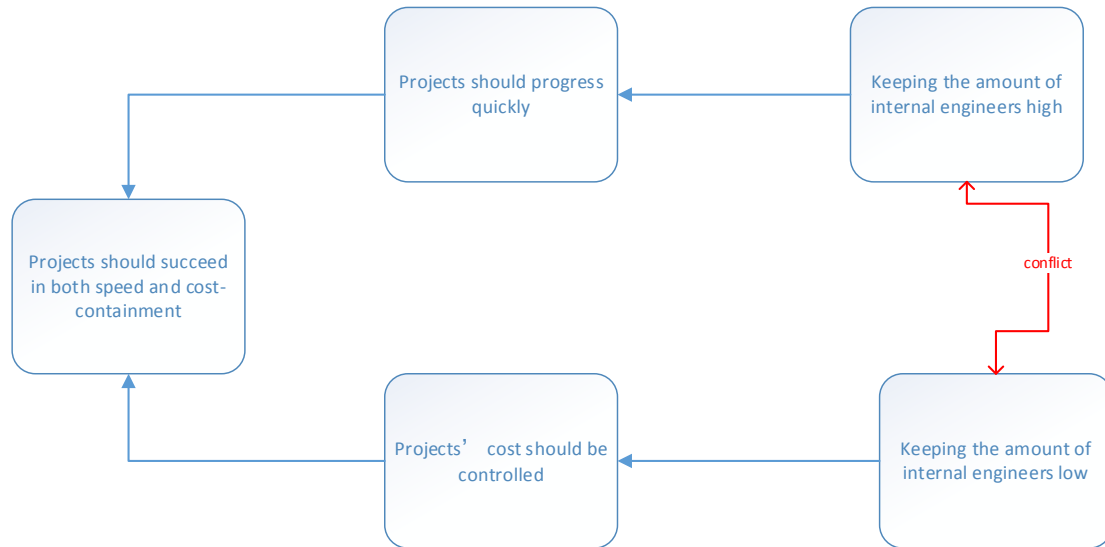
There are various conflicts in managing a group of projects. Some conflicts are more visible, such as the disputes/disagreement when discussing certain decisions. Figure 73 illustrates the first type of conflict in project management, how the disputes in selecting a technical design/solution from different options, or incrementally adjusting a design. For each project, the client side emphasizes more on cost containment through steering the design towards low cost and fast completion, while the engineering side concerns more about the safety and quality issues by take more care and preventive measures in design. Such disputes often lead to indecisions about which design to choose, as suggested in Interview Records Line number 61 to Line 67.



**Figure 73 a conflict in selecting or specifying project design**

The second type of conflicts exists in different projects competing for resources. For instance, during peak demand or rush periods for engineering resources, different projects are competing for resources. Such disputes lead to the indecision on which projects should be prioritized. An ambiguous priority ranking affects the timing of projects.

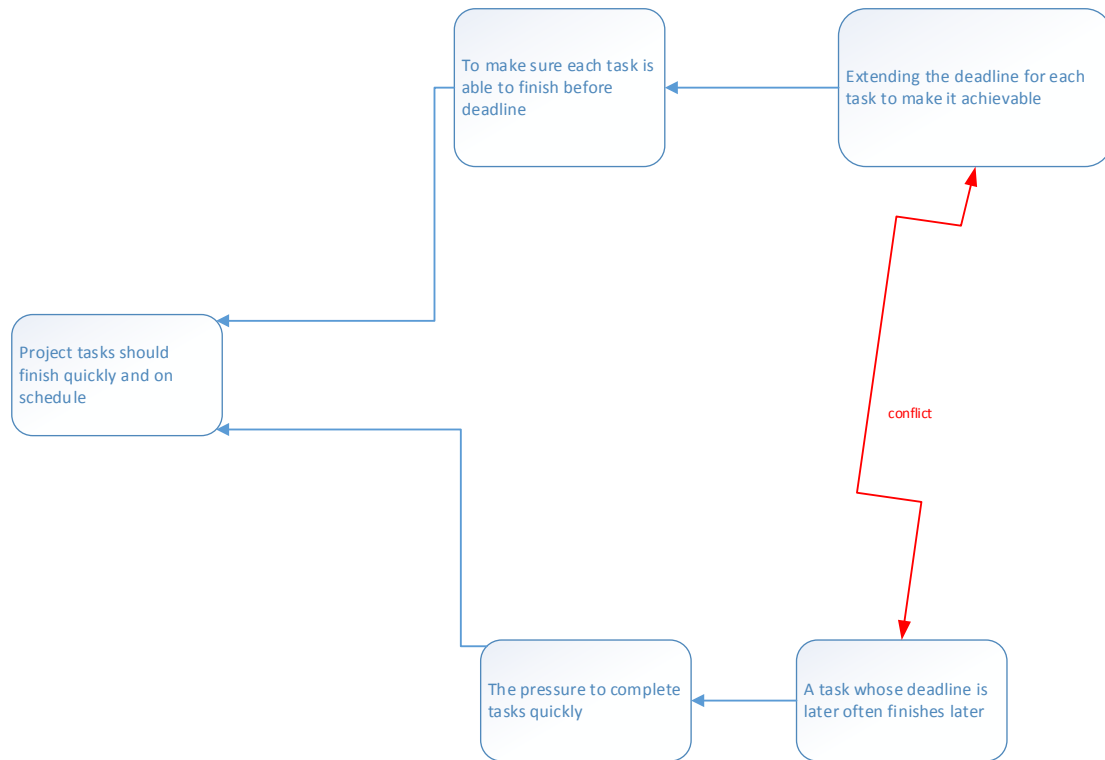
The scarcity in engineering resources also causes conflicts between the client and the engineering party. As indicated in Interview Records Line 266 to 268, there is no coordination between different clients over resource use. The manager who is in charge of all clients, simply want the engineering department to supply enough resources for all projects. However, the engineering department is held responsible to control the headcount and utilize the engineers fully. Such a conflict can be illustrated in Figure 74.



**Figure 74 the conflict in the supply of resources**

The third type of conflicts exists in how task delays persist. Figure 75 shows the considerations when setting deadline for a task. There is pressure to finish task quickly, but there is also pressure that when a task delays, the task performer is held accountable for his/her promises on deadline. The actual completion date for a task usually is influenced by the deadline set for the task. Therefore, the conflict about whether a task's deadline should be set earlier or later exists. The prerequisite "Extending the deadline for each task in order make it more achievable" explains one core problem—"schedulers react to delays with more conservative deadline setting"—which can be found in Figure 72.





**Figure 75 the conflicts in setting task deadline**

#### **4.7. Summary**

In the analysis of the problem, we first explained why some decisions tend to mismatch from reality through checking the assumptions underlying the decisions. We pointed out how the chance at which those assumption hold, affect the chance at which the decisions will be realized. Therefore, some decision which depends on some low chance preconditions heavily, is highly vulnerable. The fine grained schedules and conditional decisions help project control when their preconditions are met, but those decisions make the plan more delicate and cumbersome when facing changes.

Second, we discussed why a plan-updating process tends to be inefficient. The first reason is that, each project's information is fragmented and specialized. The information exchange is hindered by specialized functional structure of the organization and by specialized knowledge in each discipline and profession. The second reason is, each project need to strike a balance between competing goals. And different goals are promoted by different stakeholders. Disputes easily arise during discussions. The third major reason is the conflicts between speed and quality of decision making. Some hastily made decisions will cause more efforts to be corrected in later stages in projects. Therefore, project managers need to balance between efficiency and effectiveness.

Third, we investigate a common issue in project management—why tasks get delayed. Such delays are more significant and troublesome within a large and dynamic project portfolio. We trace back the delay causes to the lifecycle how a task's duration is estimated, deadline-set, and executed. We check every stage of the planning process: from estimation to task execution. We group the causes into two major types: the deadline is too optimistic, or the deadline setting of a task affects how the task gets prioritized. An optimistic deadline discloses the bias in estimation stage, while the deadline-priority relationship discloses the downsides of conservative deadline setting. We illustrates how the delay causes are intertwined, and how a conservative deadline setting actually prolong task duration, and other problems, using causal loops. Such causal loops explain why the task delays are tricky and why delays defy some simplistic solutions. Such explanations will serve as the basis for our measures to improve the current planning approach. The analysis exposes the spot where things easily go wrong, and the measures will intervene in the process to address the weak spots.

## 5. Improving the portfolio planning process

In this section the measures to fix the problems will be raised. The ways of managing projects comprise a system. A system is a set of interrelated elements (Ackoff, 1971). A portfolio management system consists of stakeholders, decisions, and the input from external environment. The decisions in a portfolio management system may either be a part of a portfolio schedule, or affect the decisions in the schedule.

Since a portfolio planning/managing approach is a system, the modified planning process comprises a new system, built upon modifications towards the current ways of planning—the old system. (Hevner et al., 2004) call the studies which seek creating solutions/system for problems as “design science”. The new planning approach to be proposed, is one type of design artifacts, as (Hevner et al., 2004) call it. The new planning approach belongs to the “method” category in (Hevner et al., 2004)’s categorization of design artifacts. (Hevner et al., 2004) grouped the solutions coming out of design science studies into four types of design artifacts. The “method” artifact, as (Hevner et al., 2004) defined, is:

“Methods define processes. They provide guidance on how to solve problems, that is, how to search the solution space. These can range from formal, mathematical algorithms that explicitly define the search process to informal, textual descriptions of "best practice" approaches, or some combination.”

Our solution stays in the method stage, which means that our solution has not been developed into the form of some concrete software or management systems.

### 5.1. *Limitations: the causes/symptoms that are not able to be resolved*

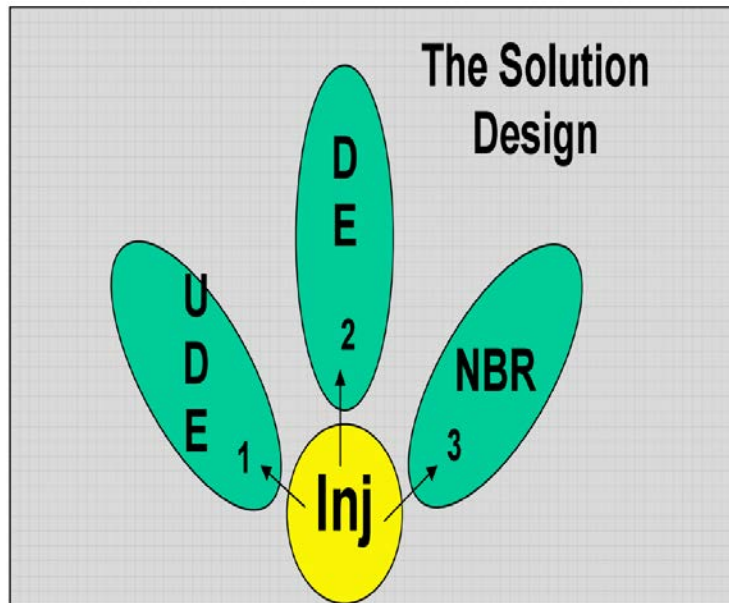
Within the symptoms identified, some problems can be tackled, while some problems are beyond the authority or sphere of influence of the engineering department. “Sphere of influence” is a term used in the Theory of Constraints (Goldratt, 1999), referring to a scope/boundary which depicts what issues are able to be influenced versus what cannot. The issues within the sphere of influence can be changed, while the issues outside the boundary of the sphere of influence have to be tolerated. Some limits originate from the authority of the engineering department, like the changes

in project selection. Some limits originate from the availability of certain input. For instance, at the beginning of each project, lack of design specification is inevitable, and thus the duration estimate and cost estimate is risky. In portfolio scheduling problem, there are limits, which will be detailed in the sub-sections below.

In the analysis of the current situation—Figure 72—the causes that limit the efficiency of project portfolio scheduling are listed. Within the causes, some causes cannot be influenced, whereas some are able to be tackled. The causes that can be tackled are highlighted with red font with red frame.

## ***5.2. Solution-designing approach***

**Basis of design:** The design of new approach is built upon the explanations why the existing ways of planning go wrong. In other words, we propose to intervene at some weak spots since we believe that such spots easily go wrong. Such weak spots are identified in Figure 7 at chapter 2. Our measures impact those weak spots through intervening in the process where the causes turn into troubles. A visual illustration of the solution design mechanism is shown in Figure 76. Each measure to be introduced is devised to tackle some symptoms and lead to some benefit. Each symptom corresponds to an UDE (Undesired Effect) in Figure 76. Each benefit corresponds to a DE (Desired Effect) in Figure 76. In Figure 76, NBR refers to negative branch, meaning the harmful effects brought by the measure. In Figure 76, “inj” refers to injection—the change to be introduced.



**Figure 76 the design of a measure to eliminate some symptoms**

Source: (Cohen, n.d.)

### **Iterative approach in design process**

We will propose a whole set of solutions for changing the whole system, but when implementing the new planning approach for project portfolios, we will adopt a continuous and iterative style. In such an iterative style, we incorporate small incremental changes to the existing planning process once a time, and observe the effects of our changes. We update our understanding of the project management system based on new observations. And such new knowledge will be referenced in revising our solution. Such an iterative pilot/test for adding changes and refining our changes, takes the same principles underlying continuous improvement in Lean and Six Sigma.

### **The reasons for choosing incremental improvement**

The reason why we choose such an incremental improvement approach is that, portfolio management is a system consisting of complex interactions. And thus a radical reform towards the whole system, or some one-shot measures adopted within certain parts of the system, may lead to unexpected effects. For instance, placing buffers in each single task did not solve task delays, but brings a bad effect—tasks' duration prolonged. The failure of such a simplistic solution, proved what Albert Einstein said “the significant problems we face cannot be solved at the same level of thinking we were at when we created them” (wikiQuote website, n.d.) and “today's problems come from yesterday's solutions” (Agyepong, Kodua, Adjei, & Adam, 2012).

Theory of Constraints (TOC) also provides a reason why suggestions need to be treated with

caution. TOC mentioned that each measure for changing the current reality may lead to harmful effect. Such harmful effect is usually caused by the combination of the changes introduced with some existing issue within the problem (W. H. Dettmer, 1997). In TOC, such harmful effects are called Negative Branches (NBR) (W. H. Dettmer, 1997). Some negative effect can hardly visible before a change is introduced. Therefore, before adopting a change, potential harms need to be evaluated, and harmful effects need to be observed through experimenting incremental changes. Such a process is illustrated by Figure 77.

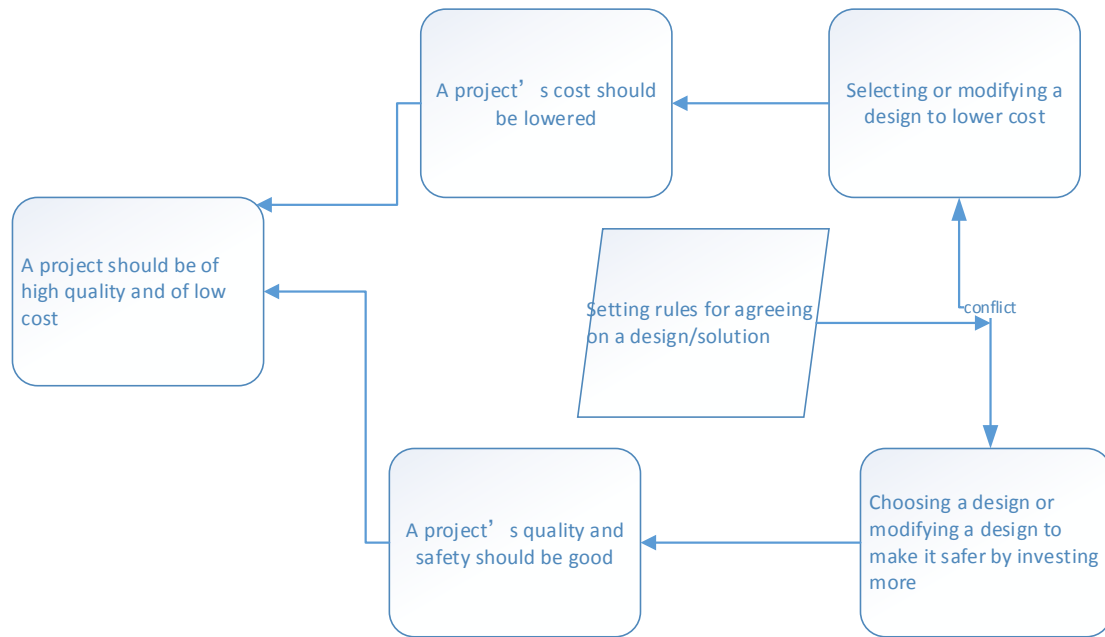


**Figure 77 each measure's possible harmful effects need to be considered and experimented**

Source: (Cohen, n.d.)

**Examples for negative effects brought by changes:** when some changes are introduced into an existing project management approach, some unexpected effects are likely to appear. For instance, when tasks are coordinated in a relay race style, task performers need not to be evaluated by whether they finish tasks before a certain date. Such a removal of accountability for the punctuality of task completion may lead to the risk that everyone finishes tasks later than due dates (Cox & John G. Schleier, 2010, p.84). For more negative branches, please refer to (Cox & John G. Schleier, 2010).

**Adding changes into Conflict Resolution Diagram (CRD) :** According to TOC, the measures to tackle a problem are devised through seeking ways to solve the conflicts within the problem (W. H. Dettmer, 1997). Figure 78 illustrates how a specific measure for improving scheduling efficiency is generated through tackling a conflict within the portfolio scheduling problem. Other measures are devised in a similar manner. And the measures will be presented in section 5.3.



**Figure 78 devising a measure to tackle a conflict in the problem**

### **5.3. Major changes**

The first direction of making portfolio planning more efficient, is to make plan-updating processes more efficient. The literature on business process re-engineering/design is referred to in the search for design methods. More specifically, the information exchange mechanism and the dispute resolution mechanism will be discussed.

The second direction to make portfolio planning more efficient is, how to cope with the mismatches. More specifically, task delays are chosen as the problem to be solved. In the chapter that analyze the reasons for task delays, two major groups of causes are identified. In the solution stage, measures will be taken to address those causes.

The third direction for improving the efficiency of making portfolio schedules, is to reduce the vulnerable decisions from each schedule. In the analysis chapter, the reasons why some decisions' chance to be executed is low, are pointed out. When a decision's chance of being realized is too low, including it in a schedule increases the incidence of discrepancies between the baseline plan and the actual status.

The changes are mapped in the workflow process for scheduling, as shown in Figure 79. The changes introduced in Figure 79 correspond to the weak spots mapped in the workflow process shown in Figure 7. The correspondence between the weak spots and the interventions is shown in

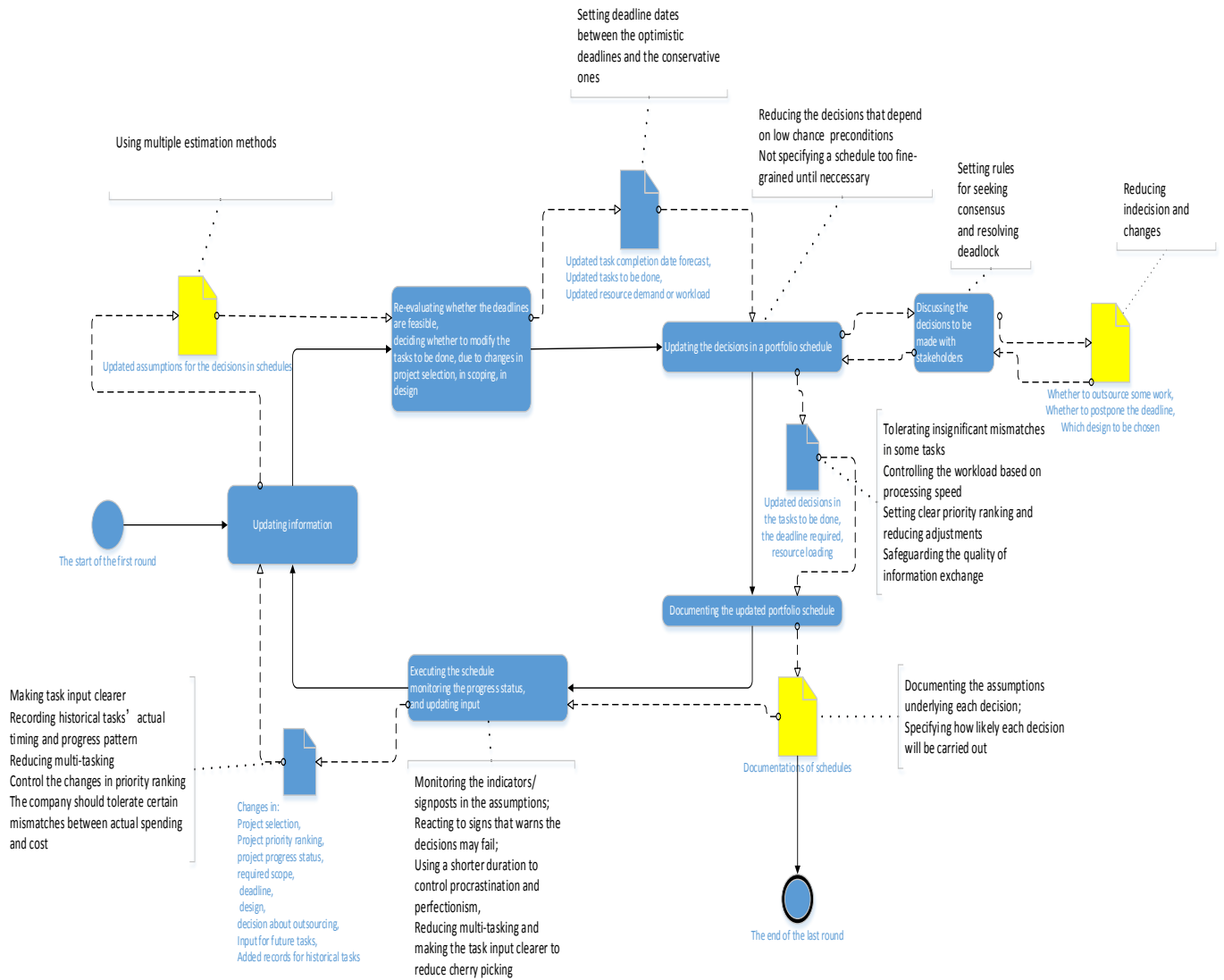
Table 4.

**Table 4 the correspondence between weak spots and interventions**

<b>Weak spot</b>	<b>Intervention</b>
In information collection stage, the specification of design/scope is unclear, the task input is missing.	Establishing a shared database to store the most up-to-date, consistent information about required project scope, specification for design and task.
Task performers undertake multiple tasks and the priority ranking varies	Control the extent of multi-tasking, and keep priority ranking clear and stable
When estimating the duration of a future task, historical tasks' actual duration records cannot be referenced, because the duration contains the disruption of multi-tasking, or some emergency issues	Adjusting the historical tasks duration to generate a normal task progress speed.
When estimating the duration of a future task, task managers tend to be too optimistic, discounting the disruption of changes	Using multiple methods to estimate a future task's duration, referencing to historical tasks' duration and their affecting factors, and also considering the traits of the future task
When setting deadline for a future task, the deadline is either too optimistic or too conservative	Setting a deadline in the probably range for the future task's completion date, but not making the deadline for each task to accommodate rare disruptions. Using buffers for a batch of tasks rather than assigning buffers within each task
When discussing project design or outsourcing strategy, the client sometimes disagrees with the engineering party	Setting rules to resolve deadlock in discussion about some normative issues or some uncertain issues.
When setting decisions about deadlines, the assumptions are not documented and monitored	Exposing the assumptions that underlie each decision and monitoring whether such assumptions hold



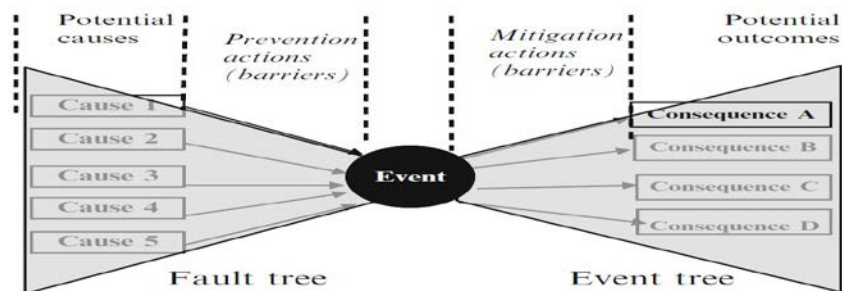
Task performers tend to order his/her tasks according to the deadline, and to the uncertainty in the content of the work	Setting an earlier deadline to prevent perfectionism and procrastination, and reducing the uncertainty in task input to reduce cherry-picking behavior
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**Figure 79 mapping the repairs to the portfolio scheduling process**

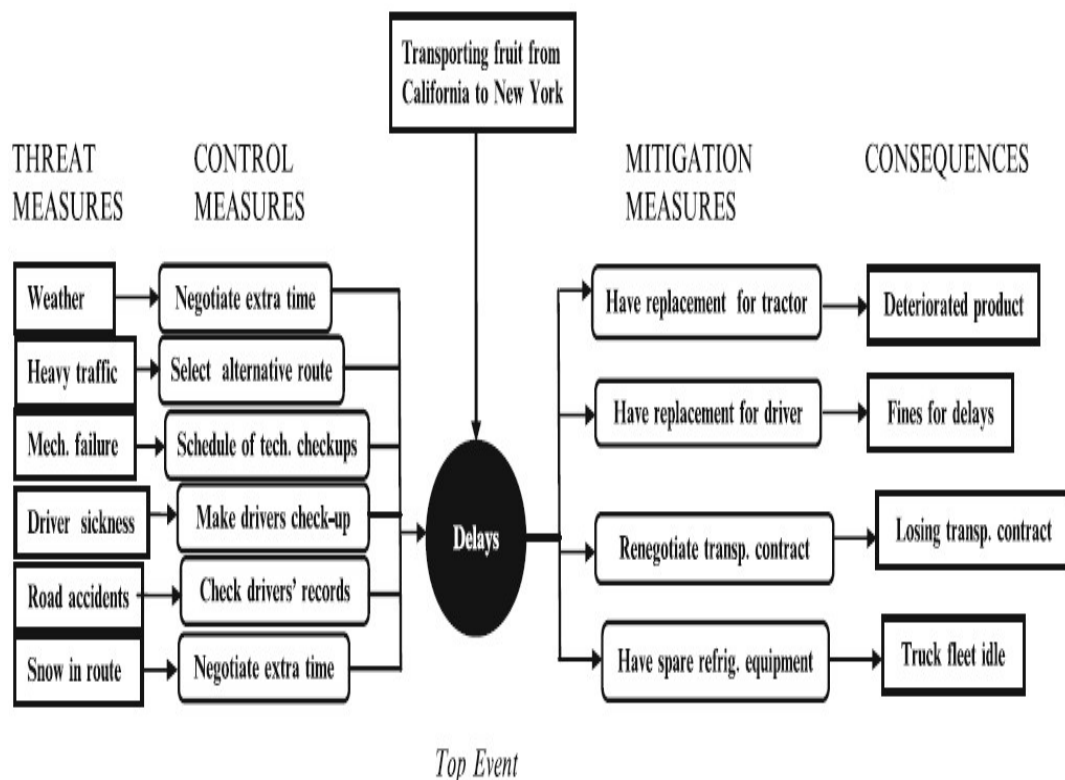
### 5.3.1. Coping with task delays

**The method to cope with discrepancies:** (Munier, 2014) traces back the causes for a discrepancy between a plan and the reality, and anticipates the consequences brought by the discrepancy. After pinpointing the stages through which a discrepancy evolve from potential to reality, (Munier, 2014) proposed different measures taken at different stages. A generic representation is shown in Figure 80. As an example for the usage of such an approach, (Munier, 2014) used Figure 81.



**Figure 80** a process for tracing the causes for a discrepancy

**Source:** (Munier, 2014)



**Figure 81** illustrating the use of the bowtie scheme

**Source:** (Munier, 2014)

As indicated in Figure 47 and Figure 61, task delays are attributed to two groups of reasons: the deadline is too optimistic or the deadline is too conservative. An overly optimistic deadline is not able to be fulfilled. An overly conservative deadline leads to procrastination, perfectionism, or cherry-picking behavior when prioritizing tasks. Therefore, the measures to tackle delays fall into two groups: the measures to tackle optimistic estimated durations which lead to aggressive deadlines, and the measures to avoid delays in a conservative deadline.

### **5.3.1.1. Tackling optimism bias by using multiple estimation methods**

The optimism in setting due date or estimating a feasible due date is named “planner’s fallacy” (Baumeister & Kathleen D. Vohs, 2007). (Flyvbjerg, 2007) suggested using reference class forecasting which is based on theories of planning and decision-making under uncertainty that won Princeton psychologist Daniel Kahneman the Nobel prize in economics in 2002. (Flyvbjerg, 2007) claimed that when predicting a future task’s duration, focusing attention only on the future task usually lead to optimism in terms of neglecting risks. Therefore, (Flyvbjerg, 2007) suggested to use a reference data set containing similar tasks which were carried out before. Adopting both estimation methods—predicting based on the future task’s traits, and based on referencing historical tasks—would probably generate more reliable estimate figures.

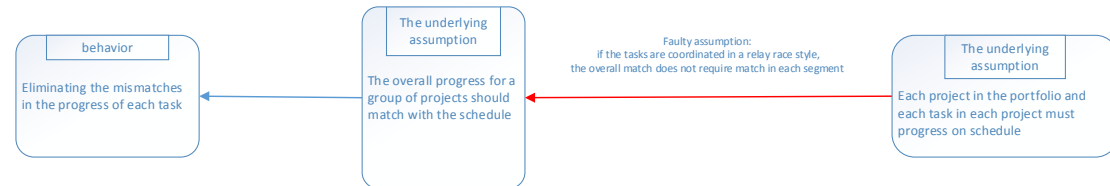
Such measures are intended to prevent the deadline setting falling into the unfeasibly optimistic zone. When the deadline for a task seems unrealistic, the high challenge level would hurt the motivation of task performers, as indicated by the Intrinsic Motivation theory. Intrinsic Motivation theory claimed that the challenge level for a task should be appropriate, because task performers need to have confidence in achieving the goal (Deci & Ryan, 2000). Otherwise, task performers would give up in attempts to accomplish the task.

### **5.3.1.2. Avoiding conservative deadlines using the Critical Chain style**

#### **The reason for adopting the Critical Chain approach in scheduling tasks**

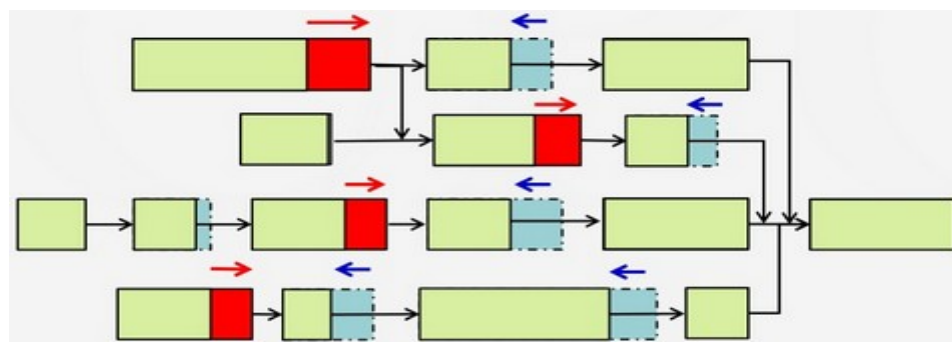
Schedulers typically update the progress of projects/tasks periodically to eliminate the discrepancies between the actual progress status and the progress specified in the corresponding baseline schedule. The underlying assumption for such behavior of plan-revision is that, every task or sub-task should progress at the scheduled pace in order to safeguard the match of progress

for the whole portfolio/project. However, such an assumption is too strict, and match in each task is not the necessary condition for match over the portfolio level. On the contrary, the former is a sufficient condition for the latter. Figure 82 shows the reason why schedulers tend to eliminate all mismatches.



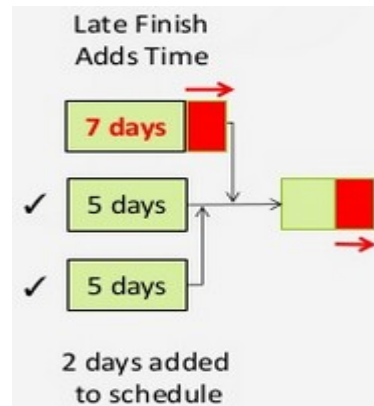
**Figure 82 the behavior for eliminating all mismatches and its underlying assumption**

To guarantee that each task is able to finish before the scheduled deadline, schedulers usually place buffer into the deadline setting. The grounds that coordinating the task progress in a relay race style helps increasing the efficiency of scheduling are that the task duration estimates already contain certain buffers, and thus the actual completion date for each task fluctuates equally around its deadline. The existence of buffer and early completion can be verified with the observation from our case companies. And based on Critical Chain theory, managing a queue of tasks through extracting the buffers from each task, pooling buffers together, and allocating buffer time according to the actual progress status of the tasks, enhance the chance that the task queue would finish on schedule. Some empirical studies also provide evidence that such a task coordination approach enhances efficiency of project progress and lowers the incidence of project delay.



**Figure 83 the critical chain approach cancels out the discrepancies in task duration**

Source: (Palmer, 2013b)



**Figure 84 if one task on critical path gets delayed, the whole project is prolonged**

**Source:**(Palmer, 2013a)

The critical path approach attempts to resolve the discrepancy for each task along the path by padding the estimated duration with buffers. Each task is scheduled with a fixed starting date and due date. If some tasks get delayed, the successor tasks' starting date must be revised. In this sense, critical path approach is vulnerable to delay in any task. And when some tasks on critical path is finished earlier than expected, the successor tasks will not start until the original starting date scheduled. Such rigidity leads to lost opportunities in taking advantage of early completion in tasks.



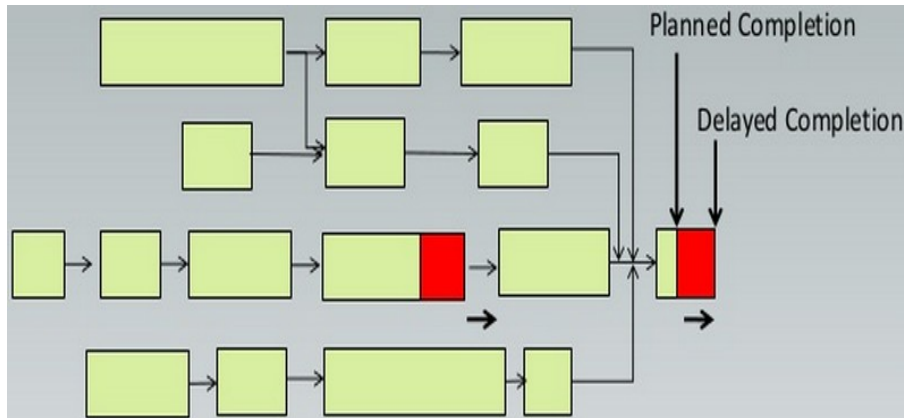
**Figure 85 the downside for putting buffer into a task**

**Source:**(Palmer, 2013a)

As is shown on the diagram above, the predicted lead time for each task is a random variable possessing a long tail, meaning the task could take infinitely long time in some scenarios. Therefore, no matter how long the time allowed for one task, there is still risk in delayed completion.

Even when each task is protected with a buffer large enough to make the remaining risk to be low, say, 10% possibility for the task to be delayed, the overall possibility for a critical path consisting of multiple tasks would still be considerably high. The risk for the whole critical path to be

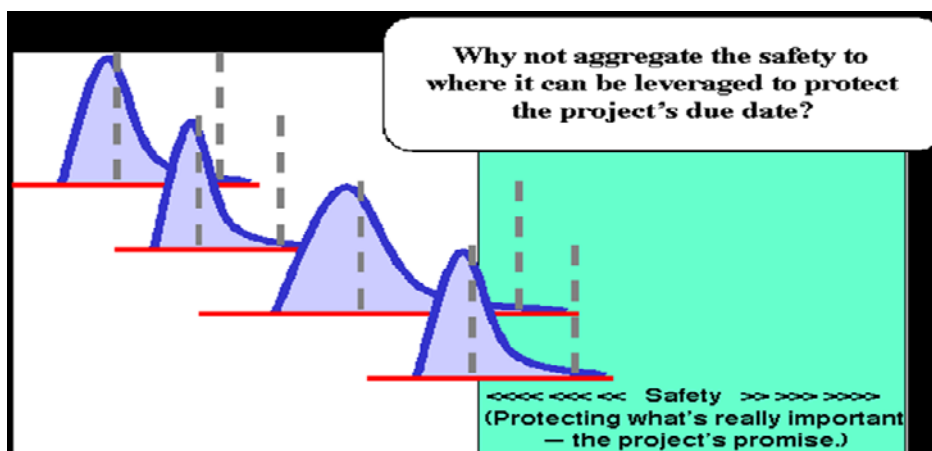
delayed is roughly equal to the sum of the risk of delay in each task on that path. When there are five tasks on a critical path, each task with a risk of 10% in the possibility for delay, the overall risk would be 50% percent.



**Figure 86** delay in one task leads to delay of the whole chain when the scheduling is rigid

**Source:**(Palmer, 2013a)

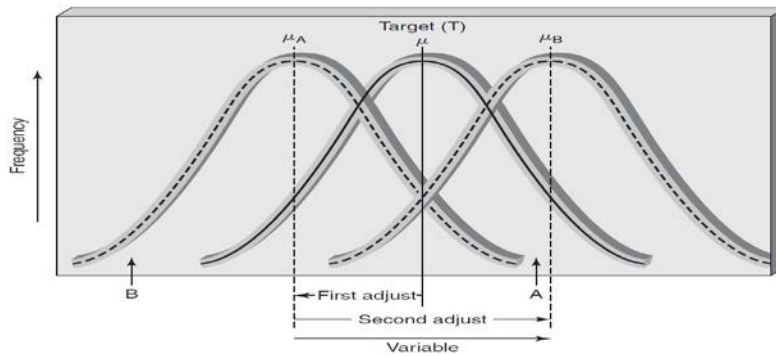
Critical chain approach concatenates multiple tasks into a chain, generating a new continuous variable that is the sum of all tasks. In statistical theory, when adding multiple variables into a new variable, the distribution becomes more symmetrical, reducing long tail in the right end.



**Figure 87** critical chain approach pools buffers for task duration together

**Source:** (Patrick, 1998)

**The statistical grounds for task duration control**

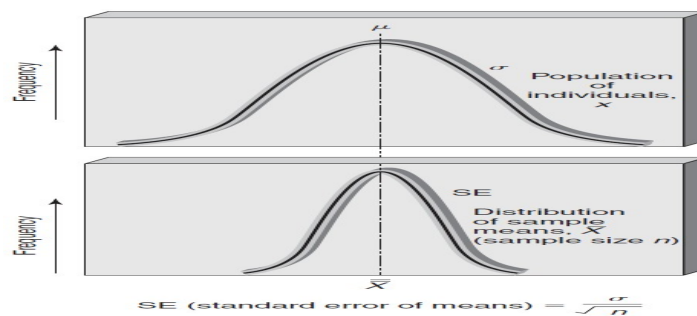


**Figure 88 Increase in process variability due to frequent adjustment**

**Source:** (Oakland, 2008)

Another problem for the attempts that try to match the predicted task duration with its actual value is that, excessive adjustments lead to shift of actual duration distribution. As (Oakland, 2008) pointed out:

“It is frequently observed that this is due to an excessive number of adjustments being made to the process based on individual tests or measurements. This behaviour, commonly known as tampering or hunting, causes an overall increase in variability of results”



**Figure 89 how the distribution of the mean narrows with more variables are added**

**Source:** (Oakland, 2008)

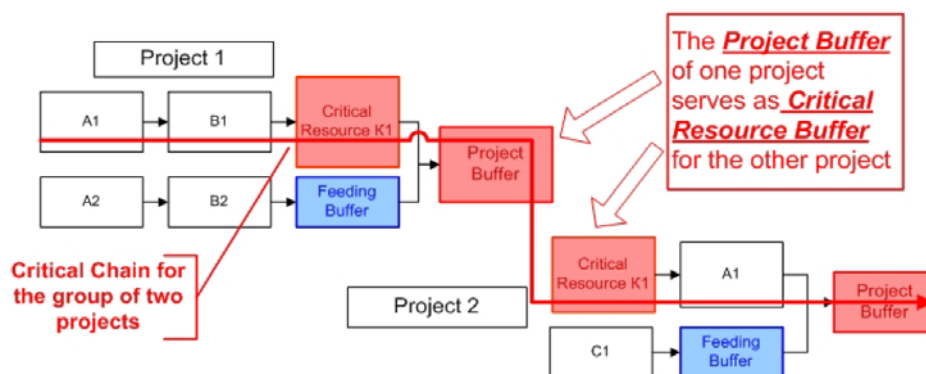
Another explanation why controlling a chain of tasks is more effective than controlling each single task is the “central limit theorem” in statistics: “even if the individual values are not normally distributed, the distribution of the means will tend to have a normal distribution, and the larger the sample size the greater will be this tendency”(Oakland, 2008). When pooling a chain of tasks together, the distribution of the whole task chain will be narrower than the sum of all constituent tasks(Leach, 2005a), and the long right tail in the distribution of each task’s duration will be alleviated.

### **How Critical Chain approach works**



In managing a group of projects, the first step of Critical Chain managing approach is to guarantee the resource availability. As mentioned before, the feasibility of a portfolio schedule depends on the assumption that resource is sufficient. Therefore, Critical Chain approach calculates how much work is achievable first. Controlling the injection of work into project task performers' desks to match the capacity of the project team in making progress, is how the Critical Chain approach guarantees the feasibility of schedules (Leach, 2005a).

When calculating the pace at which a project team can make progress in project work, spotting the busiest resources is the first sub-step of the first step of capacity calculation (Leach, 2005a). The grounds are that a team's speed in making progress is confined by the bottleneck resource: the resource who is busiest (Leach, 2005a). The bottleneck resource' desk is where the highest pile of work stacks up. Critical Chain approach protects the bottleneck resource or critical resource by placing buffers before and after the resource (Bhattacharya, n.d.), as is shown in Figure 90 .



**Figure 90** how Critical Chain approach schedules tasks in a multiple project context

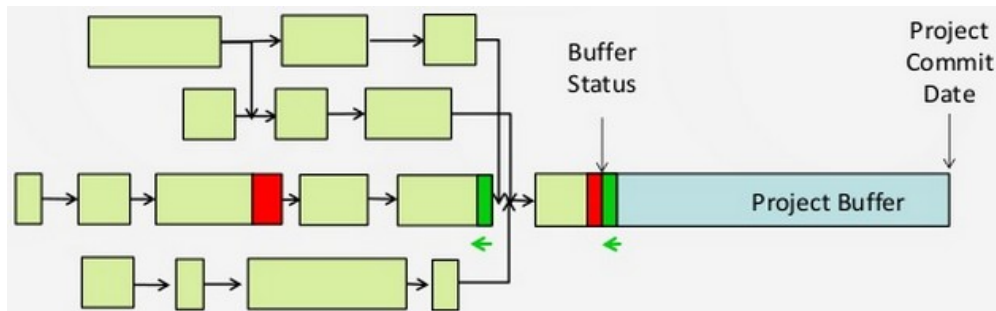
**Source:** (Bhattacharya, n.d.)

Second, Critical chain approach adopts a relay race style in scheduling tasks (Leach, 2005a): there are no fixed starting date or due date for every task in the schedule. It is worth noting that Critical Chain approach extract buffers out of each task. The buffers for all tasks are pooled together, extracted outside each task's duration estimate. Relay race style means that, as a task completes, its successor tasks start immediately.

### **Benefits of the Critical Chain approach**

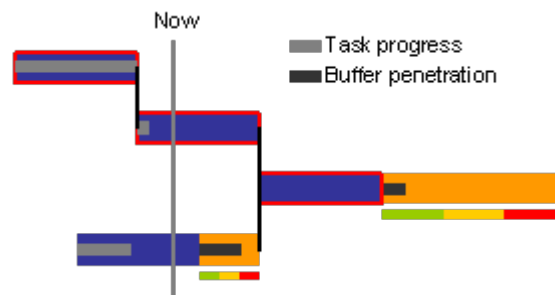
First, in critical chain approach, delay in a few tasks does not bother the concern of managers,

because a delay in one task could be offset by early completion in other tasks. Such a relay race style is more flexible and robust towards delay in one task. The schedule in critical chain controlling style is not as detailed as Critical Path approach, reducing the content of a plan and the efforts in plan-maintenance. And the plan revisions are reduced. Besides, as shown in Figure 92, not all delays in tasks bother the attention and efforts to revise a project plan.



**Figure 91 how the variability of the tasks' duration is managed in Critical Chain**

**Source:**(Palmer, 2013a)



**Figure 92 critical chain approach only attend to serious mismatches in task duration**

**Source:** (Roff-Marsh, 2014)

Second, Critical Chain approach reduces the chance that project schedules are hindered by lack of resources. It reduces an overly heavy workload and multi-tasking. Third, it also utilizes the deadline for each task to influence the actual completion date of the task, reducing procrastination, perfectionism, cherry-picking behavior, etc.

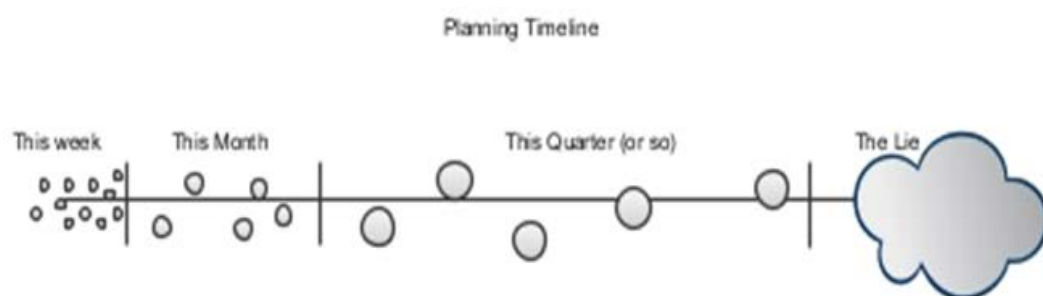
### 5.3.2. Not specifying low-chance conditional decisions

**Other empirical studies:** (Boehm, Port, & Brown, 2002) suggested to manage software projects using approaches which mix agile/plan-driven project management approaches. (Boehm et al.,

2002) provided grounds and evidence why such approaches are feasible, and necessary for managing projects. Software development projects usually adopt agile project management approaches (Glaiel, Moulton, & Madnick, 2013). Agile project management makes detailed schedules only for a short period which is approaching, because the knowledge about the near future is relatively clear and stable. It circumvents certain ambiguity in project scope specification, and adapts to changes flexibly.

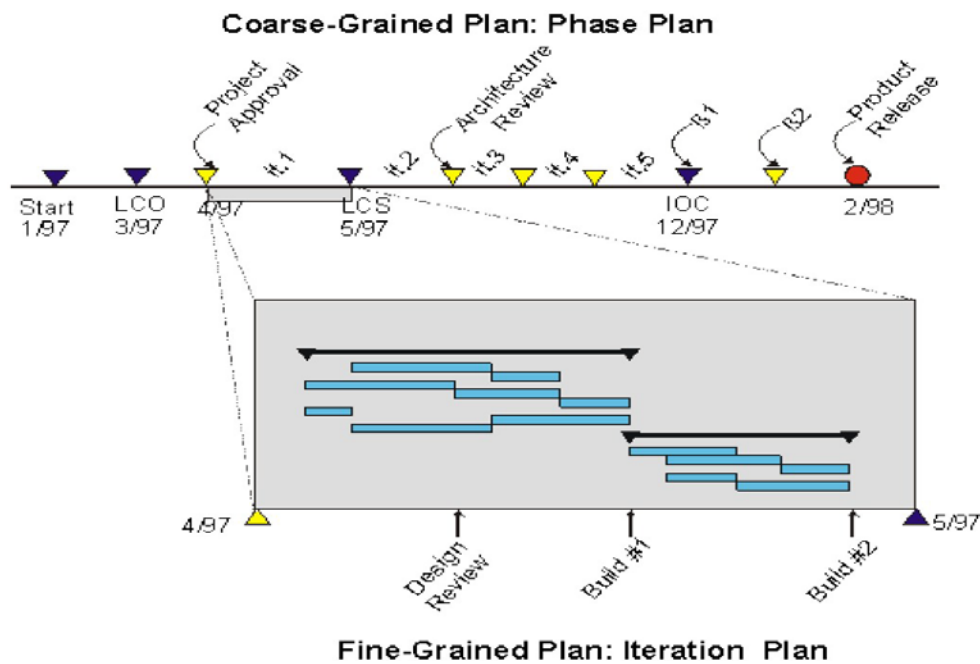
**Observations from our case company:** Our case company already adopts rolling wave approach planning style. (Reynolds, 2009) illustrates rolling wave approach using Figure 93. Only the schedule for the next two or three months are detailed specified in a weekly basis. The schedule for the farther future, is not specified in detail: no man-hour estimate, no assigning tasks to specific engineers. The two month detailed design will be updated periodically.

Rolling wave planning style is adopted in other industries too. (Minyong, 2008) discusses the grounds, the benefits and the drawbacks in adopting a rolling wave planning. (Rothman, 2006) mentioned that the length of interval for detailed planning should be chosen based on the need to foresee risks, and that a detailed plan is prone to be wrong. (Kruchten, 2002) advocated breaking down a project lifecycle into phases and then diving each phases into iterations, as illustrated by Figure 94. A detailed plan is made only for the next iteration when the current iteration is in process. (Intaver Institute Inc, 2013a) explained why adaptive style in managing projects performs better in improving the quality of decisions. Adaptive project management also divides a project into several iterations.



**Figure 93 rolling wave plan at one time point**

**Source:**(Reynolds, 2009)



**Figure 94** a fine-grained plan is a magnified view of a slice in the coarse grained plan

**Source:**(Kruchten, 2002)

More generally, planner should weigh the possible benefits and risks when adding/specifying one more decision into a schedule. If the scenario the decision is based on is not likely to happen, and the schedule decision is specified at a small grain-size, the decision had better be left aside from the schedule, to avoid high likelihood of mismatch in this decision. Under each high likelihood scenario, the plan could be specified with more decisions and the schedule can be divided into smaller grain-size. Rolling wave planning is just an illustration of such principles.

Planners could broaden the usage of the grounds underlie rolling wave approach to scenario planning. If a future decision or situation can be predicted with high confidence, more decisions can be specified upon the high chance decision/scenario, even if the decision/scenario happens in a remote future beyond two or three months ahead. For a low chance scenario or decision, even if it is located in the near future, no further decisions should be specified based on the shaky ground. Therefore, planners should evaluate the likelihood of each decision when they ponder whether to add one more decision into a plan.

### **5.3.3. Reducing indecision by setting rules in discussion**

As mentioned in chapter 2, the main issues that incur disputes are about choice of design, priority ranking among projects, and outsourcing strategy. As analyzed in chapter 4, the main reasons that

lead to the disputes are: different perceptions, different preference, and internal conflict between project goals. For instance, when discussing which design to choose, the client tends to choose a simplistic and low cost solution while the engineering party advocates for a design that is safer and of higher quality. The first cause for such disagreement, is different perception. The client perceives his/her choice as workable, while the engineer does not think so. The second cause for disputes is different preference or orientation. The engineering party is held responsible for quality and safety, while the client is evaluated by profitability or speed. The third reason is the internal conflicts between different goals for the same project. Constrained by resource limit, a project's performance can hardly be enhanced in all aspects: quality, speed, and cost.

Many disputes get stuck when there is no objective and consensus about which option is better than others. When addressing such subjective issues, making rules that are agreed by all stakeholders and that apply to all cases before discussing each specific case, help stakeholders avoid disputes or resolve disputes faster than without rules.

As mentioned in chapter 2, some project team in Dow Company adopts rules in ranking the priority between different projects. Since they spend half a year to negotiate on the generally applicable rules and all stakeholders agreed with such rules, disputes decrease compared with the era when the priority ranking is updated case by case. The proven experience of that project team with established rules, should be applied to other teams.

The social interactions between stakeholders for the same project or portfolio are mentioned more in practitioners' comments rather than academic literature. Collaborative planning is investigated in supply chain management (Dudek, 2009), and allied military operations (U.S. Joint Forces Command, 2011). Fields like supply chain management and allied military operations planning are similar to project planning in that they usually face a volatile environment and coordination is important. (U.S. Joint Forces Command, 2011) used Figure 95 to illustrate how the joint actions need to be planned basing on the common understanding, continuous information updates, and agreement towards to goals.



**Figure 95 planning joint military action by allies within a volatile environment**

**Source:**(U.S. Joint Forces Command, 2011)

#### **5.3.4. Pushing project information updates to a shared database**

**Examples of pooling information in other studies:** In literature some project control information systems used for exchanging information, updating and monitoring project plans are mentioned. (Hergunsel, 2011) mentioned Building Information Modeling (BIM) in construction projects. One function BIM take is to make project schedules and documenting them. (Gibbs et al., 2013) investigated whether the information stored in BIM system could assist identifying responsibility for delays. Such information system facilitates information sharing.

Most project decisions are conditional in that the decisions need to be carried out under a specific condition. For instance, a task cannot start if it has to wait for its preceding tasks to finish but they have not finished. Even when the task's scheduled starting date arrives, the task has to wait. Therefore, the preconditions underlie each decision should be documented, and their status should be monitored. Such status should be updated through a pushing mechanism. All the needed input for making a decision in a plan, should be pooled in a shared database. And the pushing mechanism guarantees the status registered in the database is up-to-date, and thus planners need not to collect the information and verify the consistency every time when they update schedules.

#### **5.4. *Summary***

In this chapter, several measures are suggested for changing the current planning approach. First, the limits in boosting the efficiency of portfolio planning are stated. Such limits include the internal conflicts between the effectiveness of control and the vulnerability of the schedules, the misunderstandings and disputes between different parties are inevitable, each task's duration estimate cannot equal to its actual duration, etc.

Second, the approach through which the suggestions are developed, is introduced. Each measure proposed is devised based on the symptoms observed and the interpretations of the symptoms. Third, the specific measures are listed. Each measure's grounds are explained in brief. In chapter 6 the effects of the measures proposed in chapter 5 will be evaluated.

## 6. Evaluating the effects of the measures proposed

In this chapter, the effects of the measures proposed in chapter 5 will be evaluated before the measures are implemented. The first step in the evaluation process is to choose appropriate methods. The second step is to present the findings of evaluation.

### 6.1. *The expected effects to be tested*

In chapter 1, the aim of the proposed measures is raised, that is, to enhance the efficiency of portfolio scheduling without hurting the effectiveness of project control. Therefore, the evaluation process needs to prove that the efficiency is boosted.

The efficiency of portfolio planning is indicated by the symptoms mentioned in chapter 2, and such issues are grouped into three major categories: a portfolio schedule's content mismatching with the actual progress status of the projects, the schedulers tend to eliminate all mismatches with low tolerance threshold, and updating a portfolio schedule into a new version takes too long. Therefore, whether the efficiency of scheduling is enhanced, is reflected by three aspects: whether the mismatches between a baseline schedule and the reality are reduced, whether the threshold for triggering plan-revisions is heightened, or whether a plan-revision process is shortened. Next those aspects of efficiency issues will be checked in the evaluation process.

### 6.2. *Selecting the evaluation methods*

Various methods for evaluating the effects of the design artifact, are categorized (Hevner et al., 2004) into five groups, as shown in Table 5. Since the suggestions in chapter 5 are in the form of a qualitative description, the methods in Table 5 which quantitatively measure the effects of a new system, are not applicable to this thesis. Since those suggestions have not been adopted and their performance has not been observed, the observational methods in Table 5 are also non-relevant. Finally, the static analysis approach in the analytical methods category and the informed argument approach in the descriptive evaluation methods category, are selected as the methods in evaluating the effects of the suggestions.

**Table 5 Design Evaluation Methods, adapted from (Hevner et al., 2004)**

Category	of	Method	Whether it applies to this thesis
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methods		
1. Observational	Case Study - Study artifact in depth in business environment	<b>Not applicable:</b> the proposed new planning approach has not been implemented yet.
	Field Study - Monitor use of artifact in multiple projects	<b>Not applicable:</b> It takes time to implement the new planning approach, and observe the feedback.
2. Analytical	Static Analysis - Examine structure of artifact for static qualities (e.g., complexity)	<b>Applicable:</b> it is possible to check whether the new planning approach solves the symptoms
	Architecture Analysis - Study fit of artifact into technical IS architecture	<b>Not applicable:</b> the new planning approach is already tailor-made to the specific organization
	Optimization - Demonstrate inherent optimal properties of artifact or provide optimality bounds on artifact behavior	<b>Not applicable:</b> optimization is seeking the optimal value of certain parameters, while the new planning approach has not been quantitatively specified.
	Dynamic Analysis - Study artifact in use for dynamic qualities (e.g., performance)	<b>Not applicable:</b> the new planning approach has not been adopted yet.
3. Experimental	Controlled Experiment - Study artifact in controlled environment for qualities (e.g., usability)	<b>Not applicable:</b> it takes time to experiment the new approach, and the objects being experimented have to be similar in order to attribute the contrast to differences between planning approaches
	Simulation - Execute artifact with artificial data	<b>Applicable:</b> Future Reality Tree diagram is a tool to simulate the future qualitatively.
4. Testing	Functional (Black Box) Testing -	<b>Not applicable:</b> it takes time to apply the

	Execute artifact interfaces to discover failures and identify defects	new planning measures to projects.
	Structural (White Box) Testing - Perform coverage testing of some metric (e.g., execution paths) in the artifact implementation	<b>Not applicable:</b> it takes time to apply the new planning measures to projects.
5. Descriptive	Informed Argument - Use information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact's utility	<b>Applicable:</b> empirical studies that show the effects of certain planning measures, can be found
	Scenarios - Construct detailed scenarios around the artifact to demonstrate its utility	<b>Not applicable:</b> different scenarios have not been simulated

### ***6.3. Evaluating the effects using different methods***

Three methods will be used in evaluating the effects of the changes proposed. These methods are: static analysis, descriptive methods, and the simulation method.

#### **6.3.1. Evaluating the suggestions using static analysis method**

The term “static analysis” is commonly seen in the testing of software program codes. The original meaning of “static analysis” is to check whether certain codes perform the functions they are expected to perform, without running the codes. Static analysis towards software programs works through inspection of the source code. Similarly, in the context of testing the effectiveness of the suggestions in chapter 5, static analysis means checking the measures’ actual effects proposed against their intended results.

When carrying out a static analysis towards the suggestions in chapter 5, several questions will be raised as the criteria against which the performance of the suggestions is evaluated:

a) Whether each measure actually enhances the efficiency of the portfolio scheduling process?

b) Whether there are some downsides or cost if each measure is adopted?

Measure to be taken	Efficiency boosting effect	Downside
Deleting some low chance decisions from schedules	The reduction in the amount of decisions, is likely to reduce the amount of decisions that may mismatch from the actual progress status, especially when the assumptions underlying the decisions are very likely to vary.	If the actual situation turns out as expected, the lack of corresponding decisions/reactions specified in schedules, will make those people who carry out the plans not knowing what to do.
Taking Critical Chain approach in scheduling tasks	Planners will spend less time in updating the progress of the tasks, since some mismatches in task progress between a baseline plan and the actual status, is tolerated.	The managers need to be more alert in reacting to the most updated progress status of tasks, since the tasks are not sticking to a rigid schedule.
Using rules to settle disputes	Preventing deadlock in discussions, will promote projects carry on more smoothly.	It takes time and efforts to find an agreed set of rules.  Under certain occasions, general rules may not lead to the best decisions.
Pushing information updates to a shared database	Pooling the most up-to-date information together in a common place, saves the planners time in inquiry, waiting for response, and verifying the inconsistent	Not all information can be clearly documented, and updated in time. When some changes are likely to happen, the informant may confuse whether to update the changes

	information acquired from different sources.	before the changes come true.
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### 6.3.2. Evaluating the effects through thought experiments (gedankens)

The new planning approach is designed to address the shortcomings in the original approach. Therefore, if the problems or the causes of the problems mentioned in chapter 2 and 4 can be solved through the new planning approach, the effectiveness of the new approach will be proved. As mentioned in (Cox & John G. Schleier, 2010), “gedanken exercises, or thought experiments, have traditionally been used in the sciences.” Gedanken “uses logic and simple mathematics to construct an illustrative example to validate a hypothesis” (Cox & John G. Schleier, 2010). Gedanken “have the advantage of holding all other variables constant in order that the effects of the variable being examined are isolated”, since they “examining fragments of the system one piece at a time rather than losing the effects of an individual variable in the noise of many interacting variables” (Cox & John G. Schleier, 2010). Therefore, the problems identified in chapter 2 arising under the current planning approach can be isolated one by one. Then those problems will receive thought experiments—comparison of the performance under two different planning approaches.

The problems being experimented under two planning approaches and the corresponding performance are listed in Table 6. Such problems serve as a similar role to the use cases in software testing.

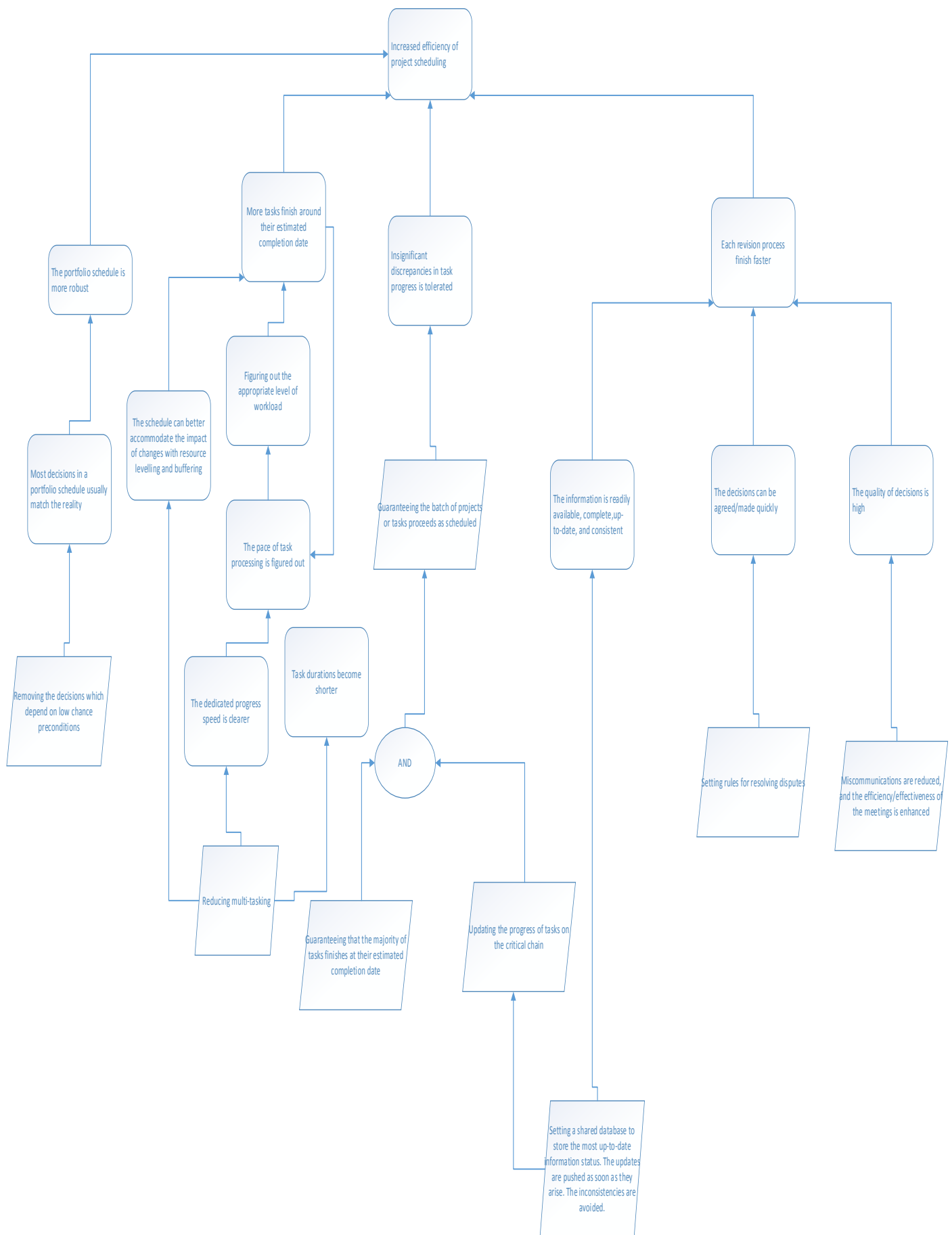
**Table 6 the performance contrast between two planning approaches**

<b>Problem</b>	<b>Performance under the current planning approach</b>	<b>Performance under the proposed planning approach</b>
The discrepancies in task progress status between baseline schedule and the reality	The rigid timing scheduling approach fail to capitalize on the opportunity of early completion on some tasks	The flexible adaptive timing schedule utilize early completion occasions to offset delays
the resource availability confines the pace of progress, making schedules unfeasible	Ignoring the resource availability threatens the feasibility of the schedules	Taking resource availability into account, reduce the chance of delay due to resource shortage
the disputes between different stakeholders make the inputs for scheduling decisions unclear	Lack of dispute-resolution rules leads to deadlocks in discussion	An agreed rule set prevent deadlocks from happening
Task duration estimates tend to be too optimistic	The ambiguity in the basis on which the estimation is derived, perpetuate the optimism bias	Explicitly listing the assumptions underlying the task duration estimates, and adopting multiple estimation methods, help the schedulers to check whether some risks are neglected, and which indicators should be monitored

		when evaluating the feasibility of the commitment dates
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### **6.3.3. Using Future Reality Tree to simulate the effects of the changes**

To visually illustrate how the efficiency of scheduling a project group can be boosted by the measures proposed, Figure 96 is used. Figure 96 utilizes a diagram format called “Future Reality Tree” (FRT). FRT is a tool devised in the Theory of Constraints, a tool used to illustrate what the future will become when the actions to be taken are in place (W. H. Dettmer, 1997). (W. H. Dettmer, 1997) suggest using FRT to verify whether the solutions proposed will generate the desired effects and whether they would lead to some unintended undesirable effects.



**Figure 96 evaluating the effects of the measures proposed using Future Reality Tree Diagram**

### **6.3.4. Evaluating the suggestions using descriptive evaluation method**

In this section, the empirical research relevant to the suggestions, will be quoted as the evidence/proof for the effectiveness of the measures.

#### **6.3.4.1. The effectiveness of removing risky decisions**

(Collyer & Warren, 2009) pointed out that “Plans with excessive detail were found to be misleading and abandoned in favor of a higher level or rolling wave approach”. The grounds (Collyer & Warren, 2009) provided for such a claim is that, the changes arise faster than the speed analysis and decision-updating—a process in which the changes are assimilated into plans.

(Collyer, Warren, Hemsley, & Stevens, 2010) quoted the words of the head of Intel, Andy Grove, that “plans are highly overrated”, and most interviewees highly recommend a rough planning approach in which “planning detail should be proportional to the accuracy of the information”. Such opinions reflect that detailed plans tend to be cumbersome when reacting to changes.

#### **6.3.4.2. The effectiveness of Critical Chain approach**

(Cox & John G. Schleier, 2010) listed the effects of adopting Critical Chain managing approach on 10 different types of projects, and emphasized there is more evidence. The 10 different types of projects include design of oil and gas platform, which carry similar traits with the projects in the case company of this thesis—design/engineering the facility or infrastructure for chemical plants. Besides, the effects are mainly embodied in shortened duration and reduced delays. **Since the projects’ characteristics and the symptoms the projects face in the relevant literature are similar to the case company in this thesis, therefore, Critical Chain approach is highly likely to help resolving the symptoms in the case company of this thesis as well.**

(Bhattacharya, n.d.) used Figure 97 to show the impacts of adopting Theory of Constraints. It is worth noting that Critical Chain theory is derived by applying Theory of Constraints (TOC) to project management, and thus usually the adoption of TOC is often synonymous with adoption of Critical Chain. Figure 97 showed that TOC brings down the project duration.

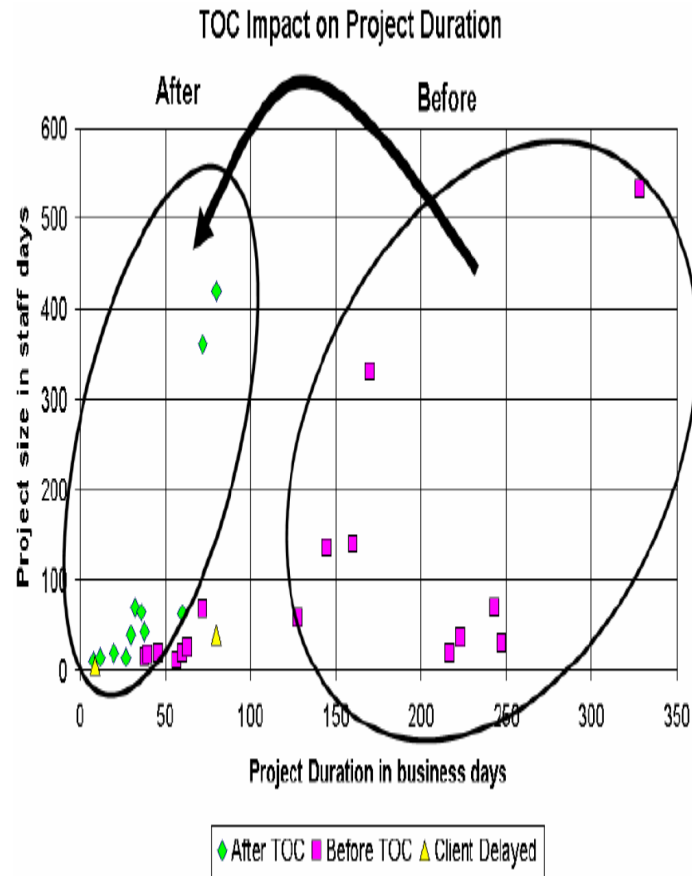


Figure 97 the impacts of adopting Theory of Constraints

Source:(Bhattacharya, n.d.)

### 6.3.4.3. The effectiveness of setting rules for resolving disputes

As mentioned in Interview Records Line 262 to 263, some project management teams within the case company of this thesis have introduced rules for ranking the priority of projects. Such rules are agreed by all stakeholders as generally applicable to all projects, and thus they will not discuss the priority ranking case by case.

## 6.4. Summary

In this chapter, the effects of the suggested measures are evaluated through static analysis and descriptive method. The evaluations showed that such measures are promising in boosting the efficiency of project scheduling and control. Some measures, like removing the decisions that are too detailed, specific and conditional, may lower the effectiveness of control. Generally, those measures are worth experimenting with.



## 7. Conclusion and implementation plan

In this chapter the answer to the research questions will be summarized. After that, the implementation plans for the changes are devised. Next, the correspondence between the problems, causes and solutions is shown. Last, future research directions are suggested.

### 7.1. *Conclusion—answering the research questions*

In the introduction chapter, three research questions are raised. Those questions will be answered one by one in the following sub-sections.

#### 7.1.1. Why is the current portfolio planning process inefficient?

Three major problems are identified. First, **the schedules easily mismatch with the reality**. The decisions are set based on assuming one future scenario out of multiple different possible future scenarios. As mentioned in Interview Records Line 38 to 41, when setting schedules for a project, the schedulers assumed that the design will be feasible, but the design turned out to need adjustments again and again. The scheduler set the deadline based on such assumptions which turn out to differ from reality. In this sense, the schedule does not work in different scenarios. As explained in section 4.1, the actual condition may differ from the assumed condition, and such deviance will lead to the vulnerability of the decisions.

What make things worse is that, planners tend to make schedules more and more detailed or specific by adding more and more decisions. For example, a task is divided further into sub-tasks, a monthly schedule is specified into a weekly basis. If the work scheduled for February is abolished, all the weekly schedules in February need to be adjusted, because the weekly schedules are made based on the arrangements for February. As mentioned in Interview Records Line 115 to 117, the schedulers noticed that detailed schedules easily mismatch with reality. As explained in section 4.1, when a schedule is specified in more detail with decisions whose implementation depends on more and more preconditions, the most conditional/dependent decisions become less likely to be carried out. Low chance decisions specified in a schedule easily mismatch with the actual progress or status when the schedule is carried out.

Second, when discrepancies appear between the project/task progress specified in a baseline

schedule and the corresponding actual status, planners tend to eliminate every mismatch, as indicated in the Interview Records. Under a rigid timing setting, all tasks are expected to start and finish as scheduled. In reality tasks can take longer or shorter than expected. As indicated in Survey Results, some task managers claim that some tasks complete earlier than scheduled. A rigid timing fails to seize the opportunity of early completion and only postponing the timing when delays appear. Therefore, a rigid timed schedule easily suffers from delays. When a task is possible to finish before its deadline, its actual completion date usually fluctuates around the deadline. As mentioned in Interview Records Line 273 to 275, even if the deadline is set with buffer, the actual completion date will usually one or two days later than the deadline. Such mismatches of actual completion date and the deadline, need not be eliminated. **The tendency to eliminate every mismatch in task progress takes schedulers much time without enhancing the effectiveness of control.**

Third, when updating a portfolio schedule, there are certain issues that affect the speed for reaching decisions or the quality of the decisions. More specifically, the lack of consensus over choosing design or outsourcing strategy, often hinder decisions to be reached. As mentioned in Interview Records Line 68 to 70, when a client disagrees with the design proposed by engineers, the uncertainty in design choice hinder scheduling. Besides, as mentioned in Interview Records Line 83 to 91, when discussing design, the unprepared stakeholders may not raise objections in the meeting, but they discover defects during the later stages of projects. As mentioned in Interview Records Line 315 to 317, the estimated duration of tasks is usually too optimistic. In the plan-updating process, some activities can easily go wrong, and generate faulty decisions. Such weak spots include approving a defected design, or being optimistic in estimating task duration. As discussed in chapter 4, the disputes originate from difference in knowledge and in stance: each stakeholder is held responsible for a different aspect in project performance. Therefore, **there are causes for prolonging a plan-revision process and for faulty decisions within each process of updating decisions.**

### **7.1.2. How to fix the problems of inefficiency**

As illustrated in section 5.2, based on the explanations on what caused the inefficiencies, several measures are proposed. First, to cope with the vulnerability of schedules facing changes,

schedulers should evaluate the likelihood of the necessary conditions under which each decision could be carried out. When the likelihood for a decision's underlying scenario is lower than a certain threshold, schedulers had better leave the decision out of the plan. Reducing decisions that are not likely to be carried out, will lower the chance of mismatch between a schedule and reality.

Second, the tasks progress should be managed using Critical Chain approach. The amount of work should match the capacity of the task performers. The tasks should be coordinated through a relay race style. The buffer to prevent contingencies should be extracted from individual tasks and pooled together. Not all mismatches in task progress bother schedulers' attention. Tolerating certain mismatches saves the planners' attention and time.

Third, preventing subjective disputes by setting dispute-resolution rules, help reduce the time for updating decisions. Besides, the information should be pooled and updated as soon as changes happen. The activities that easily generate faulty decisions need to be improved with more cautions. For instance, enhancing the effectiveness in design discussion by guaranteeing the preparation time, could reduce the incidence of faulty decisions; adopting multiple estimation methods in task duration estimation, could alleviate the chance of generating optimistic deadlines.

### **7.1.3. What are effects of the measures?**

As illustrated in section 6.3, the effects of the measures proposed, are mainly positive. The evaluation methods are static analysis, relevant empirical studies, and a qualitative projection of the future. There could be some potential harmful effects brought by the measures. However, in designing the measures, possible negative effects have been investigated. For instance, removing the deadlines at task level may lead to a loss of accountability. In addition, since the changes are introduced in an incremental and iterative manner, the harmful effects could be constrained and eliminated when discovered.

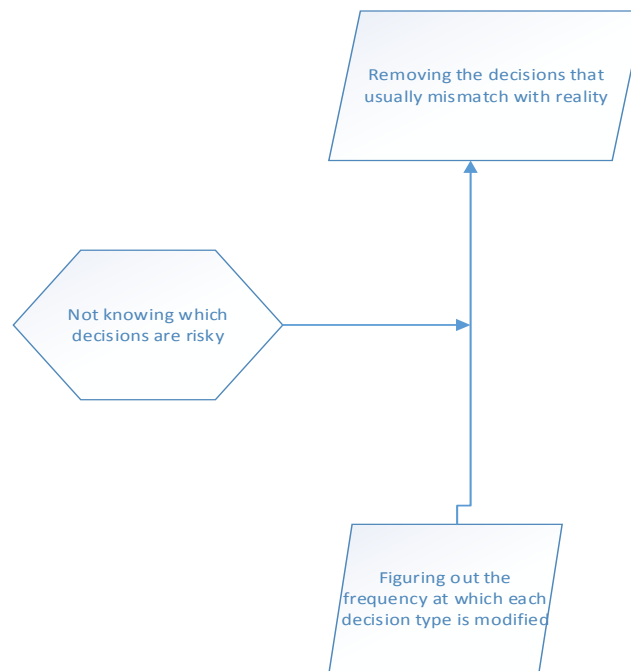
## ***7.2. Implementation plan for the changes***

The measures proposed in chapter 5 need to be implemented. The practical issues involving implementing such changes can be generated by two tools in Theory of Constraints (TOC). One tool is called Prerequisite Tree. After the changes are devised in Conflict Resolution Diagram and tested in Future Reality Tree diagram, Prerequisite Tree diagram identifies what obstacles exist if are implemented and what actions or conditions should be introduced to overcome such obstacles

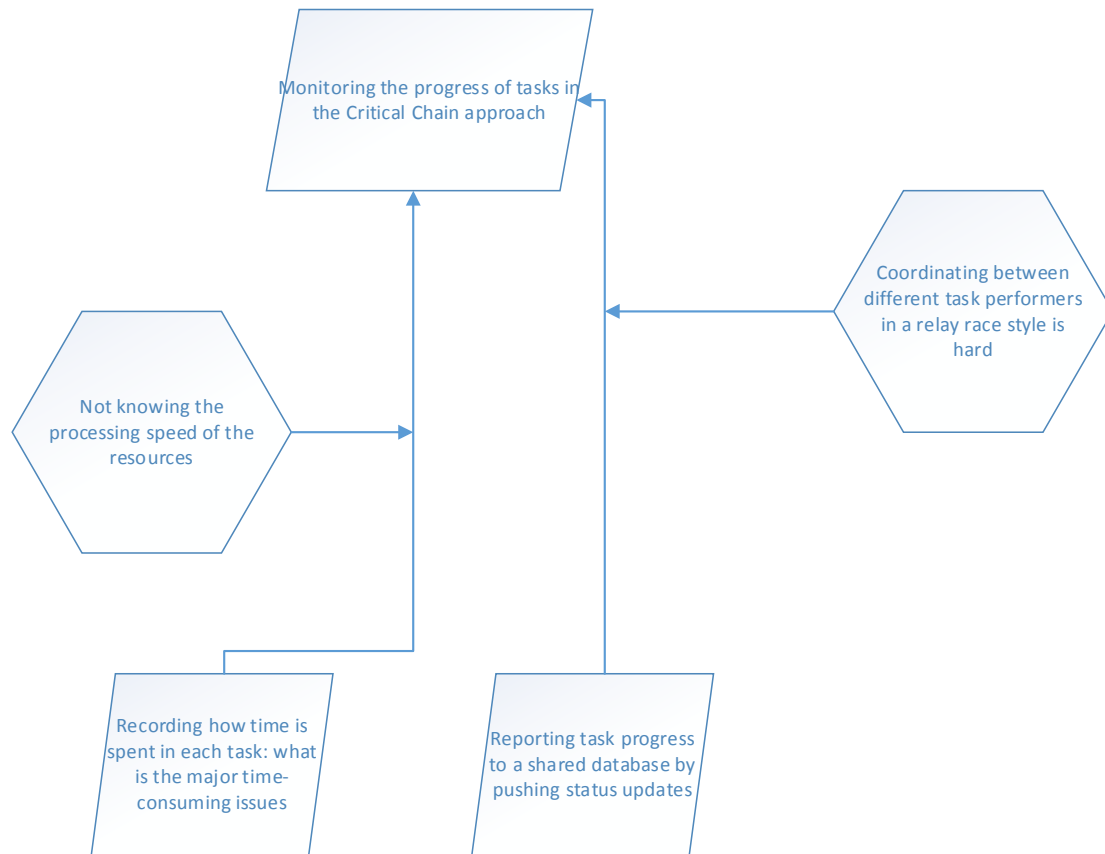
(W. H. Dettmer, 1997). Transition Tree diagram structure the roadmap through which the changes are implemented step by step (W. H. Dettmer, 1997).

### 7.2.1. The designing process for implementation plan

Figure 98 and Figure 99 illustrate how Prerequisite Tree diagram is used for figuring out the conditions/prerequisites for implementing the changes. Figure 100 illustrates how Transition Tree diagram is used in designing a step-by-step roadmap for implementing one change proposed—managing task progress in the Critical Chain style.



**Figure 98 the prerequisites for identifying the risky decisions**



**Figure 99 the prerequisites for monitoring task progress in the Critical Chain approach**

### 7.2.2. Implementation plans

priority ranking. This thesis has not gained experience in such obstacles. Therefore, next paragraphs will focus mainly on the operations of the changes proposed in chapter 5.

To identify the low chance decisions, Dow should first evaluate the frequency at which each type and level of decisions in a portfolio schedule is modified. Decision type refers to whether the decision is on resource demand, resource supply, on scoping, or design specification. The level of decision refers to whether the decision affects a project or a task, whether the decision is specified in a monthly level or a weekly level. Second, when some decisions have been pointed out as risky decisions, the most frequent reasons for decision adjustments should be identified. For instance, when the deadline for a task is exceeded, is it due to scope change, or due to emergency tasks? Third, the reasons why each decision needs to be adjusted, should be grouped into several aspects. For instance, if task schedules changes frequently, planners need to figure out whether the most frequent reason is about resource availability, or about design change, etc. Narrowing down the attention towards specific decisions and specific causes, would help planners take precautions in specifying such decisions in schedules.

To prevent deadlines to be infeasible, the estimation of task duration should be based on multiple methods: one method is to predict the duration based on the traits of the future task to be predicted, another method is to reference historical tasks duration. In order to reference historical tasks or projects, a knowledge database should be set. The lessons learnt from experience should be codified into the database. The lessons include what were the unexpected issues, which steps went wrong, and how greatly these issues affected the duration of the project or the task.

When scheduling each task, if managers hope to get the task done before a certain date, the deadline provided to task performers should be a bit earlier than the latest date allowable, since task performers tend to finish a task around its deadline. The scheduler should monitor the progress of a task sequence in a relay race style, instead of forcing each task proceeding as scheduled. Schedulers should extract the buffers from each task and manage buffers collectively.

To make sure the workload assigned to each engineer matching with his/her speed of processing, multi-tasking should be reduced. Besides, the priority ranking between tasks should be kept as stable as possible, to avoid interrupting the engineers' work at hand and make them switching attention between multiple half-finished tasks.

After figuring out the normal speed of task-processing, managers should figure out the busiest

resource when facing a specific group of projects. Schedulers should protect the bottleneck resource by placing buffers before and after the critical resource.

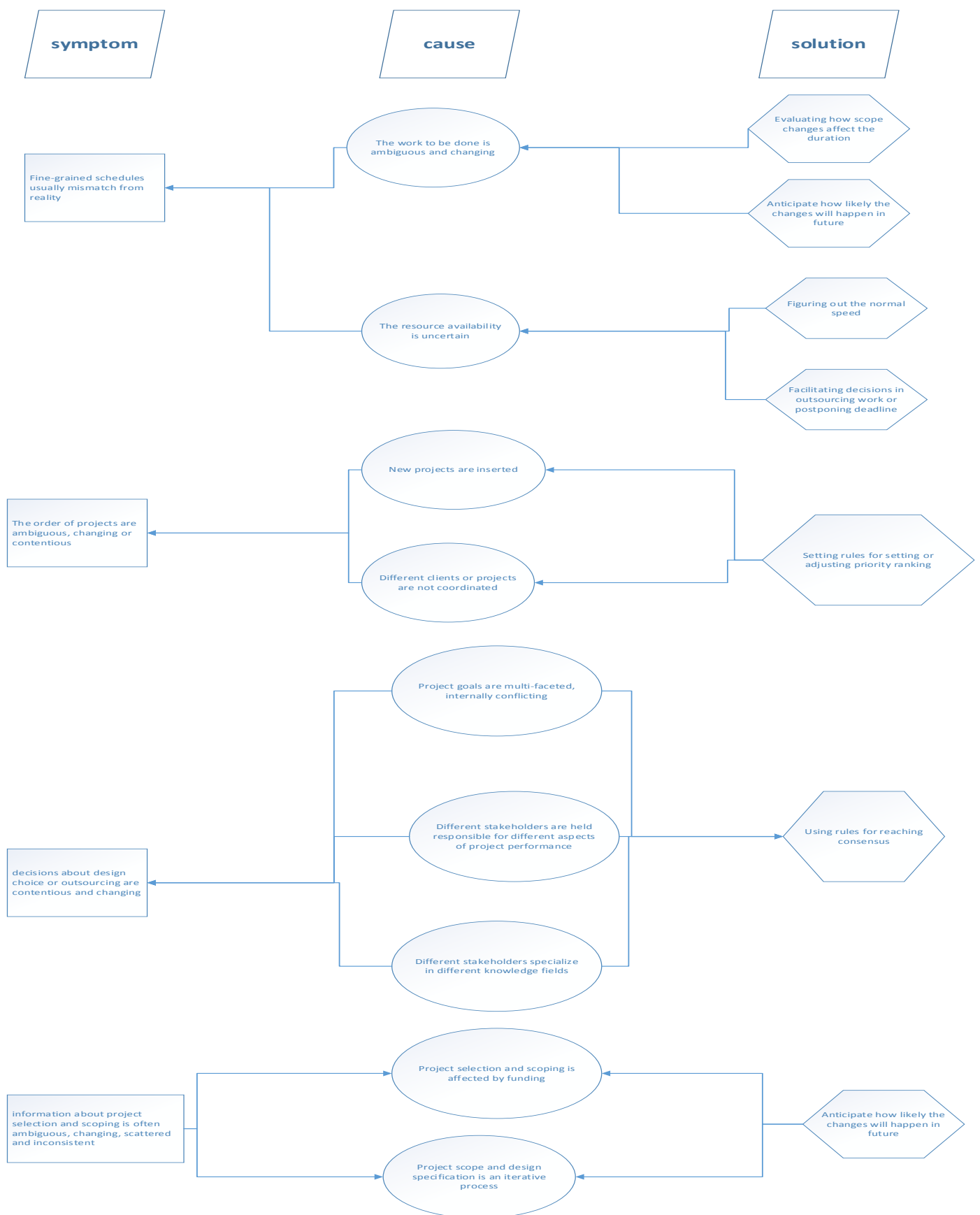
To facilitate schedule revision processes, the information needed for scheduling should be pooled together to a shared database. The updates should be pushed as soon as they arise. The information should be consistent and non-redundant. Besides, rules for resolving disagreement should be developed, just as how the rules for prioritizing projects are set and agreed by some project teams. Before discussing project design, it is important to guarantee that all stakeholders have prepared enough, in order to make the meetings effective. Rules should be set about how many days in advance should the meeting participants receive the agenda and materials for discussion.

### ***7.3. The correspondence between symptoms, causes, and solution***

#### ***measures***

This thesis unfolds from symptom-observing, through cause-seeking and solution-devising, finally to solution evaluation and implementation. The correspondence between symptoms, causes and solutions is summarized in Figure 101. Briefly put, the variability of scenarios and decisions are cautioned through evaluating the chance of each scenario and the corresponding decision; the deadlock in certain decisions are resolved through setting rules for consensus-seeking; and the task delays are tackled with measures for reducing optimism bias and coordinating task progress in a Critical Chain style. Due to the limits in page size, part of the symptom-cause-solution correspondence diagram will be shown in Appendix C.





**Figure 101 the correspondence between symptoms, causes and solutions**

#### ***7.4. Suggested future research directions***

First, the empirical studies on making schedules for a group of projects are not sufficient, especially for the collaborative design/engineering projects and the front-end phases of projects. The efficiency of schedule adjustments in face of frequent changes, is lacking. Few studies explain why detailed schedules are vulnerable or why rolling-wave planning is adopted. Although there are studies on Agile project control style, few studies have provided theoretical explanations on why the decisions in a project schedule tend to mismatch, and how likely mismatches will appear. Second, this thesis is mainly a qualitative investigation. The interactions and changes in portfolio scheduling could be modeled using system dynamics or discrete event modeling. Through modeling and simulation, hopefully the effects of changes, and the sensitivity of certain factors could be quantitatively measured: for instance, which factor impact the project's duration more sensitively than others, or what will happen to project duration if the scope changes are reduced by 20%? Such quantitative simulation models will help project managers understand deeply about the control of project performance.

Third, to figure out why projects are out of control, it is worth investigating how each stakeholder chooses a certain strategy under a certain project performance evaluation mechanism. For instance, how the deadline setting, uncertainty in task content, the iterative cycles of design changes affect the behavior of task performers. Such interactions between project management policy and the stakeholders' strategy choice, probably explain the chaos that persist.

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## Appendices

### *Appendix A: Interview records brief*

The roles in project management include:

**Table 7 The roles of the interviewee**

Job Title	Responsibility
Discipline coordinator	Guaranteeing the supply of engineers within one discipline. <sup>1</sup>
Task manager/Area lead	monitoring the progress of tasks within one discipline and within one group of projects
scheduler	Updating schedules for one group of projects. <sup>2</sup>

<sup>1</sup> Each discipline may consist of multiple groups of projects. Each group of projects shares one team of engineers.

<sup>2</sup> The schedules cover tasks from all disciplines involved in the projects

Project engineer/technical manager for projects	Transferring information between clients and engineers; estimating project costs and duration <sup>3</sup> ; responsible for technical issues
Project manager	Monitoring the progress of one group of projects, responsible for business issues
Engineer	Performing project tasks

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<sup>3</sup> Covering one group of projects

1 **Interviewee A: a discipline coordinator.**

2 **Question:** what is the content of project schedules in your company?

3 **Answer:** we carry out many projects in the same time. For each project, we need to state clearly  
4 what is the starting date, what is the deadline, who is responsible to carry out certain tasks, etc. We  
5 as an engineering department need to provide reliable estimates and promises on when each task  
6 starts and ends. We are held responsible for completing tasks on-time. The quality of the  
7 deliverable must be good. We also need to guarantee that the workload of the engineers is proper.  
8 Therefore, the schedules must be reasonable. We need to check the progress of our engineers to be  
9 sure everything goes on track.

10 **Question:** how do you usually carry out your work?

11 **Answer:** After receiving the man-hour figures from all area leads, I will check whether there is too  
12 much work for each team, for each engineer. I try to guarantee that the engineers within my  
13 discipline undertake the appropriate level of workload. Typically I assign work/tasks to engineers  
14 until every engineer's workload ratio is 90%. That means, the amount of work assigned to each  
15 engineer takes up 90% percent of the engineer's available working hours. The reason why we  
16 usually do not assign 100% workload is that, there are emergency tasks. Some small non-project  
17 tasks come unexpectedly from plants or maintenance staff. Such tasks are mainly repairing or  
18 replacing some parts of the facility. Our engineers need to help in such requests. You can never  
19 know when such requests arrive. And such tasks will take several hours or one or two days.  
20 Besides, our engineers also undertake some routine work, or take some training. Typically such  
21 routine work or training can be anticipated beforehand.

22 **Question:** what are the difficulties in making schedules?

23 **Answer:** we can hardly foresee how many projects will come, and which projects. Different  
24 projects range greatly in the workload. Therefore, we want to predict the workload accurately in  
25 order to prepare enough resource supply. Besides, the projects that are going on, usually take  
26 longer than expected. There are always issues appear. And the tasks in our discipline depend on  
27 other disciplines, when their work delayed or postponed, we often get such messages late. Each  
28 discipline has its own schedule. And usually clients disagree to outsource some work, because  
29 they need to pay for the outsourced design work. Such outsourcing decisions get stuck easily. And

each client wants its projects be finished early. And clients always assume that we engineer team have enough people to cope with the work.

**Question:** there are gates for expense projects within the engineering department, why?

Answer: our engineering department set up two gates for each expense project. Our intention is that when some expense project turns out to be too costly, we will notify the client. We ask the client to re-consider whether to continue the project, or to transfer the money allocated on the expensive project onto other projects.

**Question:** what are the reasons for revising schedules

Answer: There are many reasons. An extreme example for schedule overrun is that, a project is prolonged again and again because the client decided the design in order to utilize some existing equipment. The design turned out to be infeasible, and the design needs to be reworked. Other reasons include optimism bias, we tend to underestimate unexpected issues.

## **Interviewee B: double roles: task manager and resource manager**

**Question:** how do you make sure the workload is properly assigned?

Answer: I check the workload status of every engineer. The workload is estimated and assigned to each engineer only for the next two months. We update the schedule every two weeks. Sometimes we outsource some work to some external engineering companies. I simply asked the external outsourcing company provide duration estimates.

**Question:** what do you feel most challenging in scheduling?

Answer: The schedules hardly match the reality. Our engineers have a lot of tasks at hand. Some tasks can not be worked on, because they need some input. And we can hardly know when such inputs arrive. And I want a schedule that tells engineers what they should do next in each hour on each day, without wondering. You know, surprises arise often, some tasks' inputs do not arrive on the expected date, some tasks take longer than expected, etc. Recently task delays are so common that the area leads become reluctant to promise on due dates for tasks.

## **Interviewee C: one person as both an engineer and task manager**

**Question:** how do you make schedules for tasks?

**Answer:** First, I want to tell you how our discipline works in projects. Each member in my discipline takes several projects. The amount of projects assigned to each person, is determined by considering the experience and workload of each engineer. I am new in this engineering position. I used to be a plant representative, who represents client side. Second, when I receive a project, I need to talk with client about his/her requirements—the scope of the project. I need to figure out a solution/design that fulfils the requirements. When I design the whole chemical process, I need to discuss with the engineers in each module. I need to make sure that my design is workable. I also need to check the regulation rules towards the facility design. The rules are from Dow Corporation and from the Dutch government. Sometimes some requirements from the client do not comply with the rules. I have to persuade the client. Sometimes client feel uncomfortable to be told not to do something. Sometimes some clients bypass our department to realize their requirements. They can go to the maintenance department and request “small” changes in chemical facilities. Clients evaluate we engineers’ performance every year. We feel it is challenging for us to cater to both the clients’ requirements, and comply with the regulations of the corporation. Each project may take several days. And we cannot tell how long each project will last, due to the disputes and license. Some projects need to acquire license from local government. Project managers are responsible to apply for license. Sometimes, Dow is not able to get license, and the project has to be postponed or cancelled. And it is hard for us to foresee how many projects are coming. We want to reserve one engineer to be idle and receiving emergent projects, but our hands are full. We cannot get enough people for our work. And sometimes project quantity drop down, and some engineers are idle. It is hard to match the workload with our engineers available. It takes us two or three months to hire a new engineer and it takes months for a new engineer to know how to work. New guys need guidance and assistance at the start.

**Question:** what issues need to be addressed, if we want to boost the efficiency?

**Answer:** Sometimes during the comments meeting—the meeting in which we discuss the design. All the stakeholders, the client, the construction company, the engineers from all disciplines—comment on the design: whether the design needs to be modified at somewhere in the

86 diagram. I have observed that sometimes, some participants in the meeting have not read through  
87 the design and report. They do not raise comments for changes. But in the later stages of the  
88 project, those stakeholders discovered that some parts in the design need to be modified. The  
89 changes raise quite late, cause big trouble, since we engineers have worked out detailed design  
90 based on the consensus/result of the comments meeting. When the design has to be modified, a lot  
91 details in the design diagram needs to be modified.

## 93 **Interviewee D: two task managers**

94 **Question:** how do you make schedules for projects?

95 **Answer:** well, I postpone the scheduling until the last moment. The managers in the engineering  
96 department asked to submit the schedules. However, such schedules are not accurate. They do not  
97 reflect what happen in reality. And we have not got enough input information for the schedules.  
98 For example, every task is different, and it is hard to predict how long a future task will take.  
99 Some design specifications are not clear, and such ambiguity affects how long tasks actually take.  
100 Therefore, I prefer to wait for the updates of information. I feel that the schedules cannot project  
101 the future, and thus they are not so reliable.

102 **Question:** I heard that at the outset of each project, it is hard to estimate the workload for each  
103 discipline, why is that?

104 **Answer:** at the outset, there may be multiple design/solutions as options for the project. Those  
105 solutions differ greatly. If we don't know which design will be chosen, we cannot tell how many  
106 man-hours will be needed.

107 **Question:** which activities do you feel are most inefficient?

108 **Answer:** the tool we use in scheduling—a Microsoft Excel sheet (with macros) named RAS. It is  
109 shared between multiple disciplines. When one person edits it, others can only read. And we need  
110 to contact others to figure out the information of the projects. That takes so much time. And  
111 sometimes we receive engineering assistance tasks. Some facilities need repairing. Our schedules  
112 need to be adapted for such emergencies.

113 **Question:** someone wants to have a schedule that tells them what to do on each day or each hour,  
114 do you also want plans to be so detailed?



**Answer:** that is impossible. If a schedule specifies what to do in each hour, a slight disturbance would cause mismatches. An unexpected phone call can render your original agenda disturbed. Then we need to spend time revising schedules all the time.

### **Interviewee E: a discipline coordinator**

**Question:** what is your opinion about the schedules for tasks in your discipline?

**Answer:** we have multiple teams within our discipline. The demand on engineers is not stable. And sometimes the availability of engineers changes unexpectedly. For instance, once there was an experienced engineer who had a stroke, and his work need to be handed over to other engineers. However, there are few engineers who possess similar capabilities and experience. Finally we borrow an engineer from another area/team, who happened to possess similar experience. When the schedules are tight, they are fragile to such unexpected emergencies. And I worked in other companies before. In my previous employer, the deadline for each project is specified at a certain week. As long as you submit your deliverable at that week, you fulfill your promise. But our company specifies the deadline at a specific date. It is hard to control the finishing date so accurately. For instance, sometimes, engineers would take a small break or their attention is occupied by some emergencies, and thus their work is hindered for several hours. I feel that the deadline is too specific.

### **Interviewee F: a task manager**

**Question:** how do you guarantee the schedules you make match the reality?

**Answer:** it is very hard to match plans with reality. Sometimes tasks need to be modified or reworked, due to new requests from the client. The input for some tasks is not specific, we need to wait for clients or vendors to provide such information. Sometimes we have too much work to do, we need to outsource some work. However, the external engineers do not have such expertise to do the job, or they work more slowly. For example, sometimes we outsource some work of facility modification to our Indian branch, but the Indian colleagues are not so experienced. And the Indian colleagues do not know the specific 3-D configuration of the existing facility: how long is

the pipeline, how high is the equipment away from the top, etc. The Indian colleagues work better at designing new facility from scratch, but they are not good at design modifications towards existing facilities. We need to check the quality of the deliverable coming from India. Therefore, outsourcing the work to India does not save much time.

### **Interviewee G: an engineer**

**Question:** are you able to finish tasks on time? What are the biggest challenges to guarantee on-time completion?

**Answer:** for me, completing tasks on time is usually not an issue. Sometimes tasks take longer than expected. Sometimes, the plants asked to modify the length of the pipeline, or the position of a valve. When such changes in design happen, I need to discuss with other disciplines about the new design. The integration between our work should be seamless, you know. Sometimes, the specification of the technical parameters is not clear, or we need to go to the field to check the current configuration of the facility, we need to figure out the input for tasks ourselves, or to wait for the vendor. Without such input, although I can draw the general configuration, but my task is not complete, the design is not specific enough.

**Question:** how do you order the tasks at hand?

**Answer:** usually, I order them by deadline. The most urgent tasks are the first to be handled. Sometimes, some tasks are too ambiguous in their input or may be difficult. I will first check the difficult tasks' specification out, because I know they may bring me surprise when I work on them. I need to start the ambiguous tasks as early as possible. The small tasks with clear input, can be postponed even when their deadline is earlier than the ambiguous tasks.

### **Interviewee F: a functional department manager**

**Question:** what are the major problems for you in managing the progress of projects?

**Answer:** We have more than 20 plants. They are grouped into different business areas. Each area is assigned with a project team. In each area, many projects are going on. The projects come and go, and we cannot tell the future demand for engineering work. And engineering tasks are hard to

171 manage, surprises come out: scope change, engineering assistance tasks, etc. They all affect the  
172 progress of tasks. The schedules we made, easily mismatch with the reality. We have too much  
173 work. The priority between projects is usually lacking. The plants want all their projects to be  
174 finished as early as possible. They do not care about the limit in resources. They are clients. But  
175 the engineering department cannot recruit more people, especially during the economic crisis. The  
176 budget is cut. I need to guarantee that my engineers are not overburdened. When we have a  
177 shortage of engineers, the plants usually do not want to pay for outsourcing some work. We  
178 engineers believe that, if a plant is not willing to pay for a project, the project is of low priority.  
179 We also need to guarantee the quality of the engineering solutions, while the clients usually urge  
180 for quicker completion. Another problem is, the estimated costs is too inaccurate, especially at the  
181 early stages of the projects. The range of cost estimate for a project gets narrower as the project  
182 proceeds from front-end stages to construction stages.

#### 184 **Interviewee G: a plant representative**

185 Question: what do you expect from project schedules?

186 Answer: The schedules are usually not accurate. Projects always delay. And we plant side wonder  
187 why the engineers cannot give us a reliable promise on completion date.

188 Question: how do you involve in deciding the schedules

189 Answer: As a plant representative, every year we send a list of projects to the engineering  
190 department. Within the plant, we agreed on the priority of the projects. We have some grading  
191 criteria to rank the priority of projects. Although we have such a priority index, the engineers  
192 never ask for it. Besides, sometimes there are urgent projects, they need to be handled before high  
193 priority projects. For each project, I specify the scope. I discuss with process engineers about the  
194 design. Then I asked the maintenance and construction party to hold a meeting to discuss the  
195 design before the comments meeting. My area added this meeting before comments meeting  
196 because we discover that the comments meeting is not enough to decide the design. In two hours,  
197 people seldom spot defects in the design. And it is important for the engineers, construction  
198 companies and maintenance department to agree on the design. If the design turns out to need  
199 modification in construction phase, the construction companies are rigid in sticking to the original

design. They will not modify the design even we request it. Therefore, it is important for engineers to come up with a workable, faultless design.

Question: some engineers mentioned that plants sometimes disagree with the design proposed by engineers, have you observed such phenomena? For instance, some plant feels reluctant to take a design to cater to the compliance rules, they prefer to bypass the engineers and contact the maintenance directly.

Answer: I have not experienced such disputes in my area. But I can imagine that some plants may not buy the design proposed by engineers. I believe the problem lies in communication. Engineers should discuss with plants more often about the design, explaining why the design is like that. Plants feel uncomfortable if the engineers just work out some diagram himself, and present the result to the client. Under such situation the plant may suspect the grounds for the design. We are all human beings and we hardly can get rid of subjective feelings. Some compliance rules are general, they may not apply to certain case/context. Some rules are too rigid and do not make sense sometimes. But although we plants may not like the rules, we respect the rules. And there are internal auditing to check whether the plants follow the rules, therefore, we plant side have incentive to comply with the rules. Therefore, the engineers' claim that they insist complying with the rules, while the plants do not, does not make sense to me.

## **Interviewee H: a plant representative**

Question: how do you affect the project schedules?

Answer: each year, we make a list of projects. These projects are expense projects. They are mainly about replacing old parts. All the expense projects share a bucket of budget. There are also capital projects, in which we build new stuff. The budget for each individual project is separately assigned. We send the project list to engineering department, and ask them to provide completion date for projects. And each capital project needs a proposal to apply for budget. When preparing the proposal, I need to ask the engineers to estimate the duration and cost of the project we propose. I admit that some capital projects will not be approved in the end. And in this sense, such capital projects may disturb the schedule for other projects.

Question: when do projects go wrong?

Answer: sometimes there are small defects in the design. In one project, when some equipment is going to be fixed at a certain location, we discovered that some extra supporting like cement platform is needed, otherwise the equipment will not stand. Usually such defects need small rectifications, but they do not happen very often. But the engineers had better double check whether their design is flawless. Usually the engineers hand over the design and pay no attention ever since. Therefore, engineers do know whether their design is good enough.

Question: someone mentioned that plants sometimes add new projects when they discover there is budget left, and at that time usually the engineers' hands are full already, have you experienced similar issues?

Answer: yes, we have experience funding surplus, but we often do not add new projects, instead we buy some equipment to use up the money. It is usually around November when we check the remaining funding level, and new projects cannot finish before December, therefore, we will not raise new projects. But we tend to use the remaining money, because if we have money left, we have to return the money to the corporation, and such surplus shows that our estimate was not accurate.

(The researcher discussed with Interviewee A about the use of surplus in buying new equipment. Interviewee A replied, the plants buying equipment themselves is not wise, because the specification of the equipment they buy may not fit the requirements of future projects. If the plants buy the wrong equipment, they waste money.)

## **Interviewee I: a scheduler**

**Question:** what activities take most time when you update the schedules?

**Answer:** we have above one hundred projects. Even though on average, each project may take several minutes, the total amount of time is considerable. Second, although we register tasks in computer. The software tool only records the tasks. The software assumes that the tasks are ordered as finish-to-start, but in reality we have multiple tasks run in parallel. Some tasks need the input from other tasks, but usually we have to schedule them to start concurrently because we have limited time to wait. If some task cannot finish on time, the following tasks may be able to start.

Therefore, the progress of tasks and the starting date of tasks need to be updated manually. The software's underlying logic is too simplistic to be usable. It is the activities for asking the progress of tasks, and asking whether the succeeding tasks can start, taking much time. Typing in such information into computer takes smaller amount of time compared with human interactions. Third, our area used to experience a lot of priority changes, disputes about priority ranking. But since we make a rule to order the projects, such disputes never arise again. Such rules have been negotiated with all the clients. Negotiation on rules used to take us half a year. But the negotiations save us the time on discussing each case individually. You know, every plant compete to get its projects prioritized. It is a political bargaining. People who "shout the loudest" get the priority. And the manager who is in charge of all plants, simply wish the engineering department to supply enough resources for all projects and all plants.

**Question:** what are the reasons that make schedules fail?

**Answer:** at the start of each project, the design is uncertain, therefore, the schedule cannot be accurate. Second, the project management theories made simplistic assumptions about the task progress. For instance, when I encountered delays, I will place more buffers in future tasks, hoping to reduce delays. But as I observe, when the deadlines are extended, the actual finishing date shift backward too. The finishing date is always one or two days after the deadline. Therefore, I suspect that psychological issues play a major role in task delays.

## **Interviewee J: two task managers**

**Question:** what are the biggest challenges in making schedules?

**Answer:** the biggest challenges are that, you need to guess when other tasks will finish. It is like solving a puzzle. You can hardly tell whether your schedule will match the reality. Different disciplines order the projects differently, and different disciplines may be involved in different projects. Therefore, you can hardly know what your colleagues are working on, and when they will be available. Sometimes clients cancel projects suddenly, or re-order the on-going projects.

**Question:** what are the reasons for delays?

**Answer:** we are taking too much work, and our attention is dispersed between different projects. The managers keep pushing work to us. And the efficiency of work goes down. The half-worked

287 tasks pile up.

288

289 **Interviewee K: a project manager**

290 Question: what are the main reasons that schedules do not match reality?

291 Answer: I believe the engineering department accepts too many projects. The attention of  
292 engineers split between multiple unfinished tasks, and thus the efficiency become lower.

293 Question: some engineers say that the input for tasks is not clear, and thus the progress is hindered,  
294 is it true?

295 Answer: to me, the project design coming out at each stage is clear enough for the work in the  
296 next stage. Even when such input is clear, I think the engineers should not wait, they need to be  
297 more proactive.

298

299 **Interviewee L: a project engineer**

300 Question: how do you influence the schedule

301 Answer: at the start of each project, I estimate the workload based on a reference database which  
302 recorded many projects' performance. For projects that took 1 million Euro, there is an average of  
303 pipeline design man-hours, civil engineering man-hours, etc. I will indicate the workload for a  
304 future project based on such historical data. And I will send the estimates to engineers, and they  
305 will check the accuracy of my estimates. During the progress of projects, I will coordinate tasks  
306 between different disciplines, and between clients and engineers.

307 Question: why some schedules mismatch with reality

308 Answer: there are various reasons, some projects encounter a scope change, when some client  
309 discovers they have more money to be spent, they will buy some better equipment which cost  
310 more. Certain changes lead to the adjustment of design. Sometimes some client does not  
311 understand the design diagram, and he/she approve the design, later he/she ask to modify the  
312 design.

313

314 **Interviewee M: a project engineer**

315 **Question:** what are the reasons for the schedules to fail

316 Answer: I believe that the engineers are too optimistic when promise completion dates. They  
317 should be more conservative.

318 **Question:** someone mentioned that some comments meetings are held when the participants just  
319 receive the design diagram and documents, have you experienced such issues?

320 **Answer:** I witnessed that during some comments meeting, some participants even have not  
321 received the documents. The preparation of such documents and transmission takes too much time,  
322 and hinders the effectiveness of the meetings.

324 **Interviewee N: a task manager**

325 Question: why some schedules mismatch from the actual progress

326 Answer: the estimated duration for some tasks is not grounded on clear input. We generate such  
327 estimates without knowing what it takes in the tasks. Therefore, the estimates are risky. For  
328 example, this task X is estimated to take 3 days, but the input for the task arrive when the deadline  
329 for X is approaching. At that time, we discovered that the task actually take much longer.  
330 Therefore, we have little time to react to such differences.

331 **Question:** the interface between some tasks is not clear upfront, and different disciplines need to  
332 negotiate about the interface, and the client often ask modifying the design and then multiple tasks  
333 need to be modified, does such issues happen in your experience.

334 **Answer:** Dow Corporation stipulates some global standards, the best practice in design. In theory,  
335 we should adopt such standards. If every discipline adopts the same interface as specified by the  
336 standards, such negotiations will be unnecessary. But the clients in Europe, request something  
337 tailor made, therefore, it is likely that the design need to be negotiated case by case.

339 **Interviewee O: a plant representative**

340 Question: how do you affect a portfolio schedule?

341 Answer: each year we will propose a bunch of expense projects. Expense projects are mainly



342 repairing or replacing some parts in our existing equipment or facility. We need to estimate the  
343 cost. The business managers will approve the expense projects and allocate an amount of budget  
344 for all the expense projects. Besides, we also propose capital projects. Each capital project is to  
345 create some new facility. We need to apply funding for each capital project separately. And each  
346 capital project, if approved, will get a certain amount of budget. The budget is calculated based on  
347 our cost estimate in project proposals. We add new projects to the portfolio, and we notify the  
348 engineering department when some projects are cancelled. The decision whether to approve a  
349 capital project, is made by business managers. They compare all project proposals to make such  
350 decisions. There are two evaluation gates for each capital project. At each gate, the cost estimate  
351 of a project is updated. The decision whether to approve the project is re-considered.

352 Question: what are the main reasons that the schedules fail?

353 Answer: at the start, project scope and design is not clear. Even the client does not know exactly  
354 what is best for them. Therefore, I can imagine the engineers face great uncertainty in carrying out  
355 the design. But I believe the engineers should have a can-do mentality. They need to be proactive  
356 and take initiatives in specifying the design, rather than waiting for the client to specify. The client  
357 may not know what the engineers need in order to carry out the design. Therefore, projects cannot  
358 progress as fast as we like.

## 360 **Interviewee P: a task manager**

361 Question: what the main reasons that the schedules differ from reality

362 Answer: usually projects start hastily. The managers do not spend much time figuring out what is  
363 the current status of the facility. Field inspection is omitted. Therefore, sometimes we engineers  
364 discover that extra preparatory tasks are needed, when we check the field. It is such unexpected  
365 tasks that bring us big trouble than other surprises.

366 Question: how do you make task schedule

367 Answer: I receive the updated version of project schedule, to see what are the tasks. And I specify  
368 the tasks in my discipline by dividing the tasks in Master project schedule into smaller and  
369 detailed tasks. And I estimate how long the tasks will take. And I check the hours available in my  
370 team.

371

372 **Interviewee Q: a manager on scheduling and an engineer**

373 **Question:** what is your opinion about the accuracy of the schedules? Why the project schedules  
374 mismatch the reality?

375 **Answer:** We have spent more than 20 years attempting to solve the problems in portfolio  
376 scheduling, but we have not made much progress. Different parties take different preference. The  
377 clients want low cost and flexibility. The engineers prefer a static portfolio schedule. It is not easy  
378 to find out a solution that satisfies all parties. I believe that the discipline coordinators or project  
379 engineers should do better in knowing the progress of the projects, and in foreseeing how many  
380 projects will come. They possess specialized knowledge and get a high pay for their expertise. It is  
381 their responsibility to get project progress in control. If they are not able to perform their  
382 responsibility, Dow can hire some administrative people or ordinary secretaries to do such  
383 coordination jobs. And those non-specialized people get lower pay, saving the cost of the  
384 company.

385 **Question:** if replacing the current technical managers could help, how can you tell who is capable  
386 to replace the current ones? That is, how can you distinguish who could do such jobs better? And  
387 if someone does better in such jobs, what are the traits of the capable persons, to help the recruiter  
388 find the right person? What is the reason that the current managers are incapable?

389 **Answer:** (no response.)

## ***Appendix B the survey results***

**Table 8 the factors that affect the duration of information collection**

	<b>Factor that affect the information collection stage</b>	<b>Percentage of respondents selecting this option</b>	
The first three columns are the standard options provided in the questionnaire.	The information are scattered in so many places.	82%	The percentage refers to the proportion of respondents who selected the standard option, or added their own answer for the question asked.
	The contact persons who possess such information, typically not respond quickly.	36%	
	Some information is not clear for now, for example, the plant haven't decided which design to be chosen	64%	
	there is no deadline when the information should be provided	9%	
The answer provided by the respondents, and how many percentages of respondents provide their answer	<p>“The information is scattered in so many places / disciplines”</p> <p>“Resource availability and estimated time necessary to perform a task is discussed personally with the persons involved.”</p> <p>“get/discuss status update and actual progress of the current projects with the engineers in my discipline area team.</p> <p>compare current MPS with previous</p>		

	<p>version of MPS (including my personal notes)</p> <p>compare updated current MPS with RAS and update RAS”</p> <p>“information not available when needed”</p> <p>“The information is spread all over the site. After gathering the information we aren't ready yet. We have to cross check consistency of information. Sometimes we require other disciplines/partners to do it. Again it takes time, because partners aren't aligned. They have other priorities. Actually there is no team deadline, only individual deadlines. It works like that: you weren't ready to meet my deadline why should I do my best to meet your deadline ? We are divided in teams but there is no team spirit.”</p>		
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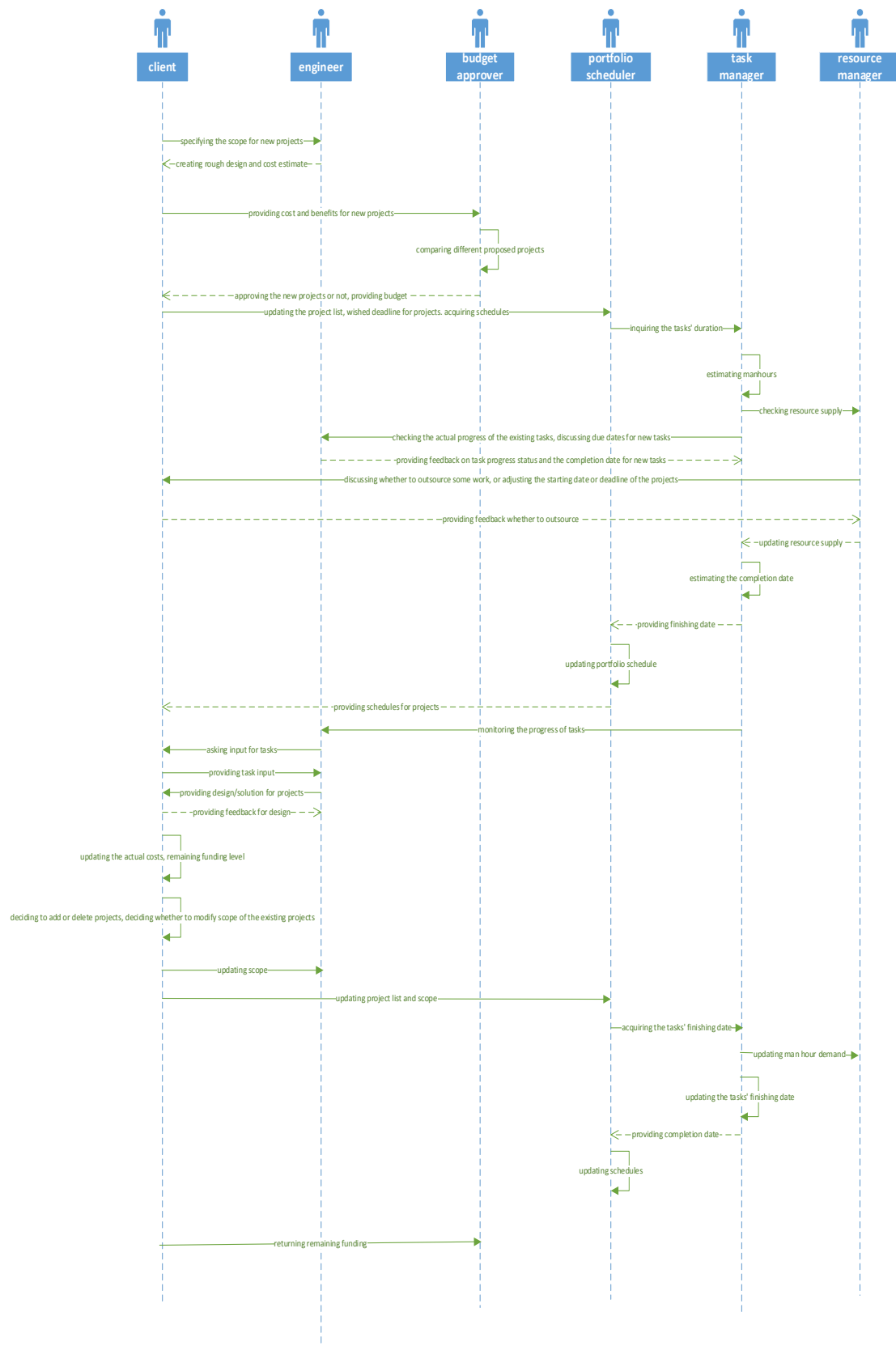
**Table 9 the factors affecting the duration of meetings**

	<b>The reason for the time spent</b>	<b>Percentage of respondents selecting this option</b>
The first three columns are the standard options provided in the questionnaire.	It is not easy to make one's idea clearly understood by others. For example, the plant may not	18%

<p>The percentage refers to the proportion of respondents who selected the standard option, or added their own answer for the question asked.</p>	understand the P&ID correctly.	
	There is disagreements about some normative standards, for example: whether to choose a design that cost less or choose a design which is of higher safety; or which project is more urgent, etc.	64%
	the participants are not well prepared for the meeting or discussion, therefore the discussion is not so effective	55%
<p>The answer provided by the respondents,</p> <p>and how many percentages of respondents provide their answer</p>	<p>“Lots of scope changes happen during discussions and comment rounds.</p> <p>”</p> <p>“</p> <p>priorities and schedule can change due to customer wishes, projects put on hold, capital availability, illness, design changes, or underestimating time necessary for the tasks involved.</p> <p>”</p> <p>“</p> <p>in the LHC area there are a lot of projects active at the same time(about 150projects)</p> <p>that means even the smallest</p>	45%

	<p>time you spent on a each project</p> <p>results in several hours in total</p> <p>”</p> <p>“All of the above (standard options) are true. But there is still another reason which is "lack of leadership". I mean having different opinions is very healthy, having different solutions is normal and realistic but you have to have a leader. One person has to make decisions. One person has to choose different options and take the responsibility for his/her decision. This doesn't happen.</p> <p>”</p>	
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***Appendix C: the figures referenced in the main text***



**Figure 102 a UML sequence diagram for the workflow of portfolio planning**





## Master Project Schedule - Baseline

DOW

A...	Activity Name	Dur.	Start	Finish	RESP	Notes	2009												2010												
							D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
	Standaard Template MPS 50M\$ - 7MM\$ (ES Tnz - SEP)	442	19-Jan-09	28-Sep-10																											
	Major Milestones	401	24-Feb-09	07-Sep-10																											
	-	401	24-Feb-09	07-Sep-10																											
	Project team Funds	0	24-Feb-09		<pm>																										
	Environmental Permit	0		27-Apr-09	<pm>																										
	Engineering Only Authorization	0	12-May-09		<pm>																										
	Authorization	0	28-Jul-09		<pm>																										
	Building Permit	0	22-Sep-09		<projE>																										
	R.T.O	0		07-Sep-10	<pm>																										
	Mechanical Completion	0		07-Sep-10	<c>																										
	IPA Milestones	381	12-May-09	28-Sep-10																											
	-	381	12-May-09	28-Sep-10																											
	Project Definition	40	12-May-09	08-Jul-09																											
	Authorization	20	30-Jun-09	27-Jul-09																											
	Procurement	180	21-Jul-09	01-Mar-10																											
	Detail Engineering	110	28-Jul-09	28-Dec-09																											
	Construction	220	18-Nov-09	21-Sep-10																											
	Commissioning	38	20-Jul-10	07-Sep-10																											
	Start-Up	15	08-Sep-10	28-Sep-10																											
	Step-1 FEL 1 - (\$&OP request)	28	19-Jan-09	23-Feb-09																											
	Step-2 FEL 2 - Prepare Process Package	50	24-Feb-09	05-May-09																											
	Step-3 FEL 3 - Prepare FEL package	50	12-May-09	20-Jul-09																											
	Step-4 Detailed Design	110	28-Jul-09	28-Dec-09																											
	-	110	28-Jul-09	28-Dec-09																											
	DETAIL DESIGN	110	28-Jul-09	28-Dec-09	<projE>																										
	Project Engineering / Project Management	5	28-Jul-09	03-Aug-09																											
	-	5	28-Jul-09	03-Aug-09																											
	Kick-Off Meeting Detail Engineering [14.15]	5	28-Jul-09	03-Aug-09	<projE>																										
	Process Automation	80	04-Aug-09	23-Nov-09																											
	-	80	04-Aug-09	23-Nov-09																											
	Develop Software	40	04-Aug-09	28-Sep-09	<pa>																										
	Training Operators	40	29-Sep-09	23-Nov-09	<pa>																										
	Mechanical Design	100	28-Jul-09	14-Dec-09																											
	MS-5xxx Mechanical Equipment (Long Delivery)	35	18-Aug-09	05-Oct-09																											
	Receive/Review/Return Prel. Vendor Dwgs -	15	18-Aug-09	07-Sep-09	<de>																						</				

■ plan
 ■ critical
 ■ actual
 ■ baseline

The DOW Chemical Company - DOW Restricted

Printed : 17-Jun-09 11:29 Page: 1 of 9

**Figure 103 a sample schedule for multiple projects used in Dow**

**Source:** Dow Chemical company internal document

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