Changing failing to plan into planning to be successful

Master thesis, December 2015

Author:
Jordy Kamphorst, University of Twente
Master: Industrial Engineering & Management
Track: Production & Logistics Management

Supervisors:
Dr. ir. J.M.J. Schutten, University of Twente
Prof. dr. ir. E.W. Hans, University of Twente
Company X

X HYDRAULICS.

UNIVERSITY OF TWENTE.

Preface

By means of this thesis, I close a chapter in my book of life. It is the conclusion of my graduation project, and thus my study Industrial Engineering and Management at the University of Twente. My time as student was fun and educational, but I am happy to start a new period in my life.

My graduation project was really enjoying and I have learnt a lot during the project. It was a hard time, but I liked to work in a professional business company with very helpful colleagues. They have helped me tremendously by providing me the requested information, for which I thank them. I thank the Managing Director and the Commercial Director in particular for their support and supervision during the project, and for giving good opportunities within this great Company.

In addition, I thank Marco and Erwin for their support and supervision in the drafting of this thesis. Without their constructive feedback regarding content, design, spelling, and grammar, this thesis was of a lower quality. Thank you both!

Finally, I thank my family, friends, and girlfriend for their unconditional support and love during this graduation project and the rest of my study period. For sure, this has helped me in completing this phase of my life. Thanks!

Jordy Kamphorst

Summary

Company X supplies (complete) hydraulic systems in a worldwide market. They are able to supply the complete solution, so from designing, manufacturing, commissioning, installing, and distributing to servicing at the end of the chain. Company X is a typical project driven organisation. The complete hydraulic solutions they supply are mostly one-offs. The deadlines for the projects are fixed and delay caused by Company X will lead to a penalty, which is agreed upon in the contract with the customer. Therefore, it is of great importance for Company X to meet these agreed deadlines. However it is hard to meet the agreed lead times, even if the internal processes are well organized. So, an important condition to meet the lead times is to set up and structure the internal processes in such a way that they are actually focused on delivering the project on time.

In order to set up and structure the processes, we answer the following research question:
"How can we improve internal processes and conditions within Company X to prepare the organisation for using their desired multi-project planning tool for meeting project deadlines?"

The aim of this research is to gain insights about the current planning process at Company X, to investigate what the desired situation is for Company X, and to investigate what improvements should be done to use a multi-project planning tool in the future.

In order to reach the aim of this research we first analyse the current situation. Therefore, we analyse the organisation structure, departments, processes, and problems that occur during the processes. We perform a literature study to position the situation of Company X and to explore the field of planning. Then we define the desired situation for Company X. We translate wishes of interviewed employees into a desired situation. The differences resulting from the gap analysis between the current situation and the desired situation, lead to interventions/improvements that we recommend to Company X.

<u>Current situation</u>
In the current situation, projects are individually planned based on infinite capacities. Four planning systems are used, which are not linked to each other. The planning systems are managed by different employees from different departments. Therefore communication and cooperation between the employees and the departments is important. Currently this proceeds arduously because of the many cross-departmental processes and the

individualistic culture. Company X is not ready yet to use multi-project planning, so first the designs of the processes and structures needs to be improved.

Desired situation

In the desired situation, the planning is organized centrally. The planning department is responsible for all planning related activities and all plans and schedules are made in one planning system. Every project is linked to each other, because they use the same share resources. The projects are executed by multidisciplinary project teams, which are jointly responsible for their projects. The individualistic culture is shifted into a corporate culture, wherein awareness, focus, and support contribute to better company-wide results. In addition, the involved employees are more able to issue more accurate lead times to the customers based on historical data of project activity durations.

Interventions/improvements

In order to reach the desired situation, incremental steps should be made. Company X first has to start with the low-hanging fruit issues such as creation of competency skill matrices, setting up KPIs to track project progress and planning performance, and setting up a tracking system to track project activity durations. In addition, Company X can switch to one planning system instead of four and they can investigate whether a team-based organisation with project teams and a centralized planning is suitable. After all these improvements, Company X seems to be ready for using more complex multi-project planning tools with complex algorithms. This might result in better planning performance, better delivery performance, higher customer happiness, and also better company-wide results.

Table of contents

Chapter 1 Introduction

This chapter provides a plan of approach for the research performed at Company X. We choose to use the name of Company X instead of the real name of the company because of confidentiality. Section 1.1 briefly describes the company. Section 1.2 provides the problem identification on which the research focuses. We show the scope of the research in Section 1.3 and Section 1.4 states the research goal. Section 1.5 provides the main research question and sub questions and the structure and approach of the research.

1.1 Company description

Company X supplies (complete) hydraulic systems in a worldwide market. They are able to supply the complete solution, so from designing, manufacturing, commissioning, installing, and distributing to servicing at the end of the chain. The employees, approximately 70, are specialized and high-tech skilled so as to provide the best, safest, most reliable, and most effective hydraulic solution for their customers. Company X is active in different segments: Aviation, Civil works, Dredging, Production Industry, Offshore, and Oil and Gas. All of these segments are distinguished by the management in three product market combinations. All segments have a system group, a spare parts group, and a service group. So in total there are 18 product market combinations within Company X.

80% of the order intake value in Euros of Company X consists of system group orders. The order intake of the system groups consists mainly of large projects, generally with a value between €100,000 and €3,000,000, where Company X often supplies the complete hydraulic system solution. In that case Company X is responsible to invent a solution for a hydraulic problem, design it, purchase the required materials, manufacture and assemble the system, and finally install and commission the system on site. The spare parts groups are responsible for about 10% of the total order intake value. When customers want to replace old parts with new ones, Company X supplies them upon request. Company X has their own service department, responsible for the orders in the service groups. These service orders cover the remaining 10% of the total order intake value of Company X. Service is one of the main important aspects for Company X, so they are available 24/7 for their customers. For large hydraulic systems, downtime is very costly and therefore the speed at which service can be provided is an important factor in this business. The service department of Company X is always ready to directly provide the service needed, such as resolving occurring issues,

performing preventive and periodical maintenance, and repairing on site and in their own workshop.

1.2 Problem identification

Company X is a typical project driven organisation. The complete hydraulic solutions they supply are mostly one-offs (except the aviation projects, which are more standardized). The deadlines for the projects are fixed and delay caused by Company X will lead to a penalty, which is agreed upon in the contract with the customer. Therefore, it is of great importance for Company X to meet these agreed deadlines. According to the commercial director of Company X, it is extremely difficult to win contracts. Therefore, Company X has to be competitive and offered lead times are often very short. Typically it is hard to meet the agreed lead times, even if the internal processes are well organized. So, to increase the chance of meeting the lead times it is important to set up and structure the internal processes in such a way that they are actually focused on delivering the project on time.

According to the managing director of Company X, several difficulties may occur during a project. All of them contribute to the failures to meet the agreed lead times. Sometimes it is still possible to deliver on time, but only by hiring very cost expensive additional personnel. Some examples of causes are (according to the managing director):

- **No insight in capacity plans of other departments**
  The sales department offers a certain lead time without taking into account the available capacities of the engineering department and the production department. Sales people do not have insight in the capacity plans of these departments, so it could happen that no or too little resources are available. If they would have this insight, they would have the ability to shift the delivery dates or in extreme cases reject the project. Ultimately, the customer specifies the end date. An alternative for Company X is to not accept the order, but often they cannot afford this luxury.

- **Project schedules/plans of each department are not linked to each other**
  Every department uses its own capacity plan and its own activity schedule of the different projects. These different plans are not linked to each other. So changes in one plan do not affect the plan of a consecutive department. For example, if a supplier delivers an item too late, this influences the plan of the production department. Production workers do not know this late delivery in advance, but they discover the absence of the item at the moment they actually want to use it. Since

changes or delays in a plan of a department do not automatically update the other plans/schedules, it is difficult for a project manager to keep track of the project progress. According to the managing director a need exists to have an integrated multi-project plan combined with the capacity plans of the departments. In that case it should be possible to see the potential effects for the entire organisation when changes and delays occur. Also various future scenarios can be simulated when an integrated multi-project plan exists.

- **High uncertainty of sales orders**

  In a project organisation with large one-off projects, it is almost impossible to forecast the sales orders correctly. Therefore, Company X is not able to purchase project-specific components and other project-specific materials on stock. For some required long lead time items, having them on stock would reduce waiting times, but these items are so project specific that it is impossible to purchase them in advance.

- **Work-in-progress (WIP) in departments fluctuates a lot**

  Since Company X has to cope with the high uncertainty of winning orders, the work-in-progress (WIP) can fluctuate a lot. It may happen that in one month the plant is almost empty, because there are no ongoing projects. However the next month may be so busy that additional personnel has to be hired to meet the agreed deadlines. This applies to all departments and when the WIP on a certain department is too high, it could influence the consecutive departments. For example, when the engineering department could not finish the drawing of project on time or has finished them incorrectly, it is not possible for the purchasing department to start purchasing the long lead time items. In most cases, this results in waiting time for the production department.

- **Too little cooperation between departments**

  To make a project successful, good cooperation between departments is required. The combined knowledge of people on different departments can lead to insights for better, safer, quicker, and cheaper solutions. The different departments are quite isolated. Everyone does their part for the project with little consideration for the effects it may have on the plans of other departments. From the moment that someone finished his activity and transfers it to another department, the new department is responsible, which is why the previously responsible departments stop caring. Afterwards, when errors or failures occur it easy to blame other

departments without reflecting on what they may have done wrong themselves or what they could do better in the future.

1.3 Research scope

In this section, we set the scope of the research. Therefore we provide the following list of boundaries to limit the research area:

- We do not focus the research on uncertainty within a project driven organisation. This is a given that we have to cope with, but we cannot convert it into certainty. However, we consider the uncertainty during the research but our goal is not to reduce the degree of uncertainty.
- As said, there are 18 product market combinations within Company X. The focus in our research is on the system groups, since these groups contain the large projects where it is hard to meet the agreed lead times. So we focus on the one-off projects and not on the service, spares, and aviation groups.

1.4 Research goal

The managing director has identified the need of an integrated multi-project planning tool that supports in meeting the project deadlines.

Our research goal is to analyse the current planning process and to investigate what the desired situation is and what should be improved/changed to use a multi-project planning tool within Company X in the future, in order to bring more transparency when regarding changes and delays in plans throughout the entire organization.

1.5 Research questions

In order to reach our research goal, we first set up a main research question and sub questions to answer the main research question. The main research question for the research is:

"How can we improve internal processes and conditions within Company X to prepare the organisation for using their desired multi-project planning tool for meeting project deadlines?"

To find an answer to the main research question, we formulate some sub questions of which the answers together lead to an answer to the main question.

In Chapter 2, we analyse the current situation within Company X to obtain deeper insights of the used methods and problems in- and outside the organisation. We have interviews with employees to obtain the required information.

Chapter 2. Current situation

- *Q2a. What is the organisation structure of Company X and what are the different departments?*
- *Q2b. Which processes are necessary to complete a project?*
- *Q2c. What is the status of planning related processes and what are problems that occur?*

In Chapter 3, we perform a literature study to explore the research field and to reach answers on the sub questions. We position the situation of Company X to describe the context of the problem we have to deal with and we investigate different ways of planning.

Chapter 3. Theoretical framework

- *Q3a. How can we position the situation of Company X?*
- *Q3b. Which ways of planning are described in the literature that are suitable for the situation of Company X?*

In the next step, we focus on the desired situation Company X wants to reach in the future. Therefore we interview employees to identify their wishes for the desired situation. Then we perform a gap analysis to identify the differences between the current situation of Company X and their desired situation.

Chapter 4. Desired situation

- *Q4a. What are the wishes for the desired situation within Company X?*
- *Q4b. What are the differences between the current situation and the desired situation within Company X?*

In Chapter 5 we provide some concrete interventions/improvements that are needed to reach the desired situation. We will provide a plan of approach for performing the interventions/improvements.

Chapter 5. Interventions/improvements

Q5a. What interventions/improvements are needed to reach the desired situation?

Q5b. What is the plan of approach to perform the needed interventions/ improvements?

The answers to all of the questions posed above together contribute to achieving our research goal. To structure this research, each part has an own chapter to answer the sub questions. After these four chapters, in the final chapter we provide our main conclusions and recommendations of the research.

Chapter 2 Current situation

In this chapter we describe the current situation of Company X. In Section 2.1 we present the organisation, we show what the structure of the organisation is and we describe the different departments. In Section 2.2 we describe the necessary processes for completing a project successfully. In Section 2.3 we give an overview of the status and problems of the planning related processes.

2.1 Organisation structure and description of departments

Before we elaborate the processes within Company X, it is good to get an overview of the organisation structure and the departments within Company X. In Appendix 1 we give an overview of the organisation structure in an organogram. In Section 2.1.1 we describe the management of Company X. In Section 2.1.2 we describe the departments that are directly involved in the projects and in Section 2.1.3 we describe the supporting departments.

2.1.1 Management

Within Company X the management is overall responsible. The department heads are part of the management team and report to the daily management that consists of the managing director and the commercial director. The managing director is the main responsible employee of the company and he is supported by the commercial director, who is also head of the sales department. The management is responsible to organize, structure, manage, drive, encourage, and motivate everyone within the company in such a way that the processes are executed in the right way. Their only goal is to achieve the overall company targets, so they should provide the necessary resources to run the organisation optimally. The management has formed a management team (MT) to evaluate regularly the progress and the current state of affairs of the company. The management is accountable to the supervisory board.

2.1.2 Project involved departments

During the execution of a project several departments of Company X are involved. In this section we describe these departments briefly such that no new departments and/or roles are discussed in Section 2.2.

Sales department

The sales department is responsible for acquiring new orders and maintaining relations with (potential) customers. The sales department consists of sales employees who are accountable for the different segments Company X is active in. So for example, someone is responsible for the sales of spare parts, while others are responsible for the sales of systems in the offshore segment. The sales director meets all employees regularly to discuss the ways of working and the status of potential new customers and new orders. Once every week all sales employees meet each other to discuss the focus customers and projects for the coming period and together they consider how certain issues should be addressed.

Project management department

The project management department is responsible for controlling and guiding the project once it is sold by the sales department. The project is transferred from the sales department to the responsible project manager and from that moment onwards, the project manager is responsible that the project will be completed according customer requirements. The project manager is involved during the entire project and is involved in all contact moments with the customer.

Engineering department

The engineering department is responsible for the designing and drawing of the desired system(s). This is the responsibility of the product/system engineering part of the department. In addition, the department also consists of employees who are responsible for engineering and programming of controls of the hydraulic systems and there are employees responsible for the documentation of the manuals for the customers. The complete engineering of a project is distributed in subprojects. Within Company X these are known as Work Breakdown Structures (WBS). Based on these subprojects the engineering activities are planned and executed.

Purchasing department

The purchasing department is responsible for ordering and warehousing of all components that are necessary for the projects. Within Company X there are two types of components that are used during the projects: the stock materials and the project specific materials. Stock materials are materials that are used more often and therefore a stock is created for them in the warehouse. Project specific materials are not in stock and therefore they need to be purchased when they are required for a project. The warehouse employees are responsible to pick all necessary components in the warehouse and transfer them to the workshop.

Production department

The production department is responsible for the assembly of the desired project system(s). For fulfilling this requirement, the department consists of several parts. The work has to be prepared and planned by the work preparer. The execution and planning of activities is done based on subprojects, the Production Breakdown Structures (PBS). Sometimes parts of the system have to be coated or welded, which might be done in the coating part or the welding part of the production department. It is also possible that some of these activities are outsourced. After assembly, the complete system is tested by testing employees to check if all functional and technical requirements are met.

Service department

The service department is responsible for all service activities that are arising from earlier projects. Company X provides warranty for its systems. So when something happens with the system during the warranty period (or after it), the service department is 24/7 available to solve the problems all over the world. It is possible that the service engineers solve the issues on the site of the customer, but it is also possible to ship the system to Company X where the issues could be solved. The service department also provides (preventive) maintenance to the hydraulic systems.

2.1.3 Supporting departments

In addition to the project involved departments, within Company X there are also departments that are not directly involved in the projects. We briefly discuss them in this section.

Finance department

The finance department is responsible for all incoming and outgoing payments of Company X. This concerns the payments from customers, the payments to suppliers, and the payments of wages to employees. The payments from customers and the payments to suppliers often take place in phases due to the large total amounts.

HRM department

The HRM manager is responsible for maximizing the employee performance. The HRM manager has different activities, such as recruiting new personnel, setting up a training and development program of personnel, and setting up a performance appraisal program.

Marketing department

The marketing manager is responsible for increasing the brand awareness of the products of Company X. The marketing manager has different activities, such as arranging fairs where Company X is present, promoting in different media (online websites, professional journals, etcetera), and maintaining the Company X website.

QHSE department

The QHSE (Quality, Health, Safety & Environment) manager is responsible for all issues regarding quality, health, safety, and environment. The activities of the QHSE manager include setting up and maintaining the quality management system, taking care of achieving and maintaining quality certificates, and taking care of the safety regulations.

2.2 Overview processes necessary to complete a project

In this section we present the necessary processes for completing a project. We give an overview of the link between the processes and the different departments during a project. Within Company X, the processes during a project are divided in 12 phases. During these phases, mostly more than one department is involved. Figure 2.1 shows the link between the processes and the involved departments. We show for every phase which departments are involved and how they are involved in that phase. At the end of this section, we provide the current planning method that is used within Company X.

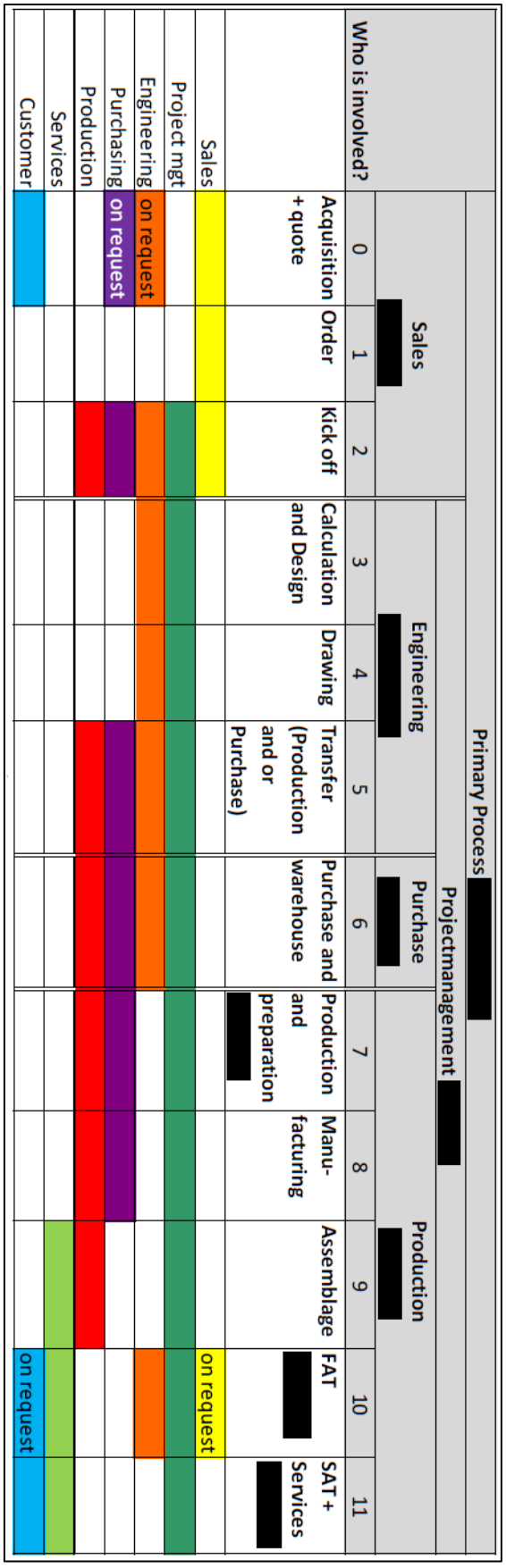


Figure 2.1 Process scheme of Company X (Source: Quality handbook Company X, some parts are blurred because of confidentiality)

Phase 0: Acquisition + quote

- *Involved departments:* Sales, Engineering (on request), Purchasing (on request)
- *Customer involved*
- *Short explanation:* During the acquisition + quotation phase, the sales department is in contact with the potential customer. The customer has an issue and Company X has to solve it when they are chosen as supplier. Therefore the sales department has to convince the customer with their offer, a good technical solution (reliable, safe, and effective), a good lead time, and a good price. Sometimes it is necessary to involve the engineering department or the purchasing department to request price and delivery time of critical components (for determining the price and lead time) or some parts of the products have to be pre-engineered. For this reason the engineering department or the purchasing department are involved on request of the sales department.

Phase 1: Order

- *Involved departments:* Sales
- *Short explanation:* During the order phase, the customer has chosen Company X as their supplier for the desired system(s). When the official order is received, the salesmen have to create a new order in the ERP system.

Phase 2: Kick off

- *Involved departments:* Sales, Project management, Engineering, Purchasing, Production
- *Short explanation:* During the kick off phase, the project is transferred from the sales department to the project management department. From that moment onwards, the project manager is responsible that the project will be completed according customer requirements. The kick off meeting is used to discuss the exact requirements and specifications requested by the customer. A rough sequence of activities is determined and so are the long lead items, such that the purchasing department can start the purchasing process.

Phase 3: Calculation and Design

- *Involved departments:* Project management, Engineering
- *Short explanation:* During the calculation and design phase, the engineering department has to design the system(s) according to the requirements and specifications of the customer. Therefore some calculations have to be made, for example calculations about pump characteristics (pressure, power, and etcetera) or

about accumulators (volume, pressure, etcetera). The project manager is involved because he has the overall responsibility of the project and should follow and control all processes during the entire project.

Phase 4: Drawing

- *Involved departments:* Project management, Engineering
- *Short explanation:* During the drawing phase, the responsible engineer has to convert the design into a dimensional drawing (Figure 2.2 shows an example), hydraulic schemes (Figure 2.3 shows an example), and part lists. Also here the project manager is involved to get the overall control of the project.

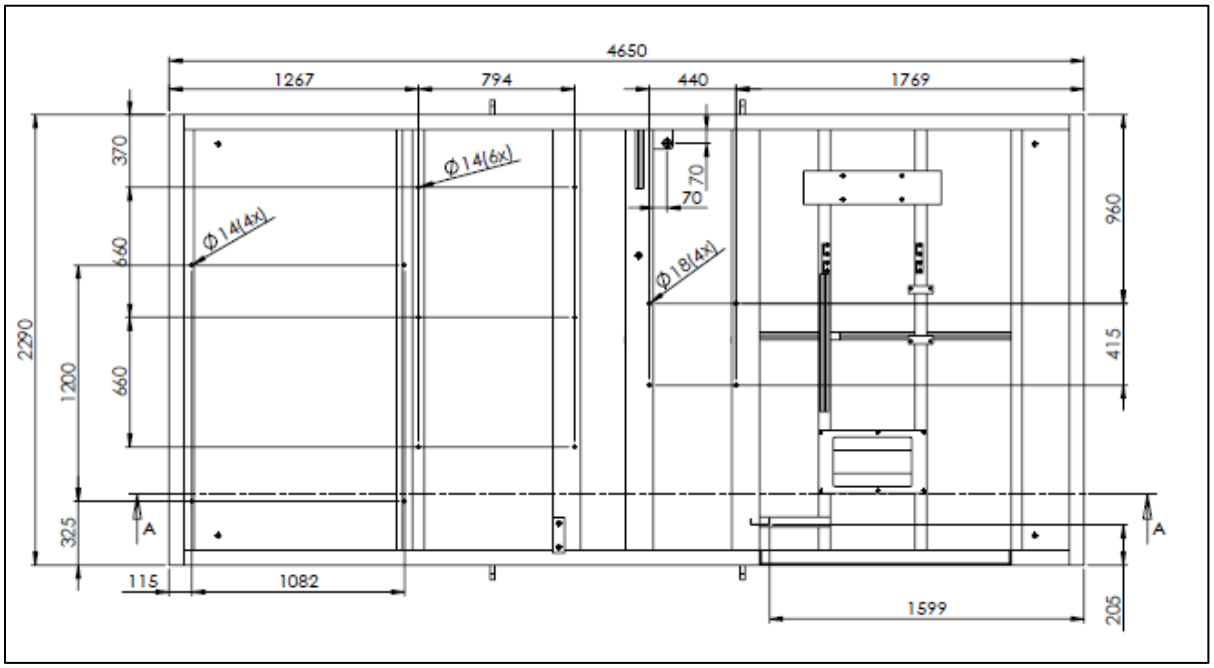


Figure 2.2 Example of a dimensional drawing

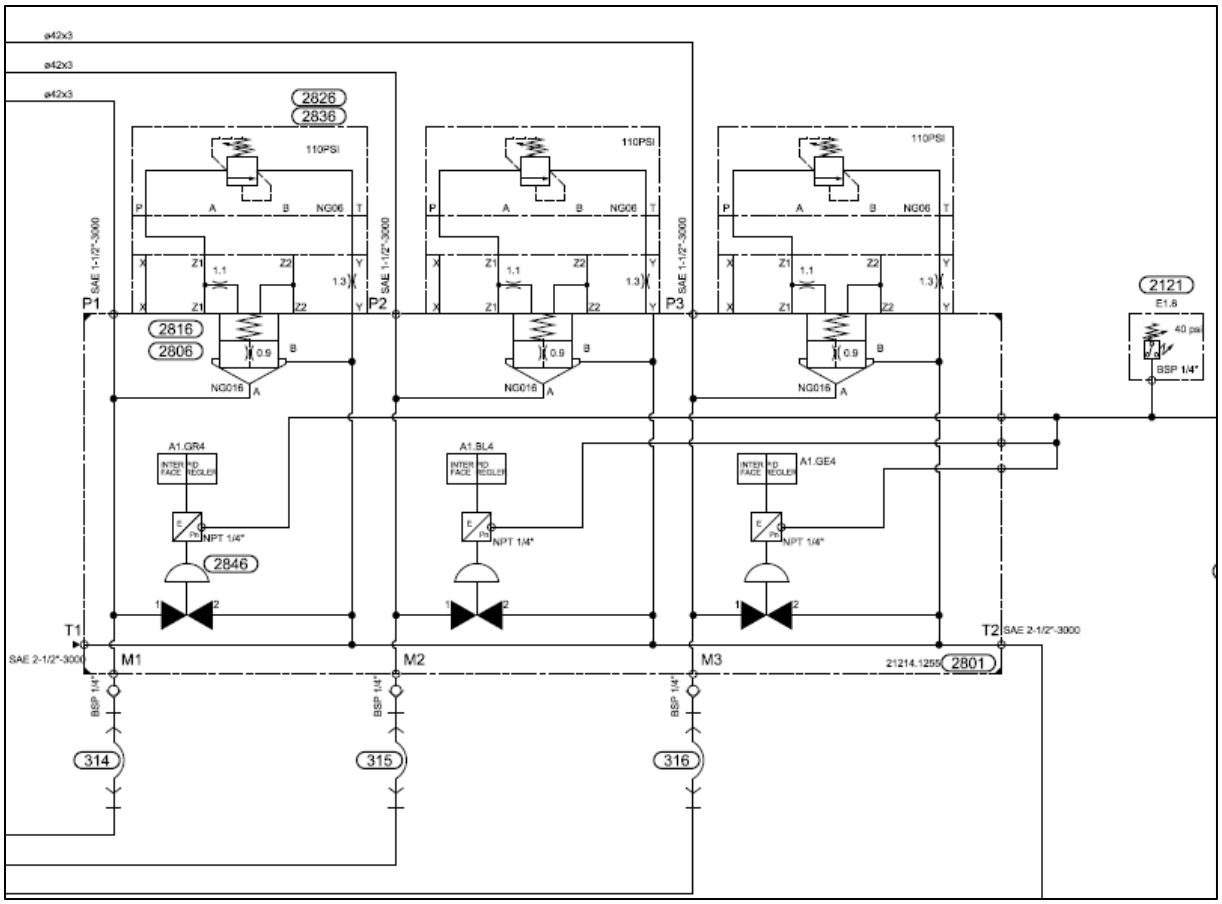


Figure 2.3 Example of a hydraulic scheme

Phase 5: Transfer (Production and or Purchase)

- *Involved departments:* Project management, Engineering, Purchasing, Production
- *Short explanation:* During the transfer phase, the actual engineering part of the project is finished and the deliverables of the engineering department are transferred to the production department and to the purchasing department. The drawings and schemes are complete and approved. The parts lists are created in the ERP system, such that the production department and the engineering department can do their part of the job. The project manager is controlling the project and involved in this phase as well.

Phase 6: Purchase and warehouse

- *Involved departments:* Project management, Engineering, Purchasing, Production
- *Short explanation:* During the purchase and warehouse phase, the purchasing department is ordering all necessary components. Some parts are manufactured parts that the production department has to assemble from components from the warehouse. The warehouse employees are responsible to pick all components per project. In this phase the engineering department is involved because they know

requirements of components, what is information that is needed by the purchasing department for purchasing these components. The project manager is controlling the project in this phase and therefore he is involved.

Phase 7: Production and preparation

- *Involved departments:* Project management, Purchasing, Production
- *Short explanation:* During the production and preparation phase, everything should be prepared to be ready for manufacturing and assembling the system. So all components should be purchased by the purchasing department, should be picked by the warehouse employees, and have to be moved in a structured way to the workshop. Together with the project manager and the production manager, the work preparer is responsible for planning the production activities.

Phase 8: Manufacturing

- *Involved departments:* Project management, Purchasing, Production
- *Short explanation:* Some parts that are necessary during the assembly phase, are not purchased (due to for example a too long lead time, a too high price, or it was easier to manufacture them) and so they have to be manufactured during the manufacturing phase. For example, some parts have to be welded before they are used in the assembly phase. This could be done by the welding part of the production department. The purchasing department is involved in this phase, because sometimes small parts that are needed for the manufacturing have to be ordered quickly. The project manager is controlling the project and therefore involved in this phase.

Phase 9: Assembly

- *Involved departments:* Project management, Production, Service
- *Short explanation:* During the assembly phase, the desired system is completely assembled. The system is divided in work packages (the Production Breakdown Packages, such as motor-pump sets, manifolds, cylinders, reservoir, frame, etcetera) that are separately assembled. These different packages are afterwards combined and aggregated into a complete system. The service department is involved, since the production department and the service department might complement each other when it is necessary. In some cases they can execute tasks of each other. Also here the project manager is involved to guide and control the project.

Phase 10: FAT (Factory Acceptance Test)

- *Involved departments:* Sales (on request), Project management, Engineering, Service
- *Customer involved (on request)*
- *Short explanation:* During the FAT (Factory Acceptance Test) phase, the complete system is tested on location of Company X. These tests are supervised by the project manager. Sometimes agreements with the customer are made that they are present during the execution of the FAT. In that case it is usual that the responsible sales person is also present to meet the customer. The engineering department decides the test protocol and is therefore involved. The service department is involved since they should be aware of the results of the FAT. This is necessary for the next phase.

Phase 11: SAT (Site Acceptance Test) + Services

- *Involved departments:* Project management, Service
- *Customer involved*
- *Short explanation:* During the last phase of the project, the SAT (Site Acceptance Test) + services phase, the complete system is transported to the customer. On site of the customer the system is installed in the customer setting, whereupon the system is tested. Service engineers perform these tests and the project manager is responsible to close the project officially. Company X provides a warranty for its systems. So when something happens with the system during the warranty period, the service department is 24/7 available to solve the problems, all over the world. Also after the warranty period, the customer could utilize the service department of Company X when it is needed.

- **Planning method used**

The project manager is responsible for a rough sketch of the project plan, after which it is refined by the department heads of the engineering and production department in consultation with the project manager. There is no planning program with an algorithm used to plan the project activities in an optimal way. The project plans are manually made in MS Project. The project manager determines a rough sequence of the activities based on his own estimate of the time required. The estimates of required time of the activities are based on their own insight and experiences in the business. Regarding the capacities of the departments, the project manager assumes that the departments have an infinite capacity (all employees of the department are available for the specific project). The department heads should convert it to a workforce plan based on available capacities.

When planning the activities, the project manager uses the forward planning strategy. This means that he makes a list of the activities that have to be done and plans them as soon as possible (precedence relations are taken into account). The project manager is aware of the deadline of the project, however he does not wait until the last possible starting dates of the activities. In this way, it is possible that the planned date of finishing the project exceeds the deadline date agreed with the customer. If so, the need for a discussion about what has to be done arises. Different issues could be discussed, such as:

- Whether there is a possibility to shift or swap several activities
- Whether it may be better and/or quicker (or even necessary) to outsource some activities
- Whether it is necessary to hire temporary additional staff in order to meet the agreed deadline

In all of these cases, precedence relations of activities have to be taken into account. Sometimes it is financially advantageous to not meet the agreed deadline and to instead pay the penalty as specified in the contract because this penalty may be lower than the additional costs Company X has to make in order to still be able to meet the originally intended deadline.

2.3 Overview status/problems planning related processes

In this section we give an overview of the status of the planning related processes and problems that might occur. As a starting point, we provide some findings within Company X that might influence the planning performance. After that, we use results of a visit to AWL (a comparable company where similar researches are performed) to further identify the status of planning related processes within Company X.

2.3.1 Findings within Company X

In this section, we provide findings that arise from interviews with the involved employees of Company X. By means of this section, we determine which issues occur frequently and are important. The focus in the remainder of this research is on these important issues.

The most frequent mentioned issues that are experienced as important could be classified in four categories, namely software/tools for planning, multiple departments involved during projects, estimation of durations of activities, and culture/awareness within the company.

Software/tools for planning

Within Company X, four different tools are used for planning. These four tools are managed and used by employees involved in different phases of the projects. The tools are not linked to each other, so a change in one tool will not automatically result in a change in the other tools. Because of the lack of a link between the planning systems, it is necessary that changes are passed on to the managers of the other systems. Since this not always happens, it is not possible to get a complete and accurate overview of single projects and all projects together.

Multiple departments involved during projects

During the different projects multiple employees and departments are involved. Sometimes processes are completed within the borders of a department, but sometimes processes are cross-departmental. In both cases, communication is a very important aspect. The communication between different departments proceeds arduously, resulting in missing information that is necessary for the process. Sometimes, this arduous communication is caused by the different stakeholders during a project. Different departments have different stakes within a project, which results in decisions that are beneficial for one department and disadvantageous for another. Due to these conflicting interests, the different departments are communicating insufficiently with each other.

Estimation of durations of activities

Wrong estimations of durations of activities might result in offers with incorrect lead times. When the durations are estimated too short, it is possible that an unrealistic lead time is issued to the customer. In that case, it will be extremely difficult to meet these agreements. When the durations are estimated too long, it is possible that Company X issues a too long lead time. This can cause that the customer chooses to cooperate with a competitor and order his system(s) there. So a good estimation of durations of activities and so the determination of the lead time is a very important aspect for the customer. Within Company X, the estimations are based on own experiences and insights and not on collected data of historical comparable activities. This information is currently not collected within Company X.

Culture/awareness within the company

Within Company X, there is more or less an individual culture instead of a corporate culture. Everyone does their job with full dedication and conviction, but only focused on their own activities and not on the whole project. So there is a lack of awareness regarding to the effects of own activities for the rest of the project and what the possible consequences might be for the planning process. Afterwards, when errors or failures occur it is easy to blame

other departments without reflecting on what they themselves may have done wrong or what they could do better in the future.

2.3.2 Perceived problems out of a similar research at AWL

AWL Harderwijk is a company that is comparable with Company X. It is also a project-driven organisation, and it develops and produces state-of-the-art automated welding machines for its customers. The welding machines are mostly unique products based on specific customer wishes. Therefore the way of business at AWL is comparable with the way of business at Company X. We visited AWL to see how they have improved their planning performance in the past decade. A project planner and a SHEQ-manager (former logistic manager) guided us to show the company and all planning related issues.

Within AWL Harderwijk two researches have been performed by students of the University of Twente, in the field of planning. The first research, by Meijerink (2003), was focused on the importance of capacity planning at AWL. The second research, by Evers (2013), elaborated on the previous research. Evers provided an overview and analysis of perceived problems in the field of planning. Table 2.1 shows the perceived problems he mentioned. We use these problems to determine the status of these problems within Company X.

Perceived problems out of a similar research at AWL	
# 1	Planning is done based on throughput times, rather than based on available capacity.
# 2	Operational scheduling and tactical planning is time consuming.
# 3	Planning responsibilities are dispersed over several layers and departments.
# 4	An overview of multiple projects simultaneously is not available in the operational scheduling software tool.
# 5	Planning methodology is the product of practice, rather than based on scientific literature.
# 6	Three different software packages are used.
# 7	Inexperienced employees often make mistakes.
# 8	Competences of employees are not mapped.
# 9	Several departments have different stakes when it comes to a project plan.
# 10	Milestones are not seen as hard deadlines.
# 11	There is fluctuation in customer demand.
# 12	The actual workload of various activities deviates from the estimated workload.
# 13	Customers change specifications during the course of a project.
# 14	Communication between departments is arduous.
# 15	Delivery of parts from customers or suppliers is often tardy.

# 16	Sometimes quality of parts, subassemblies or engineering work is poor.
# 17	KPIs related to planning performance are not always measured.

Table 2.1 Perceived problems out of a similar research at AWL

1 Planning is done based on throughput times, rather than based on available capacity.

Within Company X, the project managers determine a rough sequence of the activities based on their own estimates of the time required and the capacities of the engineering department and the production department. The own estimates of required time of the activities are based on their own insight and experiences in the business. Regarding the capacities of the departments, the project manager assumes that the departments have an infinite capacity. So also within Company X, the planning is done based on throughput times, rather than based on available capacity.

2 Operational scheduling and tactical planning is time consuming.

Within Company X, there is no employee with a full-time responsibility for planning. The department heads of the engineering department and the production department (in association with the work preparer) do schedule their individual workers to the activities, as one of the many activities that they have to carry out. Of course, it is time consuming but it is not a full-time job for someone. This might result in more time consuming planning, because no one is specialized in planning.

3 Planning responsibilities are dispersed over several layers and departments.

Within Company X, several departments/persons are involved at different stages during the planning process. This is the case because most projects are complex and nobody has the exact knowledge to know all activities within the project in detail. Besides this multi-project planning is difficult, because the project manager is responsible for a specific project and not the department heads of the engineering department and the production department (who have to schedule the employees to the activities). So, within Company X this problem is certainly there.

4 An overview of multiple projects simultaneously is not available in the operational scheduling software tool.

Within Company X, it is not possible to see whether projects are behind or in front of the planned schedule. The only one who roughly knows the progress of a project, is the responsible project manager. So the project manager has to inform the department heads of the engineering department and production department, which does not always happen. When the project manager does inform the department heads, there is no overview of all

simultaneous projects aggregated. So for a department head it is hard to identify whether it is necessary to act and make some adjustments to the schedules. Thus, the missing overview of multiple projects within Company X becomes visible in two ways. Namely, there is less project progress overview and there is no aggregate project overview.

5 Planning methodology is the product of practice, rather than based on scientific literature.

Within Company X, the plans are based on own estimates and experiences in the business. So the planning methodology is the product of practice, instead of it is based on scientific literature. While in the scientific literature is proven that using algorithms results in better throughput or levelled workload, plans are made without using algorithms.

6 Three different software packages are used.

Within Company X, different software packages are used. The software tool MS project is used by the project managers (Figure 2.4 shows an example). The ERP system is used by the engineering department and the production department (the work preparer) to plan the necessary activities. Besides that, the engineering department heads uses a WBS to schedule the engineering employees and they use Excel. So in total, 4 different tools are used for planning.

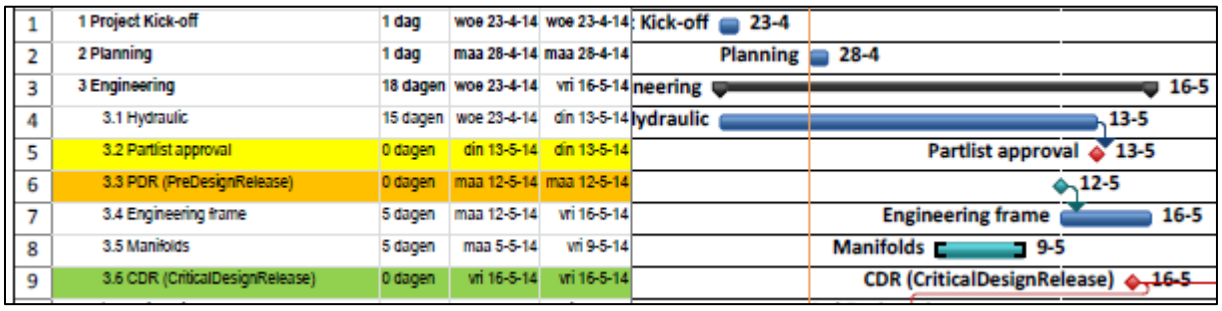


Figure 2.4 Example of a limited MS project plan for the engineering part

7 Inexperienced employees often make mistakes.

Within Company X, young technicians get the chance to develop themselves. This might result in a higher chance of mistakes on the shop floor. These higher error rate could also be due to the use of temporary workers and interns. Of course mistakes could also be caused by experienced employees.

8 Competences of employees are not mapped.

Within Company X, there is no capability matrix available. So competences are not mapped and therefore it is hard to manage the employees correctly. The managers know these competences by heart, but if they were replaced this knowledge is lost. The missing

knowledge of employee competence could result in a bottleneck during the planning process. Thus, Company X also has to deal with this problem.

9 Several departments have different stakes when it comes to a project plan.

Within Company X, different departments have different interests during the completion of a project. These interests are often opposites of each other. For example, the sales department wants a short lead time to obtain a good negotiation position with the customer. On the other hand, departments such as the production department and the purchasing department would like to have more time to execute their jobs well and expertly. In addition, the project managers have different interests. The project manager want the best for a specific project he is responsible for and not the best for all projects together So also within Company X different stakes play a role during the completion of projects.

10 Milestones are not seen as hard deadlines.

Within Company X, milestones are used in the majority of cases as the moment that the (partial) invoice can be sent. So a milestone is not seen as a hard deadline, but they are important since the money can be received sooner.

11 There is fluctuation in customer demand.

Within Company X, the fluctuation in demand for capacity is partly due to the fluctuation in customer demand. It is hard to level out the capacity demands, since it is hard to forecast the customer demand correctly caused by the irregular demands. For example, Figure 2.5 shows the cumulative percentage of the order intake of Company X in 2014. It shows no stable growth, some periods are almost without order intake while others are extremely good.

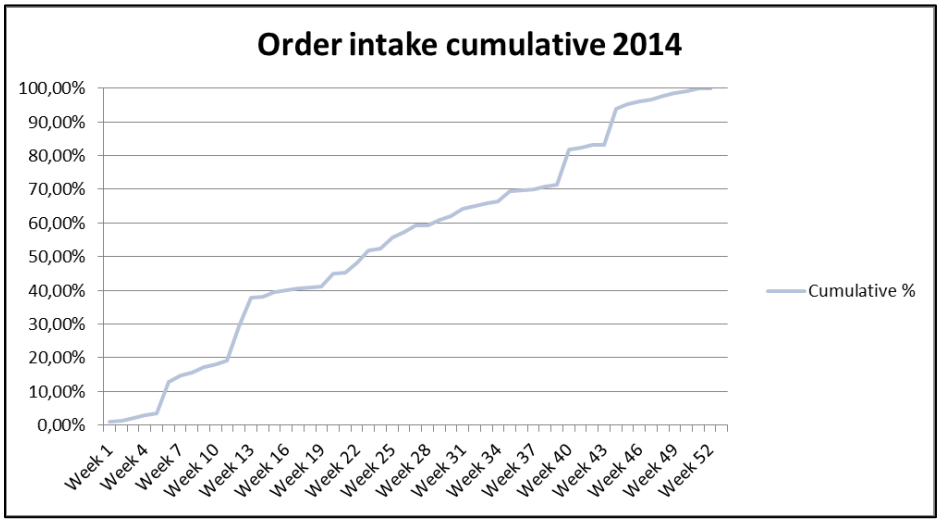


Figure 2.5 Cumulative percentage of the order intake of Company X in 2014

12 The actual workload of various activities deviates from the estimated workload.

Within Company X, the actual workload of activities mostly deviates from the estimated workload. The estimations made during the quotation phase are based on own insights and experiences, and variability is not taken into account. According to Hans et al. (2007) there are two main causes of uncertainty: the detailed information on the project becomes available gradually and the operational uncertainties on the shop floor. This information is not available for the sales person who makes the quotation and within Company X there is also a lack of feedback during the project, which makes it hard to make good estimations of the durations of activities (the next time).

13 Customers change specifications during the course of a project.

Within Company X, it often happens that customers change their specification of requirements during the course of a project. Therefore it may be necessary to change activities (or their sequence), or add or remove some activities. This is a very common issue within the business Company X is active in.

14 Communication between departments is arduous.

Within Company X, there is a lack of communication between the different departments or the communication proceeds arduously. This has the consequence that employees sometimes do not know information they have to know. It may involve a priori information, but also the lack of feedback is an issue within Company X.

15 Delivery of parts from customers or suppliers are often tardy.

Within Company X, not all delivered or supplied parts from customers or suppliers are on time. Too late delivery can postpone the starting points of different activities, which in turn may have implications for meeting the agreed deadlines. Sometimes the late deliveries are results of not respecting the standard delivery times of the suppliers by the purchasing department of Company X. The purchasing employee ordered the needed items too late because of the time pressure, resulting that it is impossible for the supplier to deliver at the desired delivery date. So tardy delivery of parts is a big issue for Company X, but it is not always (only) caused by the external parties.

16 Sometimes quality of parts, subassemblies or engineering work is poor.

Within Company X, not everything has the quality that is necessary for the project at the first time (first time right). For example delivered parts or internal work might not meet the expected quality requirements, what could cause extra work or re-ordering of parts and so loss of time.

17 KPIs related to planning performance are not always measured.

Within Company X, KPIs are measured and controlled during quarterly meetings. However, there are no concrete KPIs regarding to the planning performance. There is one KPI about the on-time delivery that is measured, but the on-time delivery is not only dependent of the planning but also of other influences (such as delivery performance of suppliers or internal quality of the executed activities within the engineering department and the production department).

- **Conclusion of comparison Company X – AWL after company visit**

All perceived problems that emerge from the research of Evers at AWL also play a part at Company X. Some of them to a lesser extent, but others appear to be more important. In addition, within Company X there are some perceived problems that are not perceived within AWL. In consultation with the project planner and the SHEQ-manager of AWL, we conclude that Company X currently is at the same level as AWL was about 10-12 years ago. AWL recommended to improve the planning performance incremental. They have experienced that big sweeping changes did not have the desired effect. AWL indicated that an important aspect to improve the overall planning performance is the switch from a single-project orientation to a multi-project orientation. In addition, it is necessary to structure and organize the organisation and their processes such that the company is aimed at completing multiple projects according to the agreed arrangements with the customers.

2.4 Conclusion

During the analysis of the current situation reveals that the current level of planning performance within Company X is relatively low (compared to comparable companies as AWL, which was at the same level 10-12 years ago). There is a lot of potential for improvements. The most important topics that require attention are the possible switch from a single-project orientation to a multi-project orientation and the organisation of internal processes. These topics are the main topics for the remaining of this research.

Chapter 3 Theoretical framework

In this chapter we provide the results of a literature study. In Section 3.1 we describe the positioning of the situation of Company X based on theory. We position the situation to create a focus for the remaining of the theoretical framework. Section 3.2 provides ways of planning described in the literature and Section 3.3 elaborates on multi-project planning and what is needed for it. For this chapter, we use scientific articles from scientific libraries (Google Scholar, Scopus, Web of Knowledge). In Appendix 2 we provide a list of used search terms to collect the desired literature.

3.1 Positioning of situation Company X

We use this section to position the situation Company X based on the available literature. Section 3.1.1 provides different production environments to identify the one suits for Company X. We use this section also to elaborate on project-drive business. In Section 3.1.2 we explain the methodological framework of Leus and Herroelen to position the situation of Company X based on the degree of dependency and the degree of variability. Section 3.1.3 describes the hierarchical project planning and control framework to position the situation of Company X based on the level of decision making.

3.1.1 Production environments and project-driven business

Production environments differ in the way the production is driven. The order penetration point (OPP), also called customer order decoupling point (CODP), defines the stage where a particular product is linked to a specific customer order (Olhager, 2003). The OPP divides the stages during the production that are forecast-driven (left from the OPP with the dotted lines in Figure 3.1) from those that are customer-order-driven (right from the OPP with the straight lines in Figure 3.1).

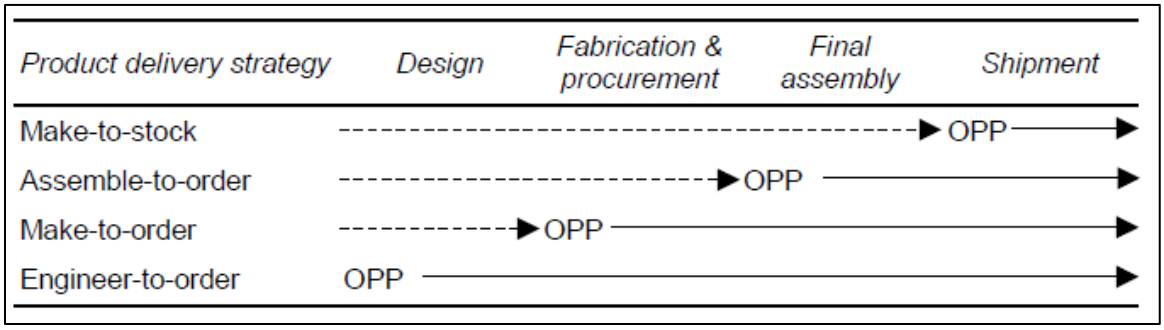


Figure 3.1 Production environments based on Order penetration point (Olhager, 2003)

Figure 3.1 shows 4 different production environments with different order penetration points. Within Make-To-Stock (MTS) environments, the product is completely finished based on forecasts and after an order, the product needs only to be sent to the customer. Within Assemble-To-Order (ATO) environments, the production is still forecast-based. After an order, the product needs to be assembled and sent to the customer. Within Make-To-Order (MTO) environments, the production is more customer-order-based. Only, the design is made based on forecast and the other stages are performed after the customer order. Within Engineer-To-Order environments, all stages are performed after the customer order is received. Company X is a typical ETO environment, since the products are mostly one-offs that need to be engineered after the order is received.

Different researchers mentioned that the nature of work has become more and more project-oriented and less routinized, due to the increasing global competition and increasing technology (Leybourne, 2007), (Wang & Salunga, 2007). A project can be informally defined as a unique undertaking consisting of a complex set of precedence-related activities that have to be executed using diverse and mostly limited company resources (Hans, Herroelen, Leus, & Wullink, 2007). Project-driven businesses often include complex product systems that have to be fabricated (Acha, Davies, Hobday, & Salter, 2004). Project-driven businesses are often characterized by the competitive environment they are part of. Staff is required to operate at multiple projects simultaneously and is under challenging time pressure (Fricke & Shenhar, 2000), (Kaulio , 2008). When multiple projects are running at the same time, it is necessary to share resources with other projects and to find a way of handling resource scarcity taking into account the overall strategy of the company (Cusumano & Nobeoka, 1998). In these settings of multiple projects it has become increasingly evident that project managers must be able to adapt not only their own evolving project needs but also to those of the concurrent projects that they themselves do not personally manage (Bendoly, Perry-Smith, & Bachrach, 2010).

A characteristic of multi-project environments is the antagonism of minimizing idle time of resources and the timely execution of projects (Ben-Zvi & Lechler, 2011). If all resources are allocated, there is no way to cope with variation during the execution of projects. Ben-Zvi and Lechler (2011) mentioned that this could lead to a cascading effect and delays in one project could cause delays in all projects that are initiated later. So variation influences the performance of timely project execution. This uncertainty may stem from a number of possible sources (Herroelen & Leus, 2005), namely: activities may take more (or less) time than originally estimated, resource may become unavailable, material may arrive behind

schedule, and new activities may have to be incorporated or dropped due to changes in the project scope. Those uncertainties may entail additional project costs due to missed due dates and deadlines, resource idleness and higher 'work-in-progress' projects (Ben-Zvi & Lechler, 2011).

Meredith and Mantel (2003) distinguish three major organisational methods commonly used to manage multiple projects, which we briefly discuss. The first method describes the act of situating projects so as to make them a part of one of the functional divisions of the company in their entirety in such a way that the functional division is completely responsible for the project. A functional division is a part of an organisation that performs a certain group of activities, so the project cannot include any other activities. Another method is the pure project organisation, in which the project becomes a self-contained unit with its own resources and dedicated staff. The third method is an intermediate method, the matrix structure. In this case, resources are associated with functional departments but are allocated to projects as well. When the matrix structure is balanced, the multi-project organisation can be modelled as a job shop or assembly shop: projects are jobs that flow between workstation (the different functional departments that perform the work).

3.1.2 Methodological framework

Leus and Herroelen (2005) develop a methodological framework that is used for the positioning of project planning methods, based on the distinction of two determinants: the degree of general variability in the work environment and the degree of dependency of the project (Leus, 2003), (Herroelen & Leus, 2005). With dependency they mean to what extent a project is dependent on influences. These influences could occur from outside the company (such as material supply or subcontractors), but they could also occur from inside the company (such as share resources with other projects). Below we summarize the developed methodological framework (as shown in Figure 3.2). The case-by-case comments are based on Hans et al. (2007).

Dependency → / Variability ↓	LOW	HIGH
LOW	*LL*	*LH*
HIGH	*HL*	*HH*

Figure 3.2 A positioning framework for multi-project organisations (Hans, Herroelen, Leus, & Wullink, 2007)

LL (low variability and low dependency):

Can typically be found in single-project organisations. Activities in these types of organisations have a low degree of variability and resources are dedicated to one specific project. These types of projects often have little interaction with other projects, which also results in less dependency.

HL (high variability and low dependency):

Can typically be found in environments with large construction projects. High variability due to the large environmental uncertainties such as weather conditions and uncertain or frequently changing project specifications. The resources are typically dedicated, because of the size of the projects. This results in low dependency.

LH (low variability and high dependency):

Can typically be found in small manufacturing organisations, for example a make-to-order (MTO) manufacturer. Variability is on a low degree because of the relatively basic manufacturing process and the low degree of complexity of the products and production processes. On the other hand the dependency is high, this is due to the fact that many projects claim the same machines/resources at the same time.

HH (high variability and high dependency):

Can typically be found in engineer-to-order (ETO) environments in which multiple complex projects are running simultaneously. Most of these projects are one-offs and completely new, which leads to a long engineering trajectory. Customers may change their specifications several times and products are very complex; therefore, the environment is subject to high degree of variability. Since such companies are running multiple projects at the same time, these companies are subject to a high degree of dependency between projects and dependency of scarce resources that should be shared.

Methodological framework applied to Company X

Company X is a company that typically could be described as an engineer-to-order (ETO) environment. Most of the projects of Company X are complex one-offs with a long engineering trajectory. During the projects, Company X is subject to a high degree of variability due to uncertainty since products are complex and customers may change their specifications several times. In addition, the variability due to uncertainty may be caused through the supply of (incorrect or too late) materials and through the wrong execution of activities. Company X is also subject to a high degree of dependency since multiple projects

are running at the same time and scarce resources must be shared. Therefore we conclude that Company X is a company that suits in the HH part of the methodological framework.

3.1.3 Hierarchical project planning and control framework

Hans et al. (2007) set up a hierarchical project planning and control framework to determine the stages where planning is involved in multi-project environments with uncertainty. Their aim was to provide a framework that is able to deal with complexity and uncertainty. The framework consists of three hierarchical levels, namely the strategic level, the tactical level, and the operational level. Besides the three hierarchical levels the framework consists of three functional planning areas, namely the technological planning area, the resource capacity planning area, and the material coordination area. Figure 3.3 shows the hierarchical project planning and control framework of Hans et al.

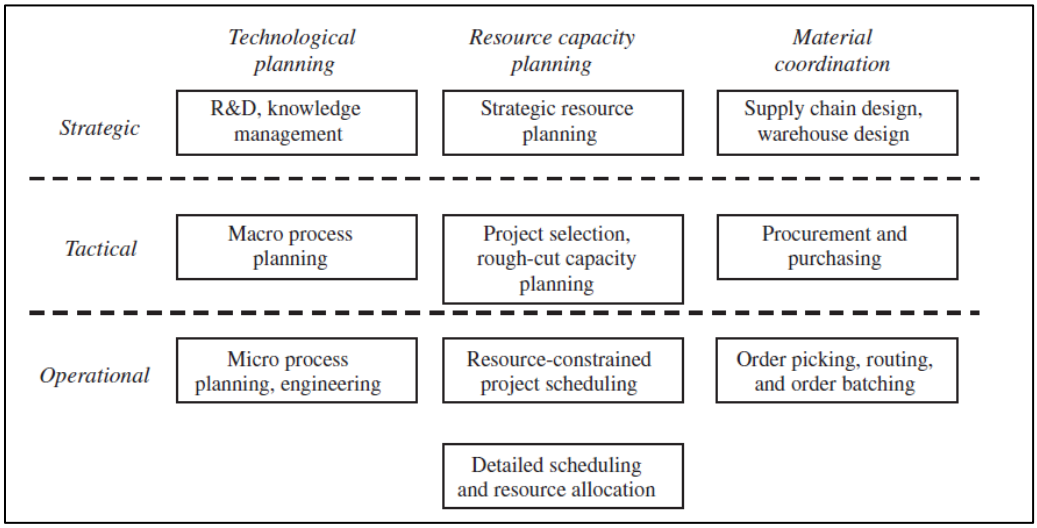


Figure 3.3 A hierarchical planning and control framework (Hans, Herroelen, Leus, & Wullink, 2007)

On the *strategic level* decisions are made by the higher (management) level of the organisation to set up a long term vision for the organisation. The decision determines the way how an organisation is going to achieve its goals, for example which products it is going to market and with what fixed capacity it should be done. In the functional planning area *Material coordination* are strategic decisions made about the design of the supply chain and design of the warehouse.

On the *tactical level* decisions in the functional planning area *Resource capacity planning* are made to allocate available capacity to available projects. The available capacity consists of

the fixed regular capacity, but it is possible to hire additional non-regular capacity against additional costs. These decisions are middle term and mostly based on known demand.

On the *operational level* short term decisions in the functional planning area *Resource capacity planning* are made to schedule the activities. At that point the activities that need to be done and their expected duration are known. The activities should be scheduled first off-line, which means that is determined who has to do the activities and in what sequence. On-line scheduling is monitoring the execution of the process, and making changes to the schedule when it is necessary.

Hierarchical planning and control framework applied to Company X

The strategic level is not part of the scope for this research, since we are not going to change the fixed capacity of Company X. Also we do not investigate whether Company X markets the right products. Our focus is on the *tactical* and *operational level* of the functional planning area *Resource capacity planning*.

During the *tactical resource capacity planning* the project selection is executed by the sales department. They are responsible to decide whether it is possible to handle the project, the project selection. The rough-cut capacity planning is executed by the project manager during the project kick off. Then a rough sequence of activities is determined, and in consultation with the engineering department and the production department the availability of the resources is checked.

During the *operational resource capacity planning* stage, the departments of the engineering department and the production department schedule their department employees to the activities to be executed. These decisions are often taken in consultation with the responsible project manager.

3.2 Ways of planning

In this section, we distinguish different ways of planning based on the amount of projects taken into account (single-project or multi-project) and the method of capacity utilization (infinite or finite capacity). In Section 3.2.1 we describe single-project planning with infinite capacity, in Section 3.2.2 we describe single-project planning with finite capacity, in Section 3.2.3 we describe multi-project planning with infinite capacity, and in Section 3.2.4 we describe multi-project planning with finite capacity. During the description of these different planning methods, we use example projects of Meijerink (2003). She used two different

projects (Project 1 for the single-project planning methods and adding Project 2 for the multi-project planning methods). Figure 3.4 shows the two simple projects.

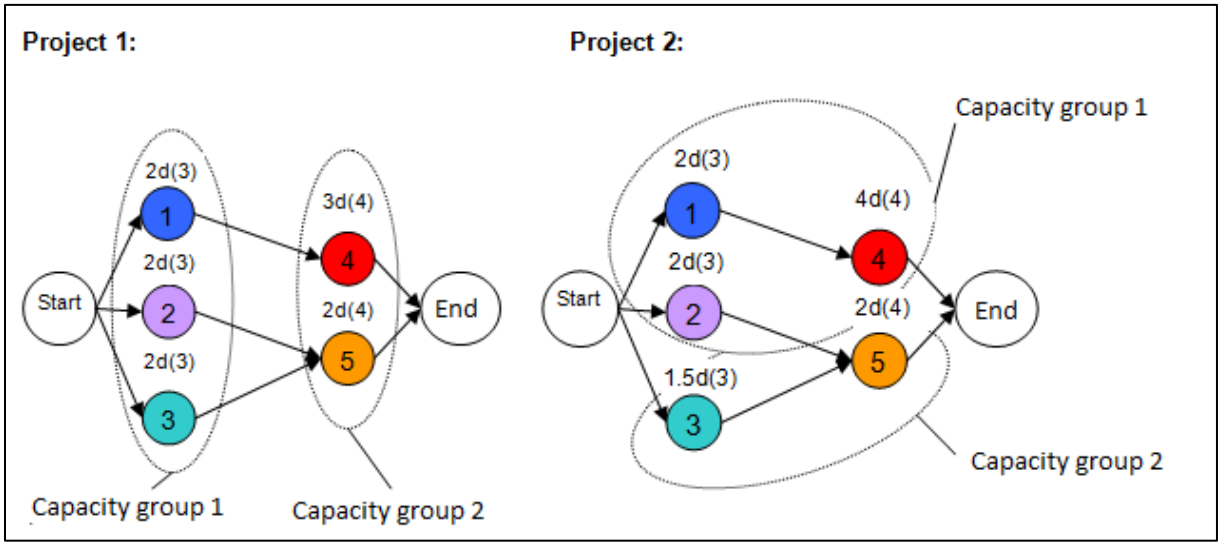


Figure 3.4 Example projects to show different planning methods based on Meijerink (2003)

Figure 3.4 shows two projects with both 5 activities. Each activity has a duration in days and the necessary amount of people during this duration is noted within the brackets. So, activity 1 of project 1 has a duration of 2 days and during these 2 days 3 employees are needed. There are two different capacity groups (for example the engineering department and the production department. Precedence relations are taken into account, such as that activity 5 of project 1 only can start when activities 2 and 3 are finished. The projects must be completed within 7 days.

3.2.1 Single-project planning with infinite capacity

Since the planning is based on infinite capacity in the two capacity groups, the only restriction of the plans is the precedence relations between the activities. Activity 4 of project 1 can only start after activity 1 is finished. The same applies to activity 5 after activity 2 and activity 3. Figure 3.5 shows the time plan for project 1 with infinite capacity.

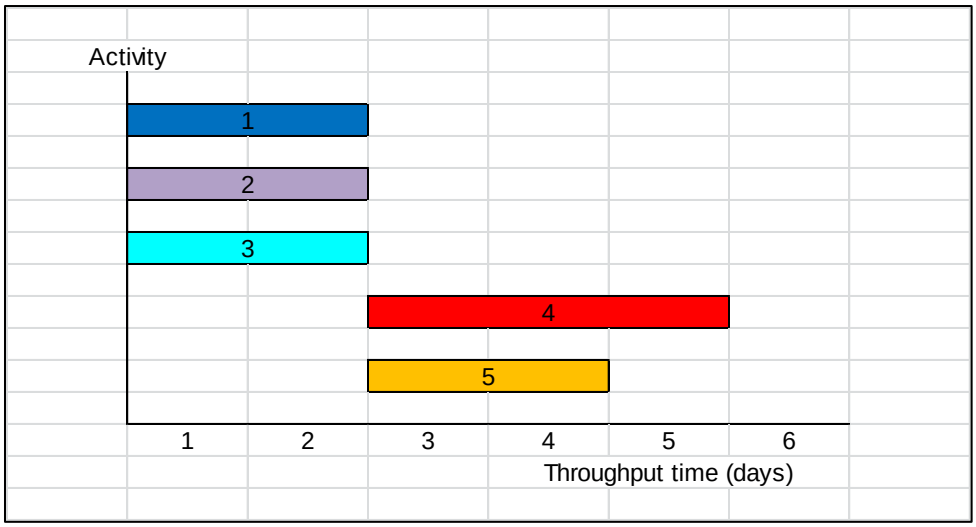


Figure 3.5 Time plan for project 1 with infinite capacity based on Meijerink (2003)

Since the capacity groups have infinite capacity, the activities can be started at the same time (precedence relations taken into account). So activities 1, 2, and 3 start directly and activities 4 and 5 start when the previous activities are finished (after 3 days). Figure 3.6 shows the needed capacities in the capacity groups for executing the time plan.

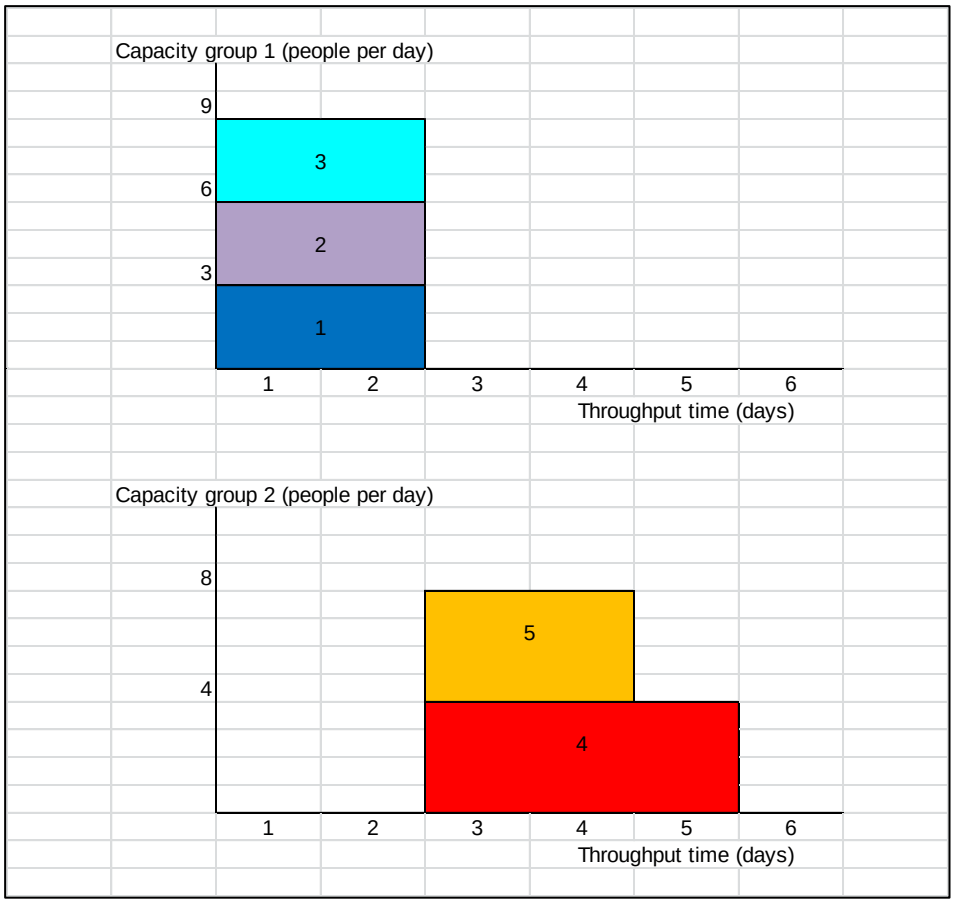


Figure 3.6 Needed capacities in capacity groups for executing time plan of project 1 based on Meijerink (2003)

3.2.2 Single-project planning with finite capacity

Again only project 1 is planned, but now the available capacities of the capacity groups are taken into account. Capacity group 1 (say, the engineering department) has 3 employees available per project and capacity group 2 (say, the production department) has 4 employees available per project. This results in the time plan in Figure 3.7.

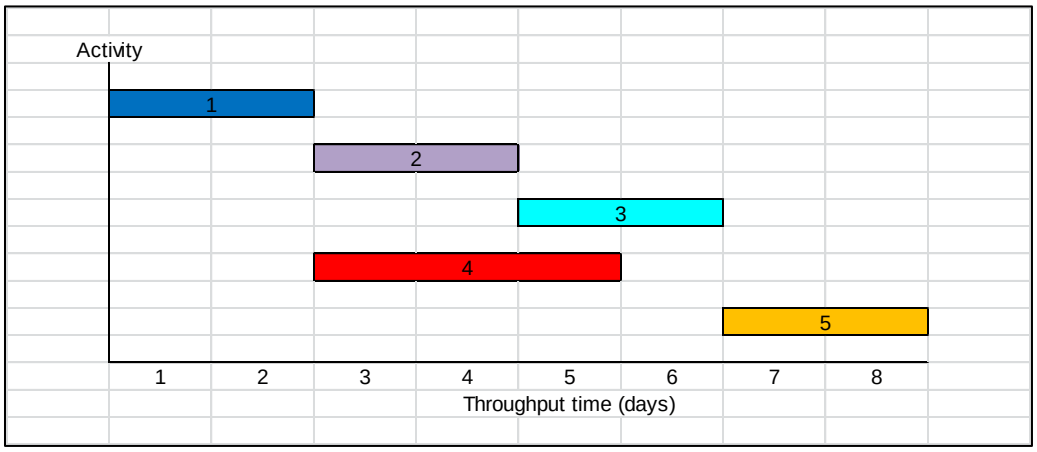


Figure 3.7 Time plan for project 1 with finite capacity based on Meijerink (2003)

In this case, it is not possible to complete the project within 7 days only with regular capacity. Because activities 1, 2, and 3 may only start when their predecessor is ready, activity 5 can only start on day 7. This means that the project is finished after 8 days, so there is non-regular capacity needed to meet the restriction of 7 days. It only makes sense if one of the following activities will be shortened with one day: 1, 2, 3, or 5. For activity 1, 2, or 3 there are 3 non-regular employees needed and for activity 5 there are 4 non-regular employees needed to complete the project within 7 days. Therefore we choose to shorten activity 1 with one day. This results in the time plan that Figure 3.8 shows.

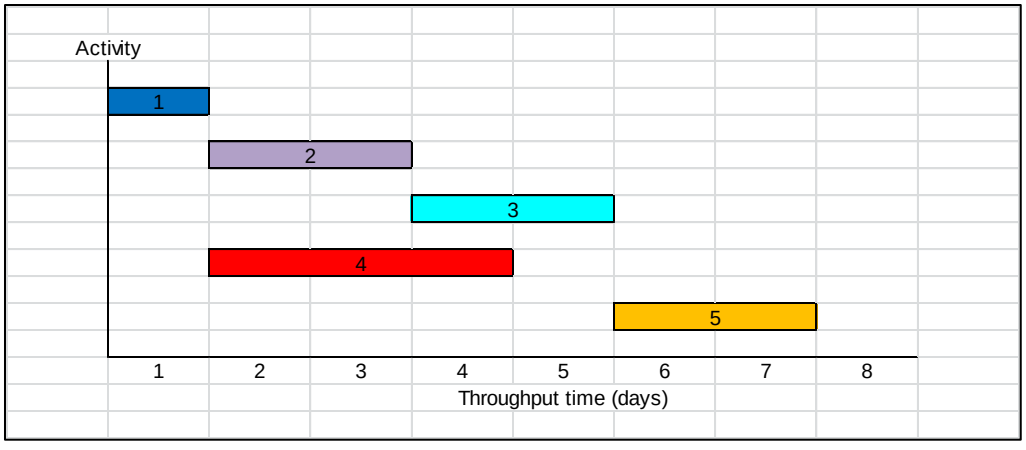


Figure 3.8 Time plan for project 1 with finite capacity where activity 1 is shortened based on Meijerink (2003)

Figure 3.9 shows the needed capacities in the capacity groups for executing the new time plan. In the figure, the non-regular capacity is accentuated with diagonal stripes. In this case, 3 non-regular employees are needed for one day.

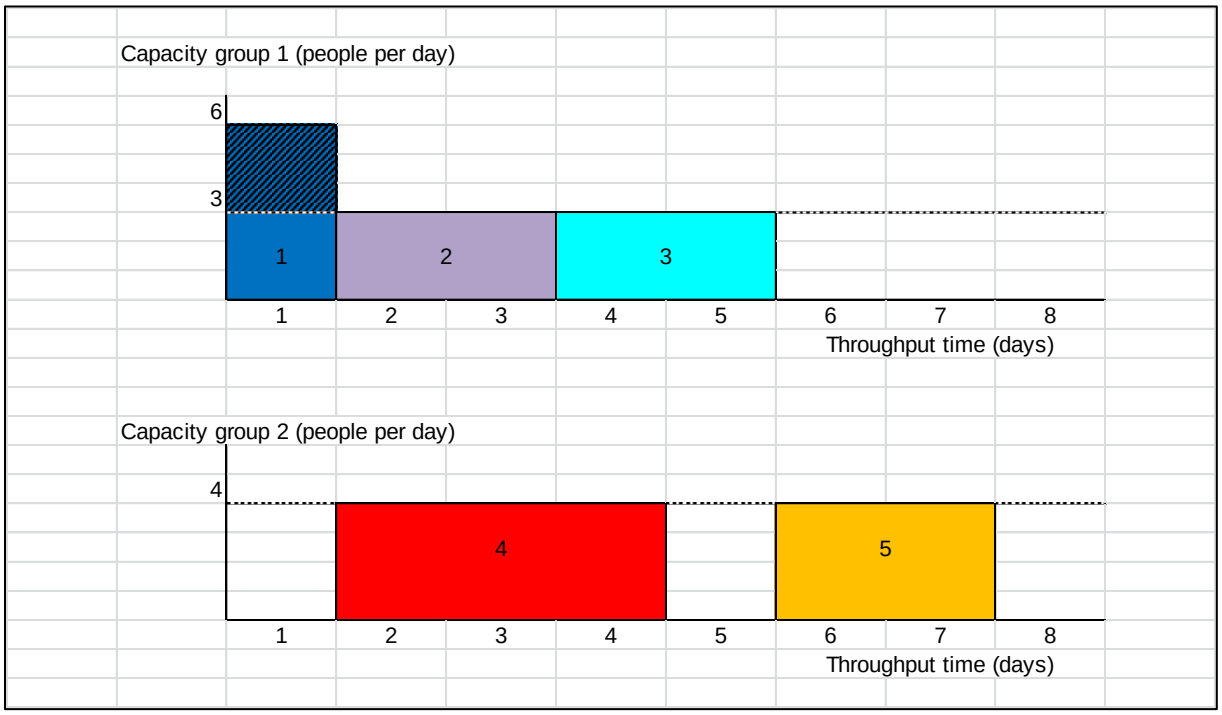


Figure 3.9 Needed capacities in capacity groups for executing time plan of project 1 based on Meijerink (2003)

3.2.3 Multi-project planning with infinite capacity

For the multi-project planning also example project 2 is taken into account. This project is comparable with project 1, but has other durations of activities and the activities are different divided over the capacity groups. In this case, the two projects both have to be completed within 7 days and we have infinite capacity at our disposal. This results in the time plans for project 1 and project 2 in Figure 3.10.

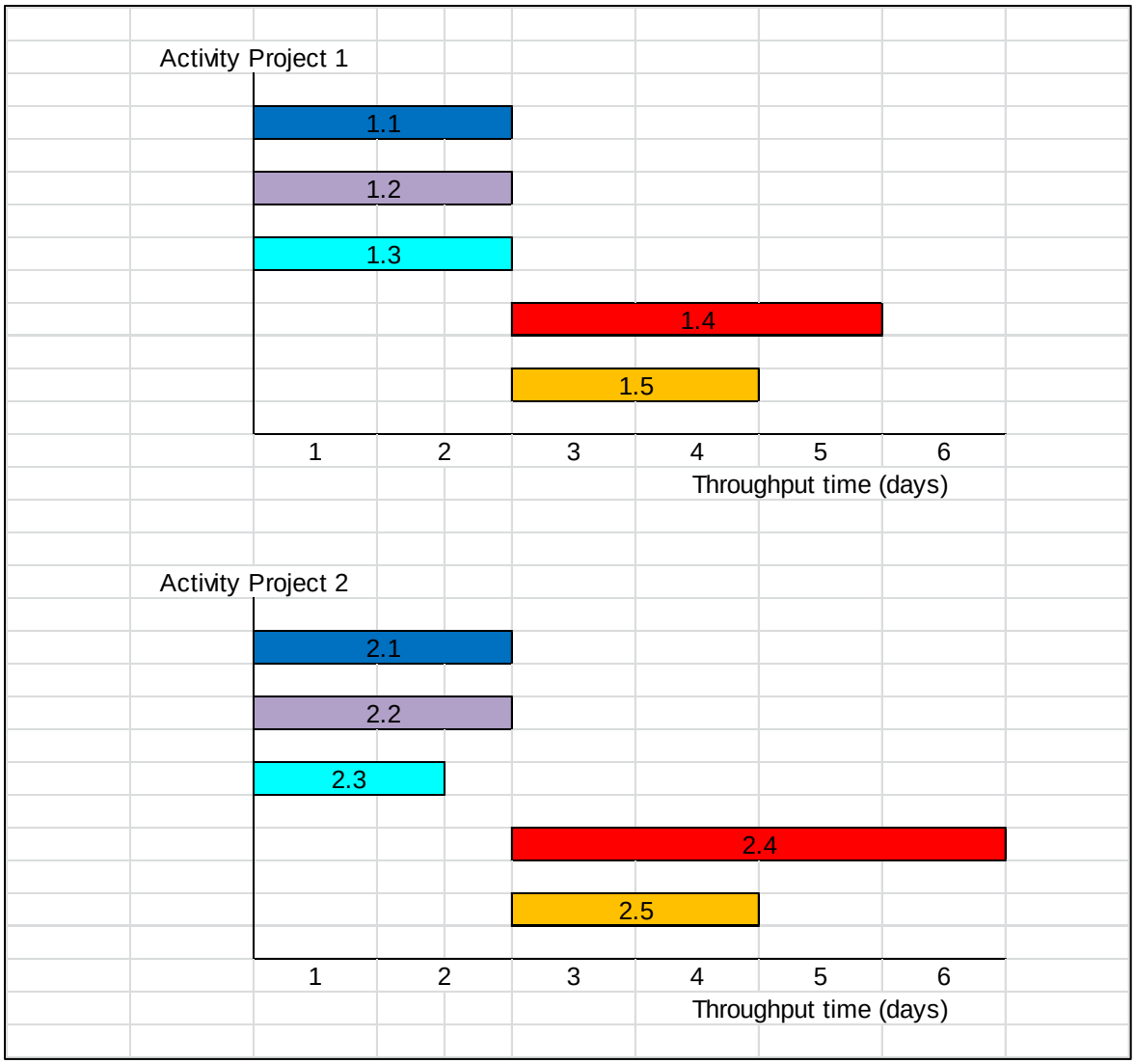


Figure 3.10 Time plans for project 1 and project 2 with infinite capacity based on Meijerink (2003)

Figure 3.11 shows the needed capacities in the capacity groups for executing the time plans. In this case, both capacity groups have infinite capacity available. So all activities could directly start when there predecessor(s) are finished.

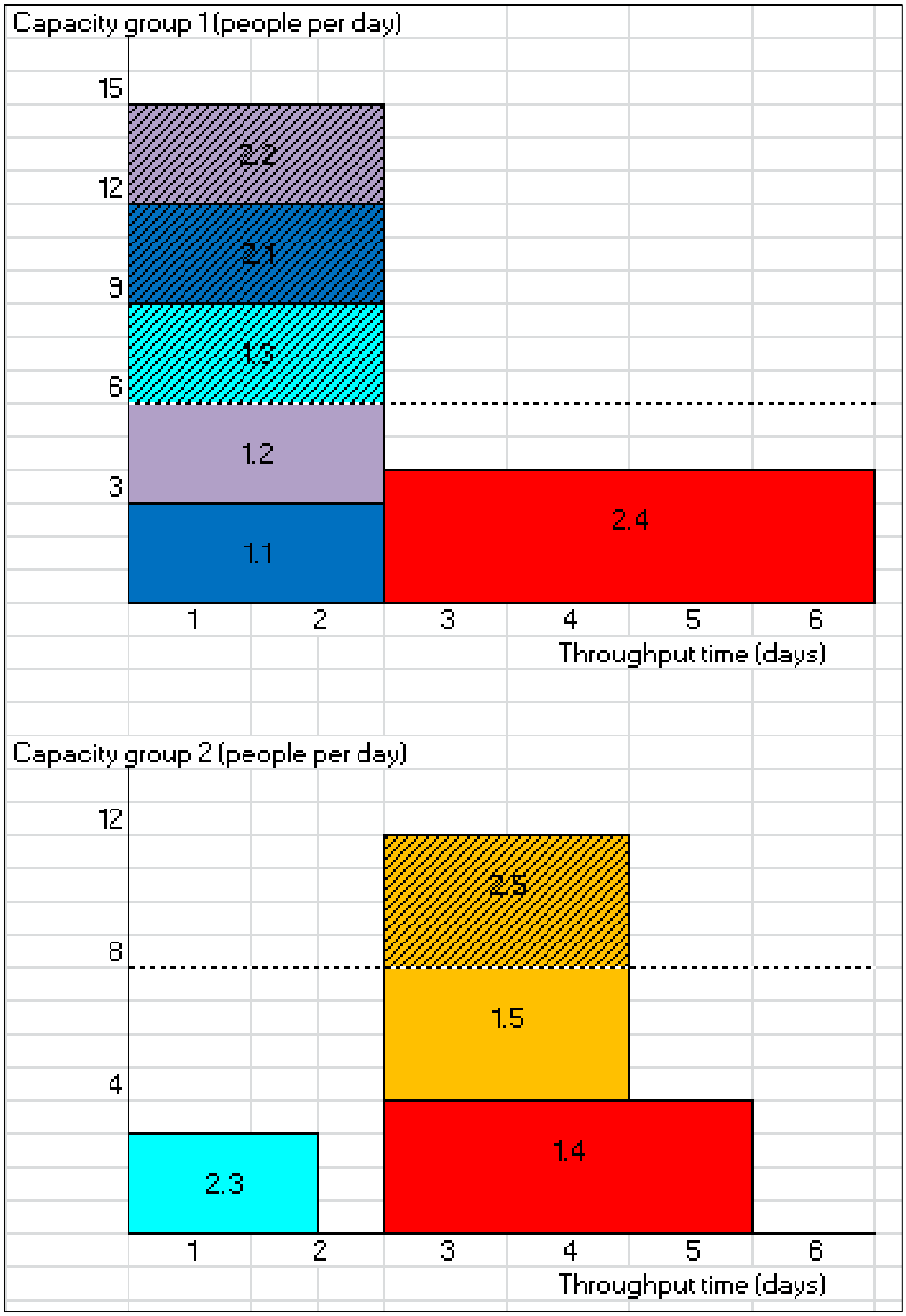


Figure 3.11 Needed capacities in capacity groups for executing time plans of projects based on Meijerink (2003)

3.2.4 Multi-project planning with finite capacity

Again project 1 and project 2 are planned, but now the available capacities of the capacity groups must be taken into account. Capacity group 1 has 6 employees available and capacity group 2 has 8 employees available. This results in the times plan in Figure 3.12.

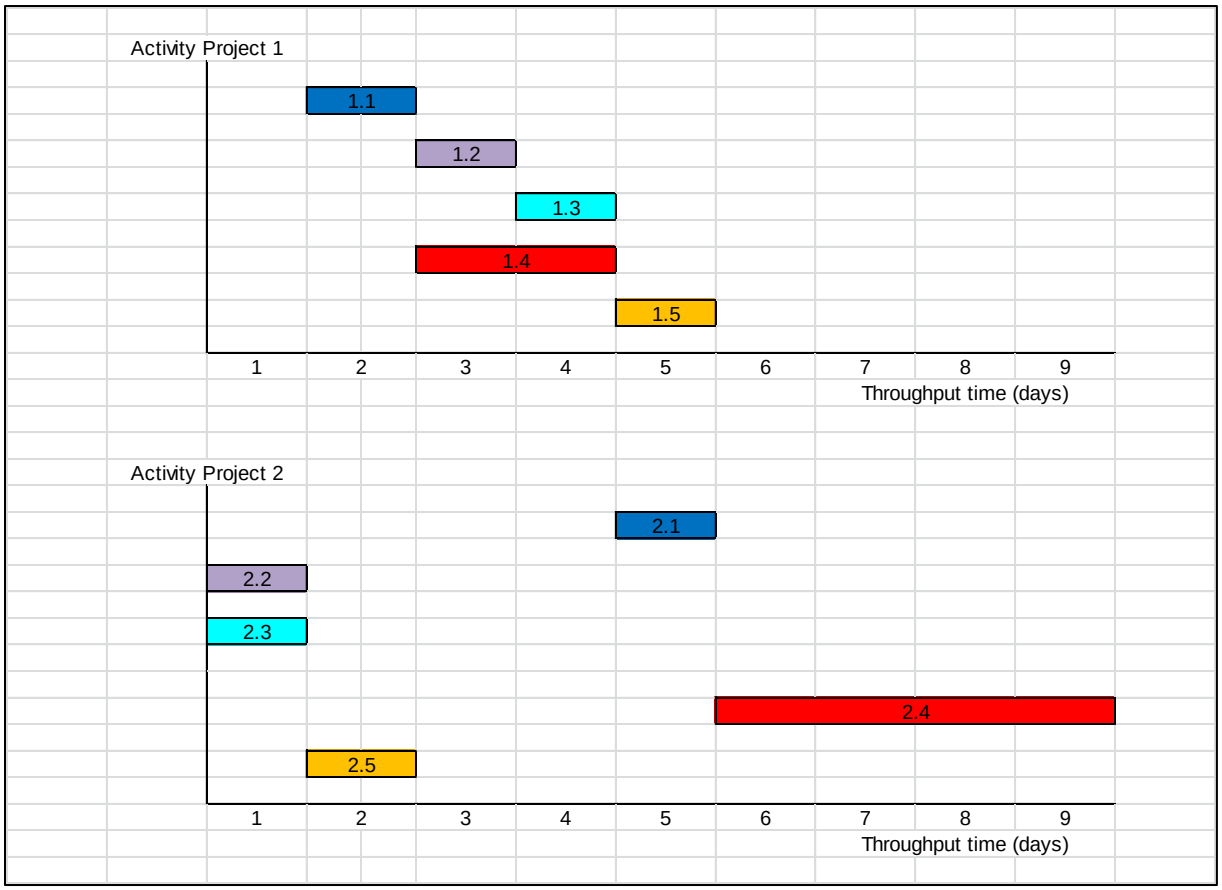


Figure 3.12 Time plans for project 1 and project 2 with finite capacity based on Meijerink (2003)

In this case, it is not possible to complete the project within 7 days only with regular capacity. Because activity 2.4 may start only at day 6 (due to his predecessors that cannot be shortened because their duration is only one day), it is necessary to shorten activity 2.4. The solution to shorten the activity with 2 days is to hire non-regular capacity. This decision results in a new time plan as in Figure 3.13.

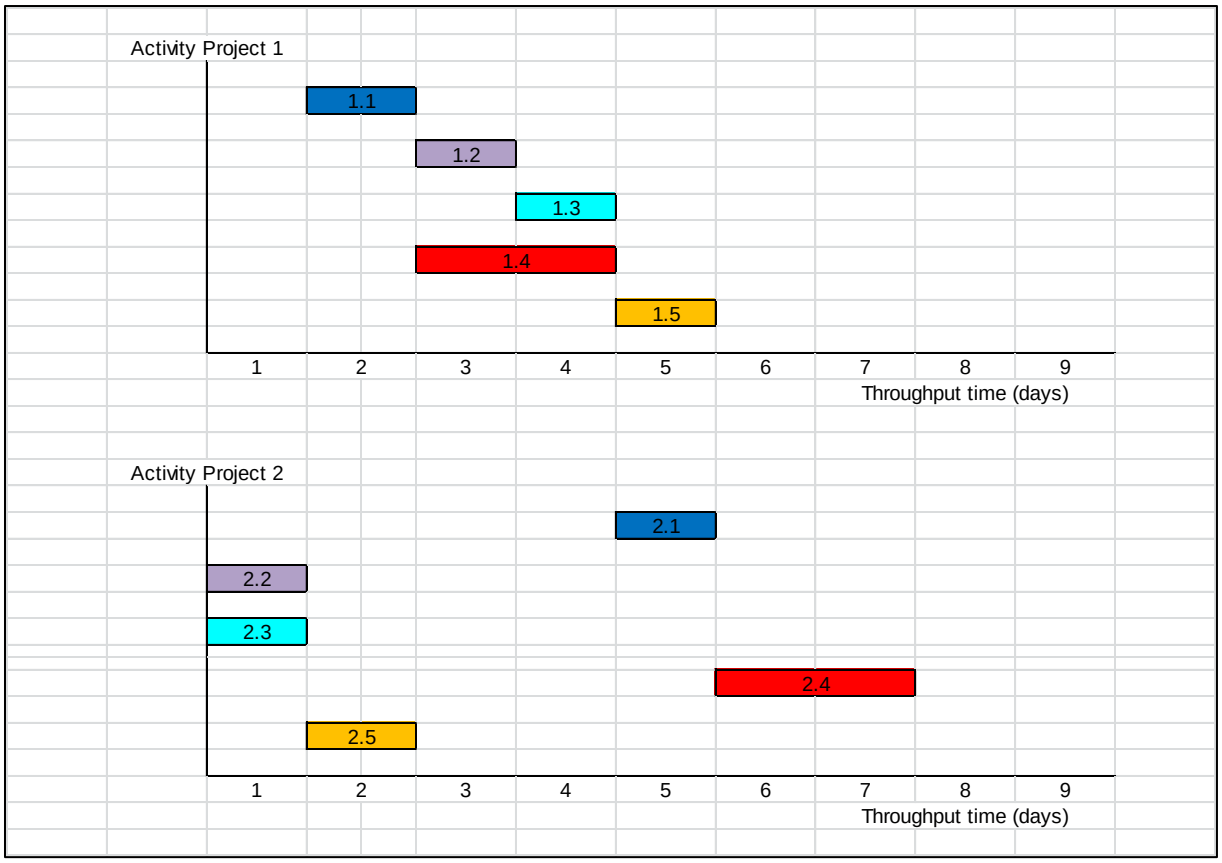


Figure 3.13 Time plans for project 1 and project 2 with finite capacity where activity 2.4 is shortened based on Meijerink (2003)

Figure 3.14 shows the needed capacities in the capacity groups for executing the new time plans. Herein, the non-regular capacity is accented with diagonal stripes. In this case, 2 non-regular employees are needed for two days.

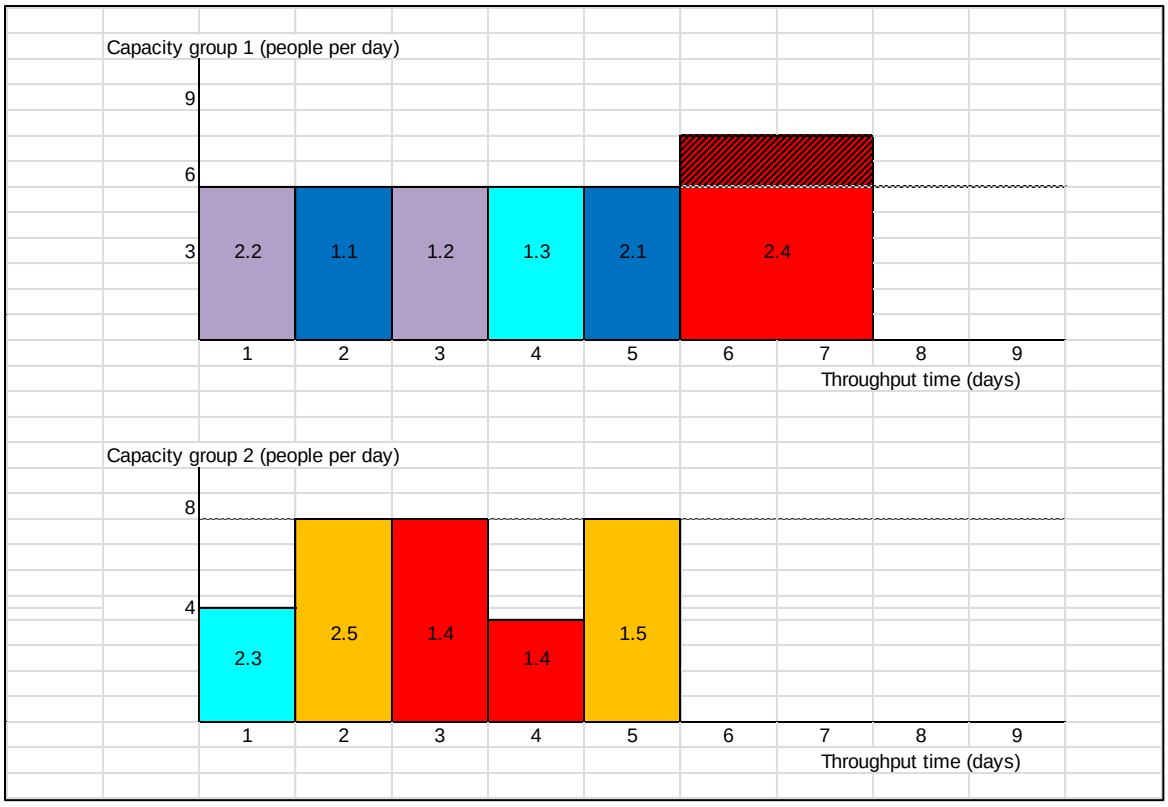


Figure 3.14 Needed capacities in capacity groups for executing time plans of projects based on Meijerink (2003)

- **Conclusion of different ways of planning for Company X**

To get an overview of the projects combined and not only separately, it is preferred to use multi-project planning. Then the plans are based on work content, instead of fixed throughput times of the projects. Therefore it shows at an early stage if it is necessary to hire non-regular capacity. The planning problem becomes more complex when the available capacities are added. However, in this way a cost advantage can be achieved due to the less needed non-regular capacity. Table 3.1 shows the differences in needed capacities for the examples of multi-project with finite and infinite capacities.

Infinite capacities	Capacity group 1	Capacity group 2	Total hours
Regular hours	224	196	420
Non-regular hours	144	64	208
Total hours	368	260	628
Finite capacities	**Capacity group 1**	**Capacity group 2**	**Total hours**
Regular hours	336	260	596
Non-regular hours	32	0	32
Total hours	368	260	628

Table 3.1 Differences in needed capacities for examples of multi-project planning

Chapter 4 Desired situation

In this chapter we focus on the desired situation for Company X. In Section 4.1 we identify the wishes for the desired situation within Company X based on interviews with involved employees. We evaluate all the referred wishes based on scientific literature and our own opinion. In Section 4.2 we analyse the differences between the current situation and the desired situation of Company X.

4.1 Wishes for the desired situation

Within Company X there are several wishes regarding to the way project activities should be planned. Interviews with involved employees show that there are different sorts of wishes to improve the performance of the planning related activities. Not all wishes are broadly mentioned or supported, some are more personal or departmental. Therefore we explain per interviewed employee their outcomes. We classify and summarize the wishes in Figure 4.1 (the yellow coloured blocks indicate that the interviewed employee refers to the respective wish). In Section 4.1.1 to Section 4.1.7 we clarify and evaluate the wishes of the interviewees. In Section 4.1.8 we conclude how the wishes are translated in a desired situation.

Engineering manager

The engineering manager has the wish of a centralized planning, because in the current situation he has to make a plan for the engineering department. He expects that centralized planning has advantages because the plans are made by dedicated employees and the plans are linked to other plans (project plans and plans of other departments). The engineering manager mentions the wish of a better awareness/culture because he has the feeling that the current culture negatively contributes to the overall company results. In addition, he indicates the wish of better estimation of project activity durations. This wish is based on his experience of claims about too late engineering deliverables while these engineering activities are estimated too short.

Project manager 1

The project manager has the wish of dedicated teams (consisting of employees of the sales department, the purchasing department, the engineering department, the production department, and the service department) to complete his projects according the agreed requirements with the customer. In addition, he wants on-time delivery of purchased components to avoid delays during his projects. Also he mentions the wish of better

estimation of project activity durations, because he is responsible for the actual project costs (the spent hours are part of the project costs) compared to the estimated project costs.

Project manager 2

The other project manager indicates that prefers to add more slack by planning the activities. This because he wants to avoid that people are waiting on their predecessors (due to fact that their activities take longer than planned). He also has the wish of dedicated teams (consisting of employees of the sales department, the purchasing department, the engineering department, the production department, and the service department) to complete his projects according the agreed arrangements with the customer. In addition, he wants on-time delivery of purchased components to avoid delays during his projects. Also he mentions the wish of better estimation of project activity durations, because he is responsible for the actual project costs (the spent hours are part of the project costs) compared to the estimated project costs.

Senior project manager

The senior project manager (the head of the project management department) mentions the wish of more pre-engineering during the quotation phase because he wants a better and completer view of the customer requirements when the order is acquired. This better and completer overview can be used for an improved execution of the project. He also wants a centralized planning, because he experiences that all plans (project plans and departmental plans) are linked to each other and these links are inappropriate in the current way of planning. Like the other project managers, he wants dedicated teams to complete the projects according the agreed arrangements with the customer. and the plans are linked to other plans (project plans and plans of other departments). The senior project manager mentions the wish of a better awareness/culture because he has the feeling that the current culture negatively contributes to the overall company results. Also, he wants on-time delivery of purchased components to avoid delays during all the projects. Additionally, he prefers a better estimation of project activity durations, because the project managers are responsible for the actual project costs (the spent hours are part of the project costs) compared to the estimated project costs.

Purchasing manager

The purchasing manager wants more pre-engineering during the quotation phase, because this results in earlier known components that need to be purchased. The purchasing can start earlier with purchasing the critical components. Also the purchasing manager refers to the company culture that can be improved. Since the purchasing department is responsible

for the on-time arrival of purchased components, he wants that these are delivered on time. Also he mentions the wish of better estimations of project activity durations, because the ultimate order dates are based on the estimated activity durations.

Production manager

The production manager prefers a centralized planning, because in the current situation the plans of the different ongoing projects are not linked to each other and therefore the production are needed for different projects or activities at the same time. He hopes that a centralized planning results in improved project and departmental plans. For the production department it is necessary that the needed components are available at the right time, therefore the purchased components needs to be delivered on time. The production manager is responsible for the total hours spent at the production department, so for him it is important that the project activity durations are estimated better. This will lead to a fairer comparison between the estimated hours spent on production and the actual hours spent on production.

Production control manager

The production control manager (the work preparer) also prefers a centralized planning, because in the current situation the plans of the different ongoing projects are not linked to each other and therefore the production are needed for different projects or activities at the same time. He hopes that a centralized planning results in improved project and departmental plans. The production control manager perceives a problem with the awareness and culture within the company and he thinks this is an important issue to improve. For the production control manager, it is important that the purchased components are delivered on time since he uses these delivery dates in his activities as work preparer. The same applies to the estimations of the project activity durations.

Commercial director

The commercial director wants more pre-engineering during the quotation phase, because he thinks this increases the chance of acquiring a new order. He also mentions the wish of dedicated teams that can met the customer requirements to satisfy the customer as much as possible. Therefore he thinks it is also important that the awareness and culture within Company X changes to a customer-based culture. In addition, the commercial director indicates the necessity of a better estimation of project activity durations. He indicates this issue because of the importance of issuing the right delivery time to the customer.

Managing director

The managing director wishes more pre-engineering during the quotation phase, because of the increasing chance of acquiring orders and obtaining a better and completer overview of the project at an early stage. He mentions the wish of a centralized planning since he expects that when all the plans are linked to each other this will lead to an improved overall planning performance. The next wish he indicates is the wish of dedicated project teams to improve the overall project performances. This must be combined with a better awareness/culture within the entire company. In addition, the managing director refers to the on-time delivery of the components to avoid delays during the projects. And he also refers to a better estimation of project activity durations to make the comparison between estimated project costs and actual project costs fairer and to issue a more reliable delivery date to the customer.

Referred wishes / Interviewed employees	Add more slack by planning the activities	More pre-engineering during the quotation phase	Centralized planning	Teams	Better awareness/ culture	All purchased components are delivered on time	Better estimation of project activity durations
Engineering manager							
Project manager 1							
Project manager 2							
Senior project manager							
Purchasing manager							
Production manager							
Production control manager							
Commercial director							
Managing director							
# times reffered to	1	4	5	5	6	7	9

Figure 4.1 Referred wishes of the interviewed employees for the desired situation

4.1.1 Add more slack by planning the activities

One of the project managers mentioned the possibility of adding more slack when planning the activities. He means that some extra time has to be added to the estimated durations of the project activities such that the employees do have more time for completing that activity. When the project activity durations are estimated well, the chance that the additional time is needed decreases. So it will be less likely that plans are exceeded, when the slack is added.

- **Evaluation of the wish:**

Adding slack is not workable when it is done only during the planning phase. Then the slack have to be added already during the quotation phase, otherwise it is not possible to meet the lead times agreed with the customer. When the slack is added also during the quotation phase, chances are pretty high that the new lead time does not comply with the desires of

the customer. Besides that, when employees (know that they) have more time than they need for the activities, the probability of gold-plating and/or the student syndrome increases. Gold-plating is the phenomenon of adding “unnecessary” features and capabilities because of the slack that can be eliminated (Lyneis & Ford, 2007). The student syndrome is the phenomenon of leaving everything to the last minute. In case that the employees know that safety time is built into the estimates they think that they do not need to worry about starting on time, so starts are delayed (Rand, 2000). So we conclude that this wish is not suitable for the desired situation.

4.1.2 More pre-engineering during the quotation phase

During the interviews with the employees, four times is referred to the wish of more pre-engineering during the quotation phase. When the customer approaches Company X with a certain problem, Company X has to find a solution. In most of the cases this solution is customer specific, so it has to be engineered specially for that customer. Sometimes it is possible to start with this pre-engineering before the order is definitively for Company X.

- **Evaluation of the wish:**

Pre-engineering during the quotation phase is a wish that contributes to a better proposal for the customer. The solution for the problem of the customer is then supported by drawings and not only based on computations and drawings on a beer mat. In this way, activities are executed that otherwise should be done after the order is acquired. So the chances of meeting the agreed lead times increase. On the other hand, during the quotation phase is not certain yet whether the order definitively is acquired. So, it might be possible that the pre-engineering activities lead to additional costs that cannot be earned back. In addition, the engineering manager states that he has a lack of capacity to fulfil the pre-engineering requests from the sales department. The solution of pre-engineering sounds good for him, as long as he gets the additional capacity. Since the available capacity is not part of the scope of this research, we will not elaborate on this wish in the remaining of the research.

4.1.3 Centralized planning

A lot of the wishes are related to a centralized planning. The different employees that have to deal with planning in the current situation (engineering manager, senior project manager, production manager, and production control manager) ask whether it would be better to centralize this planning. In that case someone (or a department) has a fulltime job as

planner. All planning related activities within Company X are executed by this employee/department. So everyone within the Company has to communicate all planning related issues to them. For example when a purchaser receives a message that an ordered component probably will arrive later, he has to communicate it to the responsible planner/planning department. There it will be processed in the project plans. The planning department is responsible for all plans within Company X, so all project activity plans and all capacity plans of the engineering department and the production department. Therefore it is important that plans are made in only one planning system, in which all information is gathered.

The desire is to use multi-project planning with finite capacities (as stated in Section 3.2) in the future. There are some reasons for this wish:

- The current way of planning is single-project with infinite capacity. In this way, there is no overview of all projects together. The projects are individually planned, so that different stakeholders (the project managers of the ongoing projects) are claiming the same scarce resources. Nowadays, the project managers make a project activity plan based on infinite capacity in the engineering department and the production department. Often this is unrealistic, because the requested capacity is simply not always available. To still have a good overview of the project progress and the capacity utilization, multi-project planning with finite capacity is necessary.
- By means of multi-project planning with finite capacity, it is possible to obtain insights in peaks and troughs of capacity utilization at an early phase of the project. This has the advantage of the ability to anticipate and so to prevent fire-fighting in the last phase of a project. It is better to anticipate in advance than to react last minute. Since Company X has to deal with hard deadlines of customers, sometimes it is necessary to hire non-regular capacity. When this has to be done last minute, it might be detrimental for the costs.
- It is easier to cope with changes during the project (such as change of project specifications, change of milestone dates, or change of final delivery date) if all plans of all projects are integrated in one system, in which also the capacity utilization is processed. In that case, there is an ability to see whether it is possible to swap, shift, (re)move some activities. Also, there is an ability to see what the potential effects for the rest of the project and other projects are, if changes are made in the plans of a project.

- **Evaluation of the wish:**

We see the advantages of a centralized planning department that uses multi-project planning with finite capacities to plan the projects. In the best case scenario this can perform optimally, but the question is whether there exists a tool that can deal with the multi-project planning with finite capacities. This should be investigated further.

4.1.4 Teams

Within Company X it is a wish to compose teams for every project, to improve the cooperation between the departments. The teams should be multi-disciplinary, which means that every team consists of at least one employee of the following departments: the sales department, the engineering department, the purchasing department, the project management department, the production department, and service department. The team is jointly responsible for the successful completion of the project, with the project manager as leader of the team. By allocating projects to fixed teams, the projects will get full focus. In this way, the communication is improved and the activities are better aligned. This benefits the quality and delivery performance of the different projects.

- **Evaluation of the wish:**

We believe that teams contribute to a better project performance. In that way, the collaboration and communication between team members will increase resulting in overall better project performance. However, we want to expand the wish of the interviewees for a better improvement. We think that the teams must be formatted based on the needed skills within a project. During the execution of different projects, different activities are required and for these different activities are different skills of employees needed. Therefore it is important to have a skill matrix available per department. In the skill matrix need to be indicated per employee whether he is suitable for a particular project activity or not. By linking appropriate employees to needed skills within the project, an ideal mix of team members is formatted. Since every project gets a dedicated team, there are more project teams at the same team. To manage the project teams it is necessary to set up a portfolio-management team (consisting of project managers and department heads) that is responsible for the trade-off of (conflicting) interests of project team members and the communication between management, project managers, and department heads (Platje & Seidel, 1993).

4.1.5 Awareness/Culture improvement

A more general wish is the wish to improve the corporate culture. This is a more general point, but it has also to do with planning related aspects. The individualistic culture has to shift to a corporate culture. All employees are jointly responsible for the financial results of Company X. Therefore, it is important that they are aware of what they contribute to the whole and what their performance is.

- **Evaluation of the wish:**

To change the corporate culture, it is important that it is supported from the top. In this case almost all interviewed managers/directors referred to this wish, so this is not an issue. However it will not be easy to improve the corporate culture, we think it has a positive effect on the overall (project) results of Company X.

4.1.6 All purchased components are delivered on time

Almost all of the interviewed employees referred to the wish of on-time delivery of purchased components. If these components are delivered on time, there can always directly be started with an activity. In an optimal situation, there is no delay caused by absent components and all materials are available whenever someone needs them.

- **Evaluation of the wish:**

The employees are correct when mention the necessity of on time components. But this is not part of the scope of this research, because we do not have direct influence on the suppliers of Company X. However we can improve the internal processes, such that we can purchase as soon as possible to give the suppliers more time to deliver on time, we do not elaborate extensively on this wish in the remaining of the research. However, we come back on this topic in the recommendations.

4.1.7 Better estimations of durations of project activities

All interviewed employees mention the wish of a well estimation of project activity durations. Better estimations contribute to a better estimation of the definitive lead time for the customer. In this way Company X can avoid that it issues a too short lead time to the customer, to be competitive, and that it cannot fulfil this. Also it can avoid that it issues a too long lead time to the customer, to be sure it can fulfil this, but Company X do not get the order because a competitor has a better offer.

- **Evaluation of the wish:**

This wish seems to be an important one to improve the overall project performance. For better estimations of activity durations it is necessary that they are not only based on own experiences and insights. The estimations should be justified by gathered data. Nowadays, no information about processing times and throughput times of activities is tracked. The employees do clock on the projects to keep track of the total hours spent, but not specific on activities.

4.1.8 Conclusion for translation wishes into desired situation

Not all wishes arising from the interviews with the employees are suitable for the desired situation of Company X. Some of them are no part of the scope of this research, another is inappropriate according to scientific literature, while others are appropriate to translate to the desired situation. Table 4.1 gives an overview whether the referred wishes are appropriate to translate to the desired situation and what the reason is if they are not.

Wish	**Translated to desired situation?**	**Reason if not translated to the desired situation**
Add more slack by planning the activities	No	• Impossible for meeting and issuing correct lead times • Not according to literature
More pre-engineering during the quotation phase	No	No part of the scope
Centralized planning	Yes	
Teams	Yes	
Awareness / culture improvement	Yes	
All purchased components are delivered on time	No	No part of the scope
Better estimations of durations of project activities	Yes	

Table 4.1 Overview of referred wishes are appropriate to translate to the desired situation

4.2 Gap analysis

There is a gap between the current situation and the desired situation for Company X. We use this section to briefly summarize both situations (the current situation in Section 4.2.1 and the desired situation in Section 4.2.2) as they are stated earlier and we conclude in Section 4.2.3 with the differences between the current situation of Company X and the desired situation of Company X.

4.2.1 Current situation

In the current situation of Company X, there is a matrix organisation (explanation in Section 3.1.1). The employees are part of a functional department, but they are allocated to the projects. The projects go stepwise through the organisation, they are transferred from department to department. During the project, different departments use four different planning systems and these are not linked to each other. So changes in a certain system are not processed in the other systems. This can be done manually, but therefore it is necessary that everyone communicates well to each other. The cooperation and communication is currently inappropriate (there is an individual culture instead of a corporate culture), causing differences in plans of the same project. The plans are made for every single project separately (so there is no aggregated overview) and based on infinite capacities of the departments. All of this makes it difficult to meet the issued lead time at minimal costs. The lead times are sometimes too short and sometimes too long, because of inappropriate estimation of project activity durations. Figure 4.2 shows the way how projects run through the organization.

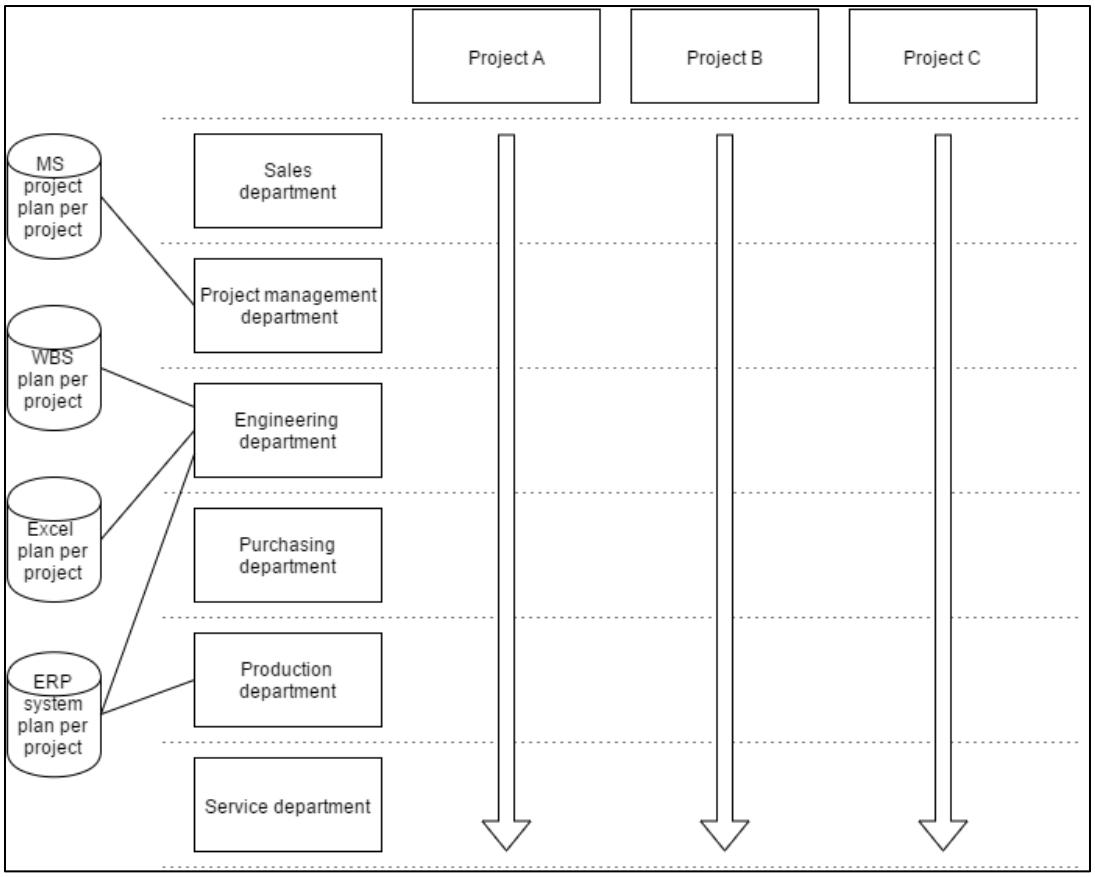


Figure 4.2 Overview of the current situation of Company X

4.2.2 Desired situation

In the desired situation of Company X, there is a team-based organisation (based on the pure project organisation as explained in Section 3.1.1) where the planning is centralized. All plans and schedules for all projects are linked an aggregated in one planning system. There is a department responsible for the planning related activities. This planning department provides all plans and schedules for all projects, based on multi-project planning with finite capacities. From the project teams, they are provided with all information about the progress and feedback of the project. Then it is possible for them to respond and adapt some plans at an early stage, to prevent fire-fighting in the last stage of a project. The fixed project teams are multidisciplinary, so at least one member of every department is present. The formation of the teams is done by the planning department, based on the competency skill matrices of the employees. With the project teams, the focus, awareness, and performances during the project will be improved. Furthermore, the lead times issued to the customer are more appropriate since the project activity durations are better estimated (based on historical data of comparable activities). Figure 4.3 shows the way how projects are executed in the desired situation of Company X.

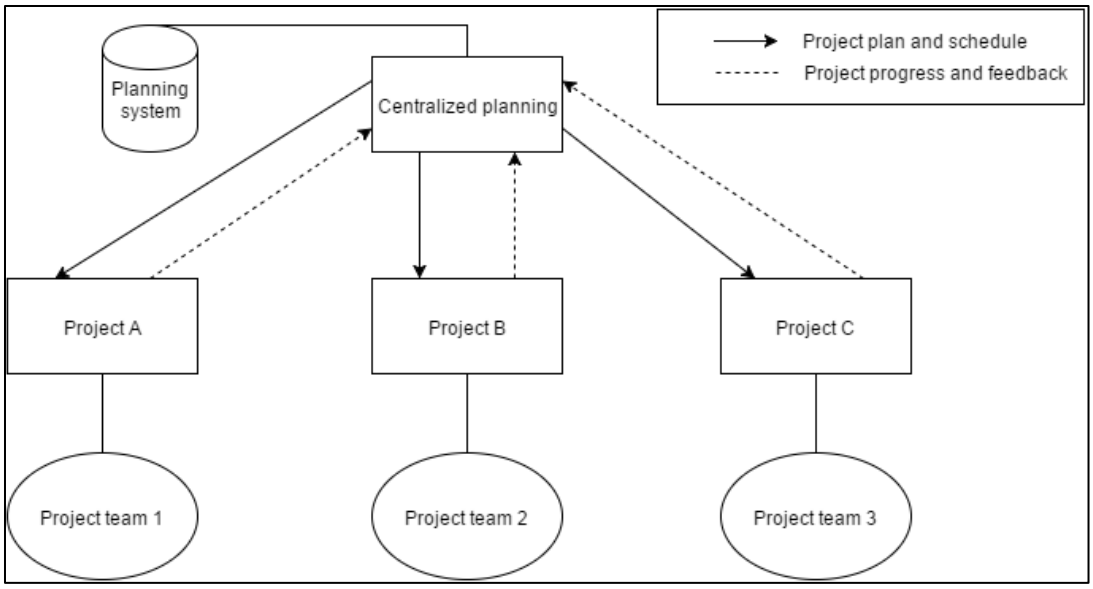


Figure 4.3 Overview of the desired situation of Company X

4.2.3 Differences between current situation and desired situation

There are some differences between the current situation of Company X and their desired situation. We summarize and show them in Table 4.2. We show the differences between the two situations by facing keywords of each other.

Current situation	Desired situation
Single-project planning with infinite capacity	Multi-project planning with finite capacity
Four planning systems	One planning system
Decentralized planning	Centralized planning
Matrix organisation	Team-based organisation
Individual culture	Corporate culture
Inappropriate estimation of activity durations	Appropriate estimation of activity durations
Low awareness of contribution to the whole	Better awareness of contribution to the whole
Arduous communication and cooperation	Better communication and cooperation
Lower quality of projects	Higher quality of projects
Lower delivery performance of projects	Higher delivery performance of projects
Higher cost of hiring non-regular capacity	Lower cost of hiring non-regular capacity

Table 4.2 Current situation of Company X versus Desired situation of Company X

Chapter 5 Interventions/improvements

In this chapter we provide some interventions/improvements that are needed to reach the desired situation for Company X. We describe the interventions/improvements that arise from the gap analysis (Section 4.2) between the current situation and the desired situation of Company X. For every intervention/improvement, we specify what our plan of approach is for executing the intervention/improvement and in which period of time it should take place. We describe every intervention/improvement in an own section, so in total there are 7 sections (Section 5.1 up to and including Section 5.7).

5.1 Visit other companies to increase awareness and to create support

As mentioned in Section 2.3.1, AWL Harderwijk had to deal with similar issues within the planning field. Two students have conducted a graduation project on this area at AWL. At the time of the first one (Meijerink, 2003), AWL was at a similar level as Company X. She gave recommendations and the second study (Evers, 2013) showed that these recommendations are partly executed in the meantime.

Nowadays, AWL has a centralized planning department that is responsible for all planning related activities. All project plans and schedules are linked to each other. AWL has stated that Company X is welcome to see what AWL has done, and how they have made the improvements. In addition, Bosch Scharnieren Doetinchem has also stated to give openness about their planning process. They have also changed much in the field of planning and are ready to show this to Company X.

By visiting these companies, the involved employees of Company X get a better overview of what is possible. In that way, they can see that it is possible to improve the current planning process. This will raise the awareness and it creates support to improve their own processes.

- Goal: Increase awareness and create support of top management.
- Time period: During the first quarter of 2016.
- Team: All employees that are interviewed during this research, so: engineering manager, 2 project managers, senior project manager, purchasing manager, production manager, production control manager, commercial director, and managing director.
- Team responsible: The managing director has to initiate it.
- Expected time required: Per company 4 hours, so in total 8 hours.

- Expected results: Increased awareness and top down management support for improving the overall project and/or planning performance.
- Possible threats:
    - After the visits, it could be that the top management is too much fixated on the way the other companies execute their planning related activities. It might be useful to pick some nice things and translate them to the situation of Company X.
    - Company X wants to improve their processes, but it is not necessary to do all improvement actions directly. After the visits, the management team might have a desired result in mind but this result could be achieved incrementally.

5.2 Switch to one planning system instead of four

Company X is initiating the implementation of a new ERP system. This will happen in mid-2016. In the most favourable case, it is possible to implement the wishes of a multi-project planning with finite capacity in this new ERP system. Otherwise a new planning system has to be selected and purchased. So first has to be investigated whether it is possible to fit in the new ERP system and in what way. Within Company X a team is responsible for the preparation and implementation of the new ERP system. This team has to investigate what the possibilities of the new system are regarding to multi-project planning and/or finite capacities. They have to consult and collaborate with the implementing party, who is able to program customer wishes into the ERP system. When it seems not possible to implement such a multi-project planning tool with finite capacities, we recommend to approach a third party such as Ortec, Primavera, or Quintig. These companies are specialized in advanced planning and optimization solutions. They can assist and support Company X in finding a way to solve their specific issues.

- Goal: Choose one suitable multi-project planning system with finite capacities.
- Time period: Before the start of implementation of the new ERP system (mid-2016).
- Team: The ERP implementation team in consultation with the implementing party of the ERP system.
- Team responsible: The purchasing manager (head of the ERP implementation team).
- Expected time required: 2 weeks of consults with the implementing party, probably another 2 weeks of consults with a third party such as Ortec, Primavera, or Quintig.
- Expected results: We expect that the new ERP system is not able to deal with all the wishes for the desired situation. Therefore we recommend to implement as much as

possible, also after consultation with the chosen third party. This party can create an add-on for the ERP system that almost fits the wishes of Company X.

- Possible threats:
    - It might be possible that the ERP implementation team is not able to judge whether the new ERP system is able to meet the planning requirements. In that case, ask the implementing party and/or the third party to help with this judgement. All parties are together to find the best solution for Company X, so they are very willingly to support in such situations.

5.3 Create competency skill matrix for every department

Every department has to create a competency skill matrix. These matrices should be used to allocate the right employees to the right project activities. The competency skill matrix has to be filled in for every employee. For every employee needs to be identified whether the employee is authorized and able to execute different types of activities. This assessment should be based on diplomas, certificates, and the experiences of the department head about the employees. Therefore, the department heads are responsible for managing the competency skill matrix of their department. The HRM manager is specialized in competence management, thus she has to set up a standard matrix and she has to coordinate the department heads in this process.

- Goal: Identification of all present skills and competences per employee.
- Time period: During the first quarter of 2016.
- Team: Every department head in consultation with the HRM manager.
- Team responsible: The HRM manager has to set up a standard matrix and has to initiate the actions on the departments.
- Expected time required: 1 hour per employee that is part of their department.
- Expected results: A competency skill matrix for every employee of Company X. For every employee is stated what their capabilities are, in what extent one is suitable for activities, if one is certified for certain activities etc. Based on these competency skill matrices could the employees be allocated to the project activities.
- Possible threats:
    - It is possible that not the correct skills and competences are identified for an employee. Therefore it is important that the department head fills in the matrix secure and thought-out. When he doubts about specific issues, he has to inform the HRM manager (she is specialized in competence management).

5.4 Set up KPIs to track project progress and planning performance

To provide feedback about the projects to the centralized planning department, it is necessary to track the progress and performance of projects and plans. Therefore Company X has to set up Key Performance Indicators (KPIs) that are tracked during the projects. These KPIs have to be formulated SMART (Doran, 1981). This means that a KPI has to meet the following characteristics:

- Specific: a specific area to improve must be targeted.
- Measurable: it must be quantifiable and progress must be visible.
- Attainable: there must be a goal at the end.
- Realistic: This goal must be reachable, given the available resources.
- Time-bound: there must be specified when the results must be achieved.

Nowadays, the KPIs are discussed once per quarter during a KPI meeting initiated by the QHSE manager.

Examples of potential new KPIs are (Pennypacker, 2005):

- Return on investment
- Productivity
- Cost of Quality
- Cost Performance
- Schedule Performance
- Customer Satisfaction
- Cycle Time
- Requirements Performance
- Employee Satisfaction
- Alignment to Strategic Business Goals

Besides setting up these KPIs, it is necessary that data is gathered to track these KPIs. Therefore a tracking system has to be set up, from which the desired data can be extracted and translated into a value for the concerning KPI. In the most favourable case, this tracking system can be built in the new ERP system.

- Goal: Defined SMART KPIs .
- Time period: During the management review in the first quarter of 2016.
- Team: All employees that are present at the KPI meeting (the process owners) in consultation with the QHSE manager.

- Team responsible: The QHSE manager.
- Expected time required: 4 hours
- Expected results: SMART KPIs where the process owners have committed themselves to.
- Possible threats:
    - That a new KPI is measurable in more than one way. In this case, it will lead to different outcomes when the data is gathered by different employees or in different ways.
    - That a KPI only is set up and measured because it has to be measured. The real goal is to measure the data to make the performance of the department visible and be able to steer processes based on these data. In that case, it might lead to improvement of the overall performance.

- Goal: An in-built tracking system for the KPIs in the new ERP system.
- Time period: During the implementation of the new ERP system (from mid-2016).
- Team: The ERP implementation team in consultation with the implementing party of the ERP system.
- Team responsible: The purchasing manager (head of the ERP implementation team).
- Expected time required: 1 week
- Expected results: A tracking system of the new KPIs implemented in the new ERP system. All the conditions to gather new data are met and the responsible employees that have to gather the data, do exactly know what they have to do.
- Possible threats:
    - Sometimes it might be possible that a certain KPI is not achievable from the ERP system and a new system has to be set up (for example an excel-file to measure that KPI). In that case, it is important that the right data is inserted in this excel-file to measure that KPI correctly.

5.5 Set up a tracking system to track project activity durations

The project activity durations have to be tracked for a better determination of the lead time to issue to the customer. Therefore it is necessary that the durations of all activities during a project are tracked and saved. Nowadays, only the hours that someone is involved in a project are clocked. However, it is necessary to know exactly what activities are done in what time. So the employees have to clock activity-specific instead of project-specific. In this way, a historical database will be built up. Within this database, different sort of activities have to

be classified and there will be an average duration of these activities. The salesmen could use this average duration when a comparable sort of activity is required for (potential) new projects. Sometimes he has to adapt this average duration for the estimation of the new duration, because of the degree of complexity of the (potential) new project. When a project seems to be very complex, the sales is able to decide to increase the average duration with some slack. In this case, the chance of unhappy customers because of not meeting the agreed delivery time will probably decrease.

- Goal: An in-built tracking system for the spent hours per project activity in the new ERP system.
- Time period: During the implementation of the new ERP system (from mid-2016).
- Team: The ERP implementation team in consultation with the implementing party of the ERP system.
- Team responsible: The purchasing manager (head of the ERP implementation team).
- Expected time required: 1 week.
- Expected results: A tracking system of the spent hours per project activity, implemented in the new ERP system. All the conditions to gather new data are met and the responsible employees that have to gather the data, do exactly know what they have to do.
- Possible threats:
    - When the employees have to clock activity-specific, they have to change several times a day their activity in the system. This results in more walking to the clocking computers and so less time for execution of project activities. Therefore something has to be invented such that it is possible to clock on project activities at the workstation/workplace of the employee.

- Goal: An usable and reliable tool for the sales employees to estimate activity durations for new potential projects.
- Time period: During first quarter of 2016.
- Team: A specific team (sales, engineering, purchasing, and production employees should be involved).
- Team responsible: The commercial director.
- Expected time required: 2 days
- Expected results: During the 2 days all team members have to discuss and convince each other in classifying all possible activities. The deliverable of this meeting is a list of project activity groups where all possible activity fits in. An average duration could be gathered for all of these project activity groups. The salesmen could use (and

adjust if necessary, for example: increase an estimated duration because of the degree of complexity of a project) these average durations during the quotation phase.

- Possible threats:
    - It might be possible that not all project activities are classified or are to classify in the list of project activity groups. Then it is needed that a work method will be devised how to deal with these project activities such that a salesmen knows how to estimate these project activities during the quotation phase.

5.6 Investigate possibility of team-based organisation with project teams

There has to be investigated whether it is possible to format a team-based organisation with project teams. To switch to such an organisation structure it is necessary that the present employees fit in the structure. It is a task for the management to investigate whether a project team organisation is suitable for the employees and the company in general.

- Goal: Advice whether it is possible to form a team-based organisation with project teams.
- Time period: Before the implementation of the new ERP system (mid-2016).
- Team: An external consultancy party.
- Team responsible: The managing director.
- Expected time required: 1 week
- Expected results: After one week should the external consultancy party be able to identify whether a team-based organisation fits the best for Company X or that it is better to stay in the current matrix organisation. Based on this outcome, a final meeting should be organized where further decisions on next steps should be made.
- Possible threats:
    - Possible threats are part of the scope of the external consultancy party. The managing director has to inform the external consultancy party to make clear that they have to identify those.

5.7 Set up a planning department

When the previous interventions/improvements are executed, the planning could be centralized. Therefore a planning department has to be formed. It can be composed of existing employees, but it could be possible that new employees should be employed when the required competencies not are available by the existing employees.

- Goal: A new centralized planning department.
- Time period: After the execution of the previous interventions/improvements. So at least during or after the implementation of the new ERP system.
- Team: The management team and the HRM manager.
- Team responsible: The managing director.
- Expected time required: 2 months.
- Expected results: After that all the previous interventions/improvements are executed, a planning department has to be formed. The HRM manager should be in consultation with the management team to find the right qualified employee(s). She could identify the needed qualifications based on the function description of the new employee, so job interviews could be held.
- Possible threats:
    - Since there is no function description present of the new planning employee, it is very important that this one is set up secure and thought-out. Otherwise it might be possible that employees are chosen based on wrong needed qualifications or skills.

Chapter 6 Conclusions and recommendations

This chapter provides the final conclusion of the research in Section 6.1 and in Section 6.2 we provide some recommendations for Company X.

6.1 Conclusions

In the current situation, Company X faces problems to meet their project deadlines for the customer. The managing director expects that this is partly due to the inappropriate design of processes in the planning area. Every project is planned separately and there are different planning systems, which are not linked to each other. In addition, the management team of Company X doubts whether the current organisational structure is correct since the cooperation and communication between departments seems inappropriate.

The aim of this research was to analyse the current planning process, to investigate what the desired situation is for Company X, and to investigate what improvements should be done to make use of a multi-project planning tool in the future.

Therefore, we formulated the following main research question:
"How can we improve internal processes and conditions within Company X to prepare the organisation for using their desired multi-project planning tool for meeting project deadlines?"

From the analysis of the current situation, we conclude that the current design of the planning processes results in a number of imperfections. Several planning tools are used and they are not linked to each other. In addition, every project is planned separately and there is no aggregate overview. So changes in a certain project plan (which happens a lot), do not influence the plans and schedules of other projects automatically. This does not necessarily be a problem, but then a good communication and cooperation between the projects and between the departments is required. Because of the many cross-departmental processes this is currently not always the case. Besides this, Company X is not always able to make an accurate estimation of the duration of project activities. Therefore we conclude that Company X is not ready yet to use complex multi-project planning algorithms. It is important to first have the design of processes and structures at the right way, before continuing in depth.

The desired situation of a centralized planning department in a team-based organisation with project teams is not immediately feasible. This desire should be achieved incrementally. First the low-hanging fruit issues (are issues that have effect without a huge effort) have to be tackled, before that more complex decisions could be made. Our conclusion is to switch to multi-project planning with finite capacities in one planning system. All the project plans and schedules have to be managed by a centralized planning department. The projects are completed team wise. A team is jointly responsible for their project and all employees together are responsible for the company wide results. Therefore a good communication and cooperation is necessary, wherefore the awareness and support of employees should be improved. The culture has to shift from individualistic into a corporate culture.

6.2 Recommendations

We recommend to follow up the interventions/improvements that are mentioned in Chapter 5. In addition, we advise to do some further research about the more complex and tough multi-project planning algorithms. When all improvements are made, the design of the processes and structure is ready for taking the next step. The plans do not longer have to be based on own experiences and insights, the optimal plans could may result from a complex planning tool that uses algorithms and heuristics to find the optimal multi-project plans.

Therefore it is important to comply with all constraints, such having appropriate estimations of project activity durations, having an appropriate overview of competencies and skills of the employees, and having support of the employees to follow the plans resulting from the planning tool. If all this is well organized, it should be easier to manage the plans and thus to meet the issued delivery dates to the customer. In that case, the customer happiness will increase which has positive effects on the company results.

As stated in Section 4.1.8 two of the wishes are not further elaborated, because they are not part of the scope of this research. However, we have some recommendations for these wishes.

The pre-engineering during the quotation phase is valuable process improvement, but currently there is a lack of capacity at the engineering department. We noticed that it mainly concerns a shortage of the lead engineers. Those lead engineers are technically the best educated, and therefore they are required during almost all projects. Besides that, they have to check the work of other engineers. So they have to do a lot of tasks and too few lead engineers are available. Therefore, the addition of pre-engineering during the quotation is

not possible yet. We recommend to develop younger engineers into lead engineers and/or hire new technical educated lead engineers.

Concerning the delivery performance of the suppliers, which is not part of the scope now, we advise to keep track of the delivery performance. This delivery performance ranking can be used to set the suppliers thinking and so as a big stick. When suppliers see that their competitors perform better, they have to improve their performance in order to keep acquiring the purchase orders of Company X.

Reference list

Acha, V., Davies, A., Hobday, M., & Salter, A. (2004). Exploring the capital goods economy: complex product systems in the UK. *Ind Corp Change*, 505-529.

Bendoly, E., Perry-Smith, J., & Bachrach, D. (2010). The perception of difficulty in project-work planning and its impact on resource sharing. *Journal of operations management*, 385-397.

Ben-Zvi, T., & Lechler, T. (2011). Resource allocation in multi-project environments: planning vs. execution strategies. *Technology management in the energy smart world (PICMET), 2011 proceedings of PICMET '11*, 1-7.

Cusumano, M., & Nobeoka, K. (1998). Thinking beyond lean. *The Free Press, New York*.

Doran, G. (1981). There's a S.M.A.R.T. way to write management's goals and objectives. *Management Review*, 35-36.

Evers, J. (2013). *Insights into the importance of scientific methods for tactical multi-project planning at AWL.* Enschede: University of Twente.

Fricke, S., & Shenhar, A. (2000). Managing multiple engineering projects in a manufacturing support environment. *IEEE Transactions on Engineering Management*, 258-268.

Hans, E., Herroelen, W., Leus, R., & Wullink, G. (2007). A hierarchical approach to multi-project planning under uncertainty. *The international journal of management science*, 563-577.

Herroelen, W., & Leus, R. (2005). Project scheduling under uncertainty: Survey and research potentials. *European Journal of Operational Research*, 289-306.

Kaulio , M. (2008). Project leadership in multi-project settings: findings from a critical incident study. *International Journal of Project Management*, 338-347.

Leus, R. (2003). *The generation of stable project plans. Complexity and exact algorithms. .* Leuven: Ph.D. thesis. Katholieke Universiteit Leuven.

Leybourne, S. (2007). The changing bias of project management research: a consideration of the literatures and an application extant theory. *Project Management Journal*, 61-73.

Lyneis, J., & Ford, D. (2007). System dynamics applied to project management: a survey, assessment, and directions for future research. *System Dynamics Review*, 157-189.

Meijerink, C. (2003). *Tijd voor capaciteit?* Enschede: University of Twente.

Meredith, J., & Mantel Jr., S. (2003). *Project management. A managerial appraoch.* New York: Wiley.

Olhager, J. (2003). Strategic positioning of the order penetration point. *International journal of production economics*, 319-329.

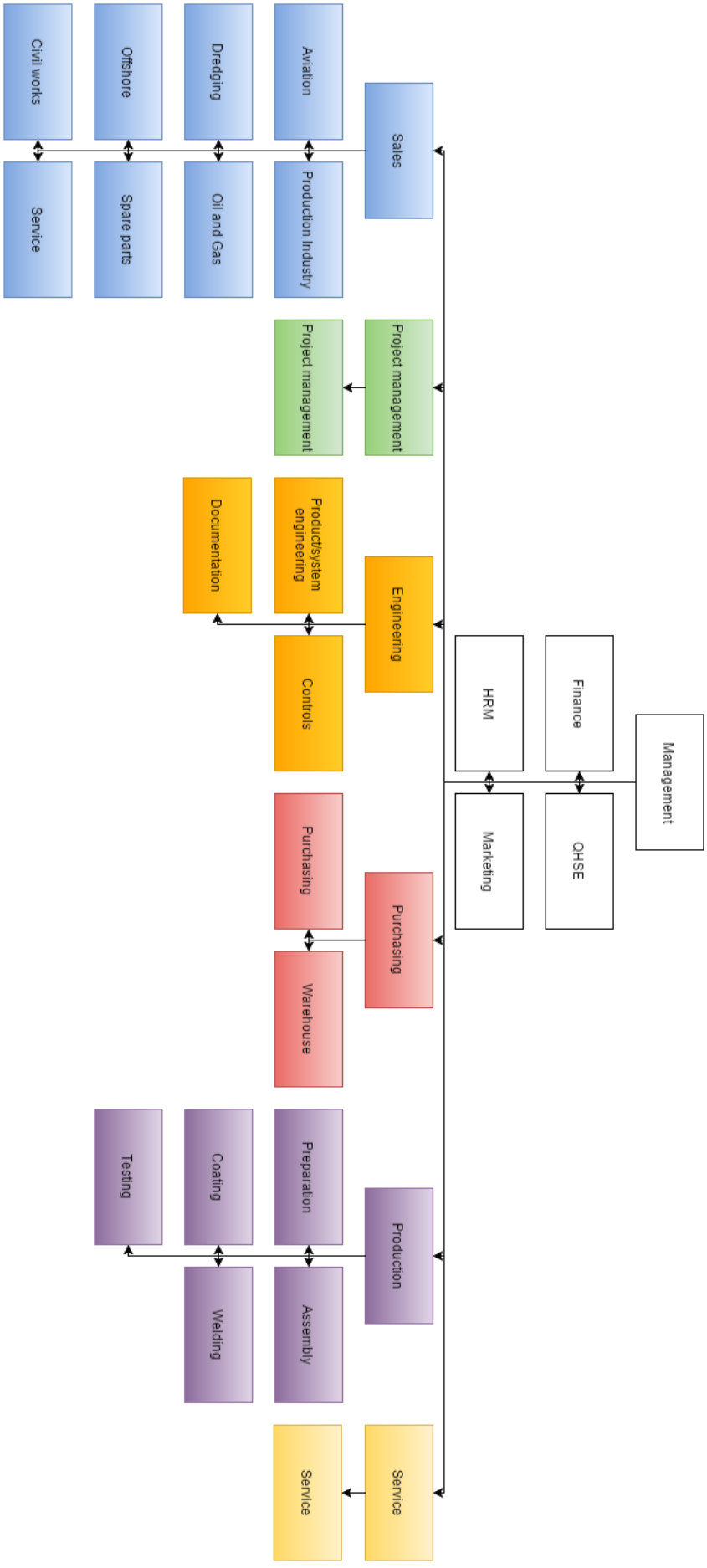
Pennypacker, J. S. (2005). *Measures of Project Management Performance and Value.* Center for Business Practices.

Platje, A., & Seidel, H. (1993). Breaktrough in multiproject management: how to escape the vicious circle of planning and control. *International Journal of Project Management*, 209-213.

Rand, G. (2000). Critical chain: the theory of constraints applied to project management. *International Journal of Project Management*, 173-177.

Wang, R., & Salunga, A. (2007). Trends 2008: Project-Based Solutions. Enterprise Solutions for a Project-Based World. *Forrester Research*.

Appendix 1 Organogram Company X



Appendix 2 List of search terms used for the literature study

- Capacity planning
- Complex product systems
- Customer order decoupling point
- Dynamic multi-project
- Dynamic project management
- Framework multi-project
- Framework planning
- Key performance indicators
- Key performance indicators project management
- Multi-project
- Multi-project environments
- Multi-project planning
- Order penetration point
- Planning methods
- Production environments
- Project business
- Project-driven business
- Project management
- Resource allocation
- Sharing resources
- Smart key performance indicators