RE-ENGINEERING NON-FLOW LARGE SCALE MAINTENANCE ORGANISATIONS
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RE-ENGINEERING NON-FLOW LARGE SCALE MAINTENANCE ORGANISATIONS

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door

Arie Jan de Waard
geboren op 16 september 1961
te Leeuwarden
Dit proefschrift is goedgekeurd door de promotoren:

Prof.dr. W.H.M. Zijlm

Prof.dr.ir. J.E. van Aken
To Caroline

"The only thing that is in our way, is just believe ONE can do it;
so don’t blame anybody, start with yourself."
Preface

The research presented in this dissertation is primarily inspired by the control problems of the Royal Netherlands Navy Dockyard (RNN) in Den Helder. In my career as a Mechanical Engineering Officer of the Royal Netherlands Navy (RNN), I have experienced the dockyard in different ways. The first experience stems from my practical training period on board HNLMS Tromp in 1986. Being a trainee, I was only responsible for a few technical ship systems; yet this period was my first encounter with the dockyard in my role as a 'customer'. Next, I learned to know the dockyard from the inside during the writing of a dissertation concerning the evaluation of an automated system for logistical support. During the following four years I was again a customer of the dockyard, as I was placed on board RNN ships. In 1992 I returned for my first 'shore job' to the dockyard. I worked for about one-and-a-half year as head of the evaluation section within the production department.

During these various encounters with the RNN, two observations were prevalent. The quality of the dockyard's work varied from satisfactory to excellent in ninety-nine of the hundred cases. However the due date performance was below acceptable levels. Especially when the maintenance tasks deviated from what was initially foreseen, the dockyard was not able to react flexibly and to smoothly co-ordinate the various production units. These problems were not caused by incompetences of the dockyard's employees, but were traced back to the strongly discipline-oriented organisational structure that resulted in a highly fragmented planning and control structure, lacking adequate and consistent information flows, and therefore unable to react to the rapidly changing customer demands.

By the end of 1993, I was asked by the then Director dockyard, Commodore RNLN W.M. van Gulpen, and the then Director production department, Captain RNLN B. Wienbelt, to participate in a joint research project with the University of Twente. Initially, the project merely aimed at the development of an automated Decision Support System for the macro level operational planning. Luckily, discussions between Prof Dr. W.H.M Zijm, Commodore van Gulpen, Captain Wienbelt, and myself resulted in the notion that an improvement of the dockyard performance also required a thorough restructuring of the dockyard's organisational structure.

Ultimately, this made me a project leader of a team, which composition varied during the different research phases. The backbone of the team consisted of employees of the various dockyard departments. In addition, members of the Production and Operations Management (POM) group of the University of Twente formed a continuous factor. Occasionally, several students have, as a team member, carried out parts of the research project. This joint effort of dockyard employees, researchers of the University of Twente, and students of the University of Twente, the Eindhoven University of Technology, and the Royal Netherlands Naval College, resulted in a new organisational model with the corresponding information systems structure. The team even tested parts of the new structure by performing pilots within the dockyard. The co-operation with the University of Twente also resulted in a prototype decision support system for macro level operational planning. Both the pilots and the tests of the prototype provided positive results.

In the beginning of 1998 the project team presented the final results of the research project. In view of the positive test results, the dockyard management decided to implement the new structure. At that point, I was relieved as project leader of the re-engineering team and became a team advisor. This enabled me to spend more time on my dissertation and to gather the necessary complementary data. The research structure was based on a multiple case study. To this end, the results of the dockyard case were to be tested in various other companies. Therefore I visited several companies of which I have described four as a case study in my dissertation.
Unfortunately, not every company could be used as a case study due to the incongruence with the research domain discussed in this dissertation. Nevertheless, I want to thank all the companies that have spared time to discuss their organisational structure. Ultimately, the processing of the dockyard results, the case studies results, and the material obtained through theoretical studies resulted in this dissertation.

Many people have contributed to the dockyard’s engineering project and in particular to my research project. I would like to thank them all, without your help and dedication this dissertation would never have been written! In spite of the risk that I am unjustly forgetting to mention someone, I would like to address some persons in particular.

First, I want to thank my promotor Henk Zijm, chairman of the Production and Operation Management group (University of Twente, Faculty of Mechanical Engineering) and Joan van Aken, (Eindhoven University of Technology, Faculty of Technology Management, Department of Organisation and Management). Henk, your inspiring and convincing attitude motivated me tremendously during the research project. Especially when there were setbacks you inspired me to again face these problems. In this respect I will never forget your many winged expressions. Joan, your contribution to the structured set-up of the research design was very valuable. Your calm but energetic way of conducting a discussion opened many new angles of incidence.

Next, I want to thank all the employees of the Royal Netherlands Dockyard. You all form a magnificent company that is worth ‘fighting’ for. I hope that in spite of the uncertain times, inside as well as outside the dockyard, you will still keep up your spirit. I would like to specially thank Commodore RNLT W.M. van Gulpen and Captain RNLT B. Wienbelt, their vision, push, and continuous support made this project possible. The successor of Commodore van Gulpen, Captain W.A. Dekker, was confronted with a project in an advanced state of execution. Nevertheless, he showed continuous support and interest for the project, for which I am grateful.

Next, I want to thank all the project team members from outside and inside the dockyard. Nico Molenaar was my assistant project leader for approximately one and a half year. Nico, although you can sometimes feign a grumpy attitude, your humour and inspiration formed an indispensable factor in the team. Daan Meijer contributed to the project during the four research years from his position as Director Engineering and Production Department. Next, he took over my place as a project leader for the implementation of the new organisational model. Daan, I would like to thank you for your constructive contribution to the project and last but not least wish you a lot of wisdom and strength in the implementation period. In addition, I want to specially memorise the following team members: Wim Rossen, Joop van Vliet, Jan-Willem Rustenburg, and Marco Groenestein. I cherish special memories to each of you, many thanks for your support and contribution.

Next, I want to specially thank two persons of the University of Twente. Ronald de Boer completed his PhD research on the Decision Support System (DSS) for the dockyard. Marco Schutter is a researcher of the POM group and also contributed to the development of the DSS. Ronald and Marco, I want to thank you for your devotion to the dockyard’s re-engineering project. I have got to know you both as expert researchers with an open and pleasant way of communicating.

Last, but not least, I want to thank all my friends for their continuous support during the four year research period. I know I have not been as social to you as I should have been, but I promise that I will make it up to you all in the coming period. Next, I like to address a special word of thanks to my parents. Although life has not been easy for them, they always stimulated me and strongly believed in me; for me you are the greatest! The last person I want to mention is Alex: you have brightened my life!

Arie Jan de Waard
Amsterdam, January, 1999
Summary

The research described in this dissertation deals with the organisational structure of non-flow Large Scale Maintenance Organisations (LSMO's). An LSMO is an enterprise of a considerable size (i.e. more than 150 employees), with as its primary tasks the maintenance, overhaul, and modification of technical systems. A dominant characteristic of the processes within these organisations is the high uncertainty with respect to the timing and size as well as the actual work contents of customer orders. The 'non-flow' adjective indicates this dominant characteristic.

Just as in other industrial branches LSMO's have experienced a growing demand for quality, flexibility, and responsiveness. Unfortunately, the old, generally functionally oriented, structures are often not able to satisfy these demands. As a result, the need for organisational change becomes inevitable. However, despite of the rapidly growing literature on Business Process Redesign in general, we are not aware of much literature addressing a design model for our particular field of interest. Nevertheless, such a model is highly desirable in view of the unique control problems arising in these organisations, due to the various types of uncertainty mentioned. These companies need concepts, tools, and techniques to improve the controllability of their operations in order to deliver maintenance services that satisfy tight specification, time, cost, and quality criteria. To date they lack one or more design models to guide and support the design and development of appropriate control systems.

The construction of a design model for LSMO's starts with the selection of a design process. We first use this design process in a large initial case, after which the results are generalised into a generic LSMO design model. This design model consists of a set of technological rules, which prescribe how the desired controllability improvement can be achieved. To prove that the design model fulfills its primary goals, i.e. to improve the controllability of non-flow LSMO's, the model is tested on a sequence of secondary cases. In principle the collection of supporting evidence in the secondary cases should be continued until 'theoretical saturation' is obtained.

In an environment with a high degree of uncertainty traditional functionally oriented structures are highly unsuitable to meet the rising demands. To provide a large variety of maintenance services and to frequently implement new technologies it is necessary to focus on a process-oriented organisation. We base the process-oriented design process mainly on the Dutch sociotechnical approach. This so-called 'Integral Organisational Change' approach consists of four steps. The first one comprises a diagnosis of the environment and the determination of the characteristics of the organisation. In the second step we develop, based on the diagnosis of step 1, the strategy and vision of what the organisation should be. The third step concerns the actual design of the organisational structure. First, we design top-down the activities that have to be performed to manufacture the desired services (the production structure). Next, we define bottom-up the control activities needed to execute the activities of the production structure (the control structure). Finally, we design the supporting information structure.

The multiple case study starts with the control problems experienced at the Royal Netherlands Navy Dockyard. The problems in this initial case, which manifested themselves primarily in a very weak due date performance, were caused by changing customer demands and a dysfunctional organisational structure. Initially, the dockyard management solely blamed the existing information systems and believed a new information system would solve most problems. However, an examination of the control problems showed that the functionally oriented
structure, with a strict separation of non-physical and physical activities, organised in many sequential steps, was simply not capable to match changing demands. Next, a project team developed a new organisational model with the use of the four steps of the design process. The resulting generic design model can be characterised by the following seven technological rules.

First, the organisational structure of a non-flow LSMO should be process-oriented. A functional organised production structure is not able to cope flexibly with a highly diversified and strongly irregular demand pattern these organisations are confronted with. In particular, the many disturbances and deviations from the work planned that occur during execution require a structure in which planning and doing is integrated and oriented towards the customer.

The second rule concerns the integration of the non-physical and physical activities. Due to the fact that almost every order contains many unique elements, the non-physical activities in an LSMO (specifications of customer requirements, global and detailed capacity planning, engineering and process planning) play a key role. In addition, physical and non-physical activities are closely related, not only since the latter steer the former, but also since feedback from the physical activities provide a welcome additional input for updating e.g. engineering and process planning standards. To this end, an organisation in which preparation and production activities are integrated, or at least executed within well-established working units, seems to be highly beneficial.

The third rule prescribes an organisational structure that ideally consists of three levels at most. More general, it is important to put control tasks at the lowest possible level (i.e. as close as possible to execution). Only if an employee or working group is unable to overlook the consequences or the range or a control decision, these decisions should be placed on the next higher level. Related to the time-horizons of decisions, we usually distinguish between macro, meso and micro level decision making.

The fourth rule advocates the use of a strict planning hierarchy, in particular with respect to capacity planning and scheduling. Here, we distinguish aggregate capacity planning and detailed capacity scheduling, separated by a process planning phase. Such a planning hierarchy should provide a clear framework, such that at each organisational level sufficient slack is available to cope with small disturbances. In this way a planning system becomes robust, i.e. not every disturbance should immediately induce planning changes at the same or, even worse, the next higher level. Two kinds of capacity should be distinguished. Aggregate capacity defines the overall available capacity on the level of skills available, expressed in a total number of hours. It is used primarily to recognise at an early stage whether additional capacity may be needed (subcontracting, overwork, hiring temporary manpower). Detailed capacity denotes the work assigned to individual workers or teams. Both appearances of capacity should be used simultaneously, but distinguishable, to enable a smooth transfer from aggregate to detailed planning. In this way, controlled and consistent capacity plans emerge.

The fifth rule introduces the portfolio management system. At this operational macro level feasible portfolios are constructed, based on trade-offs between often conflicting short term objectives of project leaders and work package managers on the one hand, and department heads on the other hand. The result of the portfolio meetings should be an unambiguous priority setting of projects and work packages.

The introduction of multi-disciplinary teams is the subject of the sixth rule. By integrating the planning, support and execution of tasks within a team as much as possible, we significantly increase the problem-solving capabilities of the workforce. Being confronted with the many sources of uncertainty (timing, work contents, etc.) the possibility of low level decision making is essential in order to attain a sufficient level of flexibility and promptness.

The last rule underlines the possibilities offered by modern information technology. Recognising the enabling role of Information Technology at an early stage is essential when designing new organisational structures. As elements in an information structure we distinguish system software, the state-independent and state-dependent
software shells, and finally decision support systems. In particular the use of intelligent decision support systems for multi-order processes is now recognised as an important enabler to support the portfolio management methodology.

The application of these seven technological rules (or, alternatively, the presence of the associated characteristics) has been tested in four follow-up case studies. In succession, we considered the organisational structure of a maintenance company for railway freight trucks, a maintenance company for army equipment, a shipyard for US Navy ships, and an engineer-to-order (ETO) company that manufactures large transformers. The ETO company was added due to high resemblance of ETO and LSMO processes.

The result of the follow-up case studies showed that many of the previous technological rules were present in the various companies. In some cases we cautiously concluded that the implementation of a rule might benefit the concerning company. In other companies there was, due to for example a smaller size or a lower process complexity, no need for the implementation of a specific rule. On the whole we conclude that the results support the rules from the design model. The last case even showed that to a far extent they might also be applicable to ETO environments. However, due to the size of the follow-up case study it is not justified to conclude that we have achieved a satisfactory saturation level. More research is needed to achieve this level.

When reflecting on the research results, we recommend further testing of the technological rules in other LSMO's and ETO companies. Next, some technological rules need more extensive testing. For example, during our research project it was not possible to fully test the capabilities of a DSS prototype and the portfolio management methodology. Besides, the establishment of multi-disciplinary teams in LSMO's need further research. Due to flexibility reasons exchange between teams is often necessary. The impact of a temporary outplacement of a team member on the group coherence deserves further attention.

Although this dissertation discussed only a part of the total project as carried out at the Royal Netherlands Navy Dockyard, it is undeniable that the combination of quantitative research, aiming at the realisation of the Decision Support System, and qualitative research, aiming at the design of a new organisational structure, had a strong positive impact on both studies. Such an integration of disciplines in re-engineering studies should be strongly recommended.
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Chapter 1

1. Introduction

Non-flow Large Scale Maintenance Organisations (LSMO’s) can be defined as enterprises of considerable size (i.e. more than 150 employees), with as primary tasks the maintenance, overhaul, and modification of, often complex, technical systems. Due to the nature of these tasks, this type of LSMO’s typically faces a high uncertainty with respect to the timing and the size as well as the actual work contents of customer orders (i.e. the non-flow character). In addition, the growing demand for quality, flexibility and responsiveness, as experienced by almost any productive system in the last decades, has placed a higher emphasis than ever before on the operational availability of these systems, thereby forcing LSMO’s to adopt the similar high performance standards. Unfortunately, the old, generally functionally oriented, structures are often not able to satisfy these demands. As a result, the need for an organisational change becomes inevitable.

The Royal Netherlands Navy Dockyard (RNND) is such a non-flow LSMO for which the need to re-engineer its organisational structure became painfully clear in the beginning of the nineties. The functionally oriented structure of this maintenance facility for Royal Netherlands Navy ships was not capable to fulfil the changed customer demands. The resulting severe planning and control problems were the motive for the study presented in this thesis. The aim of this study is to design a management and operational structure (i.e. a design model) for non-flow LSMO’s which can meet these tight customer demands. Therefore, we first develop a theoretical approach to create such a structure (i.e. a process design). Subsequently, we apply this approach in an extensive case study (at the RNND). By generalising the results of this case study, we obtain a design model, i.e. an example that can be used for other LSMO’s to design their management and operational structure. In the end, we test this model in four follow-up cases.

In this chapter, we consider the characteristics of non-flow LSMO’s and the research design. Therefore, we first briefly describe the non-flow LSMO’s. We include an example of the problems faced by such LSMO’s, that indicates the need for this research. Next, we discuss the characteristics of LSMO’s with the use of a typology of production strategies and situations. The result of this characterisation contains essential control issues, which enables the formulation of the problem statement, the research domain, and the research objectives in the following section. Subsequently, we consider the research design by explaining the strategic choices, the research activities, and the contents of the multiple case study. This chapter concludes with an outline of the thesis and a summary.
1.1 A general view on non-flow LSMO’s

During the last few decades, maintenance has become an active research area. According to Tsang (1998), a survey of the literature indicates two main trends in maintenance research. One is concerned with using operations research models in reliability analysis, optimisation of inspection, repair and replacement decisions, and scheduling of maintenance activities. The other trend deals with the study of maintenance activities from a system’s perspective, focusing on issues such as performance measurement, work structuring, process management, outsourcing, life cycle costing, and the application of information technology [Tsang (1998), p.86]. However, notwithstanding the fact that this thesis deals with a maintenance issue, it does not fall in either of these two categories. This thesis considers organisational structures that are built to facilitate the execution of maintenance activities. The two main trends in maintenance research are of course important issues in the daily operation and control within these organisational structures. To breed understanding for the need for this research in this section, we first briefly describe the developments in maintenance management. Next, we consider the general features of the research subject: the non-flow Large Scale Maintenance Organisations (LSMO’s). We finish with an example of the control problems within these organisational structures.

1.1.1 Maintenance management

Companies used to consider maintenance as an unavoidable and difficult-to-control part of a process. However, the perception of maintenance has changed drastically during the last decades [Pintelon et al. (1992)]. Many companies have realised that maintenance should be an integral part of the business concept. In this vision, maintenance is a profit producing activity, instead of an unpredictable and unavoidable cost linked to the business process. According to Van Rijn (1987) maintenance management includes the following important elements:

- Establishing the necessary capacity and production volume, by ensuring the required availability and reliability of process equipment and installations.
- Managing the fixed costs (for example the maintenance labour force is an important part of the fixed costs over the short and medium term).
- Managing the operating costs through a maintenance operating budget for spares, consumables, and outside or contract service.
- Ensuring environmental and employee safety.

This list indicates that maintenance management is a mature field of study which developed itself from a ‘pioneering phase’ through a ‘controlling phase’ into a ‘management phase’ [Duijvenvoorden et al. (1993)]. In the last phase, we consider maintenance more and more from a business economical perspective. The maintenance tasks are directly related to the company objectives. A major concern is to develop ways to improve the predictability of maintenance. For this purpose, three main streams can be distinguished in maintenance management:

- Terotechnology
  The essential feature of terotechnology is the feedback on the object design, achievements, and costs. It is a combination of management and financial, technical and other methods, applied to physical objects, which aims for economical life cycle cost [Parke (1974)]. This approach relates to the specification and design of reliable and maintainable physical objects, as well as to their installation, putting into service, maintenance, modification, and replacement.
• **Logistic Engineering**

After World War II, an approach called Life Cycle Costing (LCC) was developed in the USA. In LCC, all the alternatives for a physical object were evaluated with respect to costs for the entire service life: from acquisition to disposal. This approach was extended to the logistic support by the ‘Society of Logistics Engineering’. It emphasized the logistic support of capital intensive objects [Blanchard (1974)].

• **Total Productive Maintenance (TPM)**

Total Productive Maintenance is described by the Japanese Institute of Plant Engineers as the goal to maximise the effective use of manufacturing means by introducing an integral system of preventive maintenance during the entire service life of these means (minimising down time of capital intensive objects) [Nakajima (1989)].

The relation between these three maintenance philosophies is illustrated in Figure 1.1.

![Figure 1.1: Maintenance approaches](image)

These concepts have greatly influenced the way companies think and act regarding maintenance. Apart from the question whether a company uses external or internal suppliers of maintenance, the awaking of companies that maintenance is an important part of the business process forces them to put high and professional demands on the performance of maintenance companies or maintenance divisions (internal suppliers of maintenance).

In relation to the general developments in manufacturing processes, customers of maintenance companies demand high flexibility levels (for example to carry out unexpected corrective maintenance), short lead times, short time-to-market intervals, high quality, and reliable due dates. The latest developments show that some customers even tend to specify the desirable operating time of a system, instead of the required maintenance tasks. In this case, a maintenance division or company has to perform maintenance based on this target.

This concludes the general survey on the developments in maintenance management. In the next section we move to the objects of our study: the companies that carry out the maintenance tasks.
1.1.2 Essential features of LSMO's

This thesis aims at the development of a design model for the management and operational structure for non-flow Large Scale Maintenance Organisations (LSMO's). The main task of these LSMO's comprises all the work connected with an overhaul of complex systems, including both preventive and corrective maintenance, as well as, sometimes, major modifications and upgrading activities. In particular, we focus on companies characterised by a high degree of uncertainty in the work package composition, the work preparation phase (i.e. the order acquisition, the engineering, and technical specification activities), and especially in the work execution phase. In a situation in which a maintenance organisation is in full control of the maintenance objects, it may determine when and what kind of maintenance an object should receive. For example, the maintenance department of the Royal Dutch Airlines (KLM) determines to a large extent when a plane is scheduled for a large overhaul. This decreases the process uncertainty significantly. We call LSMO's with a high degree of uncertainty non-flow. To improve the readability of this thesis we will not include the adjective non-flow each time we mention the term LSMO. However, unless we indicate otherwise, we assume that the non-flow characteristic is incorporated in the LSMO's of this thesis.

Similar to manufacturing companies, organisations dealing with maintenance and overhaul operations have faced dramatic changes in the development of their core business. Within the world of manufacturing, efficiency has long been the key performance indicator. However, changing market characteristics and customer’s behaviour, as well as major technological developments, led to a strong demand for product quality, process reliability, and flexibility and speed in delivering both products and services. In addition, the suppliers of these products and services are clearly still bound to remain competitive in terms of price and efficiency. We will elaborate more on these changes in Chapter 2. With respect to LSMO's, shorter life cycles of products and increased technological complexity have even strengthened these changing requirements. Moreover, the role of a maintenance organisation often gradually changes from purely executing maintenance and repair activities to having full responsibility for the availability of technical systems during their entire lifetime. The increased technological complexity may lead to a high level of uncertainty during order acquisition, requiring an increased effort with respect to engineering activities (in particular work specification, design, and process planning). In addition, high investments in capital-intensive processes require an optimal availability of systems, which make quality, speed of deliverance, and conformance to target due dates to become key performance measures.

Many manufacturing companies have responded to the above requirements by redesigning their planning and control structure and by adapting their organisation to these changing needs or (to put it stronger) indeed by rethinking entirely their manufacturing strategy. One way to respond is to shift towards a more product-oriented structure, i.e. to group resources (materials, means, and employees) around well-defined product clusters that can be considered more or less independently. Within service organisations, the redesign of processes around services that bear similar characteristics in terms of client responsiveness and/or technological complexity has also been recognised as an important option, often denoted by a process-oriented structure. Despite the term, this should not be confused with the classical functionally oriented organisation. Whenever we speak of a process-oriented structure, we have in mind a structure in which all process activities (acquisition, engineering, planning, scheduling, execution, and service) are organised around several product flows, independent from one another as much as possible. The motivation and arguments underlying such a process-oriented structure range from the high level of uncertainty in the work offered, a transparent planning and control structure on the appropriate levels in the organisation, to socio-technical aspects. The following summary contains the essential features of LSMO's:

- LSMO's are dedicated to the overhaul and maintenance of complex systems;
- Non-flow LSMO's experience a high degree of uncertainty in the composition of the work package, the work preparation phase, and the work execution phase;
Introduction

- LSMO's experience increasingly tight requirements on product quality, process reliability, flexibility, and short lead times;
- LSMO's are under pressure to expand their responsibility towards an integral maintenance concept.

This summary implies specific operational control tasks and problems, which we will illustrate in an introductory example.

1.1.3 An introductory example of an LSMO control problem

As mentioned before, the control problems at the RNND initiated this study. This is why we consider a case from the RNND's daily practice as an introductory example. While an extensive description of the dockyard and its processes is part of Chapter 3, we limit ourselves in this section to the necessary information for understanding the implications of the example.

The RNND is the primary maintenance facility for the platform systems of the Royal Netherlands Navy (RNN) ships. To obtain a clear view on the cost flows and the performance of the different sections within the RNN, the navy has established an organisational model in which each section has its own responsibilities and competencies. This implies, among other things, an explicit customer-supplier relationship between the operational task groups (i.e. the 'owners' or primary users of the maintenance objects: the ships) and the dockyard. As the amount of work offered on the short term is often larger than the dockyard's resources can handle, the customer and the dockyard have to agree on assigning priorities to the orders (every platform maintenance task is tendered in principle to the RNND). However, while priorities may change, the customer continues to demand an accurate, flexible, and prompt response to the resulting scheduling and execution problems.

An example of such a scheduling and execution problem is the repair of the damage on board HNLMS Tjerk Hiddes. In 1994 the frigate Tjerk Hiddes was confronted with a serious fire at the engine room, while on duty for a navy exercise. After completion of this trip, the ship was initially scheduled for a deployment of approximately five months in the Caribbean. Needless to say that, due to the fire, the exercise was not completed, but instead the ship was determined to return as soon as possible to the Naval base. Luckily there were no casualties among the ship's crew, but the first damage reports showed severe damage in the aft engine room (see Photo 1.1).

\[\text{NOT AVAILABLE IN THIS VERSION}\]

\text*{Photo 1.1: Impression of the fire damage in the aft engine room.}

The main part of the electrical cables and circuits, the electrical cabinets, the engine room aisles, the cruising speed propulsion diesel engines, the main gearbox, several exhaust pipes, and the exhaust pipe lagging, needed replacement or repair. Quickly it became clear that the Tjerk Hiddes could not be repaired in time for its trip to the Caribbean. Next, the Commander in Chief of the Netherlands Fleet (i.e. the customer of the dockyard) demanded answers to the following questions:

1. what is the expected lead time of the damage repair;
2. what are the consequences for the already arranged workload of the dockyard if the Hiddes is to be repaired in the upcoming months;
3. can the dockyard speed up the maintenance of the HNLMS Karel Doorman (a frigate belonging to the same class as the Tjerk Hiddes, that was overhauled at the time of the accident), so that it may take over the deployment of the Hiddes.
As the resources of the dockyard were completely assigned to the various maintenance orders in the upcoming months, an immediate repair of the damage would have serious consequences for the already arranged work. In addition, an earlier completion of the Doorman’s maintenance period would also have consequences for the workload.

![Resource Schedule RNND 1995](image)

*Figure 1.2: Resource schedule RNND 1995.*

To present different realistic repair scenarios, that include the consequences for the existing workload, it is necessary to obtain a clear view on the various resource loads, especially for the critical expertise groups. Figure 1.2 shows the expected overall resource load for the RNND before the repair claim of the Hidde came in. Already in this view the resource load exceeds the maximum available capacity.

![Resource Schedule RNND 1995 (including repair Hidde)](image)

*Figure 1.3: Resource schedule RNND 1995 including repair Hidde.*
So there was already a slight problem in the short term scheduling (i.e. for the upcoming three months) without taking the Tjerk Hiddes' fire into account. After determining the expected workload and the desired start and due date for the Hiddes, the resource load was plotted into the overall resource schedule (see Figure 1.3).

As expected, the incorporation of the Tjerk Hiddes' workload showed a significant increase of the workload beyond the total resource availability. However, due to a one level scheduling methodology, an unclear definition of the order acceptance and preparation procedures, a strictly functional partitioning of the entire workload into relatively small jobs, and a wearisome insight in the precedence relations between these jobs, it was hardly possible to get a clear picture of the consequences for the existing assignments. In addition the dockyard lacks a proper information system that supports these kind of scheduling problems. The result of these shortcomings was an unreliable scenario. As far as the repair of the Tjerk Hiddes was concerned this has led to a satisfied customer. The same customer, however, was dissatisfied with the consequences for the other maintenance assignments. In other words: the dockyard carried out a good damage repair job, but it did by far not realise the agreed scenario. Unfortunately, it is possible to present several analogous cases at the RNND.

As we analysed these cases, we soon discovered that this malfunctioning was not due to unwilling employees, but could be traced back to planning and control, as well as to the organisational structure. If the organisation is divided in many different departments, if the resource scheduling is almost entirely done at a detailed level, and if the information system provides poor support in the business control, then, under heavy workload conditions, it is almost impossible to deliver a prompt, flexible, and alert response to a customer demand, at least without dissatisfying other customers. This was the motivation to start the research on the development of an organisational model that incorporates the essential conditions to cope with these demands.

1.2 Characterisation of non-flow LSMO's

For the research design, it is essential to analyse the essential control characteristics of LSMO's. In this section, we define these characteristics by using a number of typology theories. We define a typology as a set of criteria and characteristics of companies and/or organisations, which classifies and describes them such that a more or less uniform type of companies or organisations emerges. In this section we first discuss a typology which is based on the terms product choice and product strategy and the related material and capacity complexity. This results in a job shop, flow shop, and/or project manufacturing characterisation with the use of a modified typology of Hayes et al. (1984) and Fogarty et al. (1991). We have selected this set of typology theories because of its explicit interest in manufacturing processes, which form an important element of our study object. Next, we characterise the non-flow LSMO's with the use of this typology set. The result of this characterisation contains the essential LSMO features and control problems.

1.2.1 A typology of manufacturing systems

The influence that a customer has on the processes within an organisation is an important characteristic. This influence is determined by the company's choice for an end product (i.e. the product choice) and the associated customer market. The choice for a product has consequences for the required machines, skills of employees, and materials. The customer market implies demands regarding lead times, due date reliability, the possibilities to customise products to customer's wishes, and the price of the product. Van Hees (1990) describes the following five basic product strategies:

1. A company manufactures and distributes its end products to stocks, and the customer is served from these stocks.

2. A company manufactures its end products on a centralised stock, and customers are served from this stock;
3. The assembly of end products is based on customer order. To this end, the company establishes a stock of components and semi-finished items. In addition a set of product options is defined from which the customer may choose.

4. The manufacturing of a product is based on customer order. Components may be re-designed according to customer specifications. The company only stores the general materials and items.

5. The design and manufacturing of a product is completely based on the customer wishes. Depending on the results of the engineering phase, the company procures materials and, possibly, components.

The basic criteria for choosing one of these manufacturing strategies are the estimated process time and the uniqueness of a customer demand. The estimated process time is the time needed to manufacture the desired product. This time interval must be significantly smaller than the delivery time requested by the customer. The customer demands contain the specific wishes for a desired product.

![Diagram](image)

*Figure 1.4: View of customer order decoupling points [Van Huis, 1990].*

For example in the domestic appliances market, a customer will accept a standardised product like a coffee-making machine. However, when he buys a car, he wants the possibility to choose from different options. If customers are prepared to wait longer for a product, provided that it can be modified to customers demands, the company may shift towards an 'assemble to order' or 'manufacture to order' strategy. Of course, it is possible to adopt a mix of various strategies depending on the market the company wants to serve. Figure 1.4 depicts the different possibilities of customer impact on the manufacturing process. The point at which the activities in the company change from forecast based towards customer orientated is called the customer order decoupling point (CODP).

The product choice and product strategy largely determine the complexity within an organisation. In this respect, we distinguish material complexity and capacity complexity. Let us consider these terms in some depth. The product choice determines the material complexity of a manufacturing process. The material complexity is defined as:

> The complexity caused by the number and variety of different materials and spare parts needed for the release of a production order.

For example, a car has a high material complexity, due to the many components and items incorporated in this product. When a company has chosen its product and next analyses the potential customers market, it
determines one, or a mix of, the five product strategies. This product strategy choice is directly linked to the capacity complexity. The capacity complexity is defined as:

The complexity caused by the different number and variety of skills and resources needed to manufacture a product.

The repetition level of a product largely determines the capacity complexity. A high repetition level means a relatively small product uncertainty, which enables an easy integration of consecutive activities and the specialisation of resources for a product. A low repetition level, on the other hand, occurs when many different products are manufactured in small batches with changing resource utilisation and routings.

The material and capacity complexity in turn can be linked to a possible classification of three basic process structures [modified from Hayes et al. (1984) and Fogarty et al. (1991)]: the job shop, the flow shop, and ‘project’ manufacturing. A brief description of each structure follows below:

1. **The job shop**
   The manufacturing of small batches of a large number of different products, that in most cases require a different set or sequence of processing steps.

2. **The flow shop**
   In a flow shop, one or various products are manufactured along the same sequential steps. The appearance of this structure may vary from continuous flow manufacturing to the assembly line and finally to the manufacturing of batches. The first one is the conversion or further processing of undifferentiated materials in a continuous flow, that follows a predetermined sequence of steps. The assembly line includes the manufacturing of discrete parts moving from workstation to workstation at a controlled rate. Finally, the batch manufacturing structure is a relatively stable line set up for different products that are manufactured in periodic batches.

3. **'Project' manufacturing**
   In a ‘project’ manufacturing structure, a complex and unique product is manufactured, which requires a set of different subtasks. The project is complex enough that the subtasks require careful co-ordination and control in terms of timing, precedence, cost, and performance. The project itself must often be co-ordinated with other projects within the same organisation [Meredith et al. (1989)]. A special type of project is the ‘on-site’ manufacturing process structure. The dominating characteristic of this structure is the transfer of workers, materials, and tools to the manufacturing site. This structure is found, for example, in the building of houses and roads, in the aeroplane industry, and in the shipbuilding industry. The product of an on-site manufacturing process can hardly be moved from one construction site to another. Elements and parts of the products are often manufactured in a flow or job shop structure.

![Figure 1.5: The continuum of the various basic process structures.](image-url)
In practice, an exact match to one of these basic structures seldomly occurs. It is more likely to find a mix of basic structures. Examples of possible exact matches are: the production and transport of crude oil at an oil refinery; and drilling platforms as a ‘pure’ flow shop structure, the building of a bridge as a ‘pure’ project manufacturing structure (i.e. on-site), and a machine shop as a ‘pure’ job shop structure. Figure 1.5 shows the continuum of the various process structures.

As we successively defined the product strategy, the product choice, the capacity and material complexity, and finally three possible basic process structures, we now link these elements in order to arrive at a characterisation for an LSMO environment.

![Figure 1.6: A diagram for the LSMO characterisation.](image)

Figure 1.6 shows the relation between the product strategy and the capacity complexity, the product choice and the material complexity, and the material and the capacity complexity, respectively. The material and capacity complexity relation indicates the basic process structure that will be dominant in the current study. We use this diagram in the next subsection to characterise the LSMO’s.

### 1.2.2 A characterisation of non-flow LSMO’s

For the characterisation of LSMO’s, we first consider their field of operation. This can be described through the EUT-maintenance model [Gerards (1991)]. This model presents an integral view of the following aspects of a specific system: engineering, manufacturing, use, designing maintenance, maintenance control and analysis, maintenance resources, and, finally, supporting services. Figure 1.7 depicts a schematic view of this model.

The focal point for LSMO’s lies in the sections ‘maintenance control and results analysis’, ‘maintenance resources’, and ‘material supplies’ (see the lower part of Figure 1.7). The contents of these sections are strongly influenced by the sections ‘use’, ‘design of a maintenance concept’, ‘manufacturing’, and ‘design of a technical system’. The design of a system, for example, largely determines the way maintenance has to be carried out when the system is operational. For example, the decision in the design phase to build a motor in a locomotive as an interchangeable object with easy disassembly and installation tasks has high implications for maintenance during
the operational life of this engine. Although the design and application of maintenance rules is not the subject of this thesis, we notice that the cycle 'system design', 'system manufacturing', 'maintenance concept design', 'use' (including maintenance control and results analysis), and the 'terotechnology' feedback to the design phase is essential in maintenance. The terotechnology feedback transfers the findings from using and maintaining a system to the design methodology, in order to exploit this knowledge when new technical systems are designed [Geraards (1991), p.636]. We must enable the use of this cycle in our design model by incorporating a strong 'results analysis' function.

Although a lot of effort is put into the predictability of maintenance, it will never be possible to fully specify the work contents of a maintenance task: when carrying out a maintenance process, little by little the full implication of an assignment gets clear.

Figure 1.7: The EUT-maintenance model [Geraards (1991)].
Also the customer will be involved in the decision process of what kind of repairs should be undertaken. Therefore, the maintenance process will seriously depend on the nature of a specific job.

This survey of the possible activities within an LSMO and the nature of its process enable us to characterise the LSMO's. To characterise an LSMO we first determine the material and capacity complexity based on the product choice and product strategy. Next, we consider the possible basic process structures for LSMO's.

The products of LSMO's are ready-for-use objects. A company provides maintenance or modifications to repair an object or secure its availability. This description of the LSMO end products (i.e. the product choice) leaves the precise determination of the material complexity open. The material complexity depends fully on the actual object and the corresponding maintenance tasks. We conclude therefore that the material complexity for LSMO's may vary between low and high.

The customer has in general a large influence on LSMO's. A customer brings in the maintenance object together with a functional specification of the required maintenance tasks. It will never be possible to fully anticipate on these customer requests. In case of a strong alliance between the customer and an LSMO (i.e. for example when the LSMO and its customers operate within the same concern structure), it is possible to slightly anticipate on the maintenance tasks, for instance by keeping track of the object and its system performance (e.g. through vibration measures) and through a joint scheduling of duration based maintenance tasks. Another possible strategy is to adopt a repair-by-replacement strategy. In this case, installing a working item in the object repairs it. The defective item is repaired after the object has been put into service again. This strategy demands a significant investment in spare parts. However, in spite of these uncertainty-eliminating strategies, in an LSMO environment the customer will still highly influence the manufacturing process. Therefore we conclude that the customer order decoupling point varies between the 'assemble on order' (i.e. the repair by replacement strategy: CODP 3) and the 'purchase and produce on order' (i.e. the manufacturing process is fully based on the customer wishes: CODP 5). This product strategy results in a capacity complexity that varies between average and high.

The estimates for the material and capacity complexity lead to a basic process structure, varying from a job shop, via the batch manufacturing, to a project manufacturing structure (see Figure 1.8). The job shop structure is generally found in the maintenance of smaller objects, which only need a few materials. If the maintenance is large and incorporates many different materials and spare items, then the basic process structure is 'project' oriented. The reduction of uncertainty by, for example, a repair by replacement strategy or the maintenance of many identical and relatively small items may lead to a small batch manufacturing process. The basic process structure continuum from Figure 1.5 also applies to this LSMO characterisation, where we have excluded the continuous flow and large batch manufacturing processes (see Figure 1.8).

![Figure 1.8: The continuum for non-flow LSMO's.](image)
Therefore, it is also within an LSMO more likely to find a mix of basic process structures. For example, in addition to the project approach of the overhaul of an aeroplane (which is an on-site task), separate sections are established to maintain items like the propulsion engines and the landing-gear tyres. These sections fall in the job shop category.

The job shop/small batch/project characterisation implies the following properties for an LSMO manufacturing process [Van Rijn (1985)]:

- a complex process;
- a large product assortment;
- many different routings and lead times;
- small batch sizes (sometimes equal to one);
- a multi-order situation with many orders simultaneously in execution;
- parts of the order are subcontracted to other companies.

The control problems for this manufacturing process concern the quotation of realistic due dates and lead times and the realisation of these due dates [Van Rijn (1985), p.105], next to cost control. While investigating the LSMO environment, we observed the high resemblance with the engineer-to-order processes (ETO). An ETO process comprises the engineering (i.e. the design) and production of custom-built products based on a specific customer order. Muntslag (1993) distinguishes the following typical control problems for the ETO environment [Muntslag (1993), p.10]:

- variable and inconsistent throughput times which are difficult to control, leading to problems in meeting due dates with respect to the consecutive physical production processes;
- difficulties in forecasting the resource capacity requirements for a customer order, leading to large discrepancies between the budgeted and actual costs of producing the order;
- an excessive number of changes to the product design after the technical specifications have been released for manufacturing, leading to unnecessary extra costs and delays in the throughput time;
- poor decisions due to a lack of information about the technical, time-related and financial consequences of various decision alternatives.

These problems are almost identical to the problems in an LSMO environment. An essential characteristic is the high uncertainty factor in both processes. However, there is a slight but very important difference in the process uncertainty. The product of an ETO company is an artefact, i.e. a new product. Therefore, the uncertainty is mainly caused by the nature of the customer order (i.e. the innovation level), changing customer demands, and incomplete or faulty engineering results. In an LSMO on the other hand, the input is an existing entity: the maintenance object. The nature of the defect and/or the condition of the object are preliminary conditions. This leads to so-called potential and unknown defects, which, in the worst case, are not discovered until the execution phase.

This characterisation of LSVO's and its environment and the comparison with the ETO control problems lead to the following summary of essential environmental and process characteristics:

**The environmental characteristics:**

- LSMO's experience a high uncertainty in the customer demands, with respect to the timing, the size, as well as the actual work content of each order. This uncertainty is dominantly present in the order acquisition phase, the preparation phase, and finally the execution phase.
- The customer has a high influence on the maintenance process.
- The nature of maintenance makes it impossible to fully anticipate on the customer requests.
The process technology characteristics:

- LpMO's face a complex process with many product variants and cross-over routes.
- The process is a multi-order manufacturing process with many orders in execution simultaneously, which generally need a large number of different skills and resources (i.e. the capacity complexity varies between average and high).

This characterisation of the LpMO environment and process technology is the basis for the problem statement and the research objectives in the next section.

1.3 Problem statement and research objectives

In this section, we first discuss the problem definition. Next, we describe the research domain by considering the characteristics of the LpMO's that are subject of our research. We conclude this section with a survey of the research goals.

1.3.1 Problem definition

This thesis deals with the development of a design model for the operational and management structure for LpMO's. Despite the rapidly growing literature on Business Process Redesign in general, we are not aware of much literature addressing a design model for our particular field of interest. Therefore, the following problem definition will be central in this thesis:

The high uncertainty factor with respect to the size, composition, contents, and timing of customer orders, with which companies active in Large Scale Maintenance Operations are faced, cause difficult control problems. Such companies need concepts, systems, tools, and techniques to improve the controllability of their operations in order to deliver maintenance service within the constraints of agreed specification, time, cost, and quality. To date, they lack one or more design models to guide and support the design and development of appropriate control systems.

Next, we define the class of LpMO's that are subject of our research project.

1.3.2 Research domain

The domain of this thesis is defined as non-flow Large Scale Maintenance Organisations. The term 'large' points to a company size of at least one hundred and fifty employees. This seemingly arbitrary lower bound ensures the possible occurrence of control problems, as described in Section 1.1.2 and Section 1.2.2. In general, smaller companies have fewer problems with due date reliability, costs, quality, flexibility, and promptness. The reason is that, on the one hand, their order-book is relatively small, which yields a less complex multi-order situation (i.e. the resources are assigned to fewer orders). On the other hand, the division of tasks among different employees and management layers is in general less scattered. Due to the smaller workforce, these companies can simply not afford an extensive division of control tasks. Obviously, the resulting face-to-face feedback leads to a more quick detection and solution of problems.

The second characteristic of the research domain concerns the high degree of uncertainty of the multi-order work package (i.e. the non-flow character). In principle, each company faces uncertainty, but the causes of these uncertainties differ among the market and manufacturing processes. In a large batch manufacturing process of televisions, for example, uncertainty stems from market demand, but hardly from the manufacturing process itself. The uncertainty in our field of study stems from the timing of an order, its actual work contents, and the unexpected changes during the work execution.

The problem definition, as presented in the previous section, limits the research domain to LpMO's facing a high variety, small batch (or even one-of-a-kind) work package. The production structure of these LpMO's can be
characterised as a job shop, small batch assembly, and/or project process structure (see Section 1.2.2). Note that these basic process structures incorporate the uncertainty characteristic that is experienced in LSMO's. In a large batch assembly or mass production process, on the other hand, there exists a more or less continuous flow of identical or highly similar items, hence hardly any uncertainty in the acquisition, preparation, and execution phase occurs. Therefore, as explained in the characterisation of LSMO's, the latter process structures are not included in our research domain.

Based on these observations, we define the research domain as follows:

The research is focused on non-flow large maintenance companies with an uncertain multi-order work package (regarding the size, time of occurrence, composition, and work contents) and a production process that is characterised as 'job shop/small batch/project'.

As mentioned, the LSMO characteristics bear quite some resemblance with the ones of an engineer-to-order (ETO) company. Therefore, we decided to slightly enlarge our study by testing the design model in an engineer-to-order company.

1.3.3 Research objectives

Based on the problem definition of Section 1.3.1, and taking into account the limitations of the research domain, the objectives of the research project are described as follows:

The objective of the research, described in this thesis, is to develop and test a design model for the management and operational structure of non-flow LSMO’s. The application of this design model should enable the LSMO’s management to control their operations in such a way that the organisation is able to deliver a timely, accurate, low cost, and high quality maintenance service.

This design model should serve as an example for a specific class of LSMO’s (i.e. the research domain). The way to achieve these objectives is explained in the strategic choice of the research method (Section 1.4.1).

1.4 Research Design

We discuss the research design on a strategic and on an operational level. On the strategic level, we describe the overall set-up of the research. The discussion of the operational level, on the other hand, describes the various activities needed to perform the research. In this section, we first describe the strategic research choices. Next, we move to the research activities and the case study built-up.

1.4.1 Strategic choices

The term paradigm reflects the combination of types of research questions asked, the allowed research methodologies to answer these questions, and the nature of the intended outcomes of that research. Based on this paradigm definition, Van Aken (1998, p.4) distinguishes three classes of scientific disciplines:

1. the formal sciences (like philosophy and mathematics)
2. the empirical sciences (like the natural sciences and some social sciences, such as sociology)
3. the design sciences (like the engineering sciences, medical science, and modern psychotherapy).

The formal sciences aim to build systems of propositions that are tested for their internal logical consistency. The empirical sciences describe, explain, and, possibly, predict observable phenomena within their research fields. The design sciences aim to develop knowledge for designing and realising artefacts or to improve the performance of existing entities. Much of the research within the design sciences is based on the empirical paradigm of the description, explanation, and, possibly, prediction of phenomena. However, an important
extension in the design science paradigm is the development of design knowledge (i.e. knowledge which enables professionals to solve problems in their field of interest). As we want to develop knowledge on an appropriate operational and management structure for a specific class of LSMO's, we adopt the design science approach for the study of these LSMO's.

The construction of a design model for a class of LSMO's is based on a selection of a design approach or design process. The selected approach is then applied to one large initial case, after which the results are generalised to a generic design model. Next, the resulting model is tested on a number of additional cases. In this, we follow the problem solving cycle approach, outlined by Van Aken (1994). First, the problem is defined out of an initially messy context. Next, we select the design process that basically can be seen as a sequence of logical steps to build up a design model. This approach is subsequently applied to an extensive primary case, resulting in a preliminary design model (for that case). Next, through an elaboration on the characteristics of similar LSMO's, the model is generalised to a generic design model. Finally, in order to provide evidence that the design model indeed fulfils its primary goals, i.e. to improve the controllability of non-flow LSMO's and similar organisations, the model is tested on a sequence of secondary cases (a multiple case study approach).

A design model may be seen as a solution to a design problem (in this case, the problem how to structure an organisation such that it is able to control effectively non-flow LSMO processes) which has been tested in its context. Generally, these models consist of a set of heuristic technological rules, i.e. prescriptions that describe how a desired controllability improvement can be achieved. The application of a design model is far from similar to the application of an algorithm or recipe, but instead consists of 'customising' the general design model for the specific situation in question [i.e. the heuristic nature, Van Aken (1998), p.5]. Hence, the effect of the application of the design model on the performance of a system cannot be proven as conclusively as the results of the application of an algorithm. However, testing the design model in a set of follow-up cases may lead to sufficient supporting evidence [Miles et al. (1984), Yin (1984), Eisenhardt (1989, 1991), Kirk et al. (1986)]. In principle, collecting supporting evidence should be continued until 'theoretical saturation' is obtained [Eisenhardt (1989)].

An important issue in the development and testing of heuristic technological rules is the question of generalisation (or external validity). To what extent can the results found in the case studies also be expected in other cases? To answer this question, we use the analytical generalisation method [Kennedy 1979]: on the basis of logical reasoning, the effects of the rules are generalised to cases which have as many as possible relevant characteristics in common with the examined cases. The claim one can make in the last phase of the problem-solving cycle, with respect to the application domain, depends on the set of cases studied.

![Figure 1.9: The problem solving cycle.](Image)
The cases in this set should have common relevant characteristics which define the application domain, but on the other hand should sample as much as possible the variety within that domain (theoretical sampling, see Eisenhardt (1989), p. 537; Kennedy, 1979). This reflection concludes the problem-solving cycle.

Figure 1.9 illustrates the problem-solving cycle for this thesis. This is the so-called reflective cycle [Van Aken (1996)]: choosing a case, planning and implementing interventions (on the basis of the problem solving cycle), reflecting on the results, and developing design know-how to be tested and further developed in subsequent case(s) [Van Aken (1998), p. 7].

1.4.2 Research activities

In this section, we outline the research activities. The research started with the control problems experienced at the Royal Netherlands Navy Dockyard (RNND), caused by changing circumstances (i.e. higher customer demands) and a dysfunctional organisational structure (experienced, for example, through poor due date performance). Initially, the dockyard solely blamed the existing information systems and thought a new information system would solve all problems. However, after an examination of the nature of the control problems, it became clear that it was necessary for the dockyard to fundamentally redesign all maintenance engineering and production processes, involving both work organisation and production planning and control.

The functionally oriented structure, with a strict separation of non-physical and physical activities, organised in too many sequential steps, was simply not capable to fulfil the rising demands.

Subsequently, a project team was established, consisting of experts and employees from the dockyard, the Royal Netherlands Navy, and the University of Twente. By using the reflective cycle, we first developed a design approach, based on an eclectic selection of theories. This design approach has been used in the actual re-engineering process of the Royal Netherlands Navy Dockyard (RNND). A new organisational structure with the supporting information systems architecture was developed. Parts of the new structure were tested in practice by means of clearly defined pilots. The results of these pilots were used to improve the new structure. In addition to the tests of the organisational structure, members of the project team have developed and built essential elements of the information structure. These prototypes were also tested in the Dockyard’s real-life environment.

The result of this extensive case study is the final organisational structure with its information architecture. Next, we have generalised this structure for a class of non-flow LSMO’s. The resulting design model is subsequently compared with existing or new structures, encountered in four follow-up cases. The necessary information was gathered through visits to various companies. The duration of these visits varied between one to a few days. Supplementary information, whenever necessary, was obtained through telephone conversations or electronic mails. In this way we obtained a reasonably complete view on a company’s management and operational structure.

In the cases, we investigated the presence or absence of the essential features of the design model. Whenever an essential feature was absent, we analysed whether the implementation of this feature would benefit the company in question. In addition, we discussed the benefits or drawbacks of organisational structures that deviated from the design model. The results of these follow-up case studies should provide the start to achieve ‘theoretical saturation’ of our model. Eventually, reflecting the test results with the problem definition and research objectives concluded the study. At last, we formulated the research conclusions and discussed possible further research topics. In the next section, we consider the build-up of the multiple case study.

1.4.3 The multiple case study

As described in the research activities, we first apply the design process to the RNND. Subsequently, we evaluate the used design approach and generalise the results into a generic design model. Next, this generic design model
for a class of LSMO's is to be tested in various companies. Therefore, we examined three LSMO companies and one ETO company. These cases have to satisfy the research domain defined in Section 1.3.2. To already provide the reader with insight in the Dockyard case and the case studies build-up, we briefly discuss in this section the general characteristics of the Royal Netherlands Navy Dockyard, the Rail Freight Wagon Maintenance of the Netherlands Railways, the Mechanical Workshop of the Royal Netherlands Army, the Norfolk Naval Shipyard of the US Navy, and finally Smit Transformatoren.

* The Royal Netherlands Navy Dockyard

The Royal Netherlands Navy Dockyard (RNND) is located in Den Helder, in the north-western part of the Netherlands. The main task of the Dockyard is to maintain and modify the platform systems of Royal Netherlands Navy (RNN) ships and systems of many RNN shore facilities. Platform systems are roughly defined as the ship's hull, the propulsion system, the energy supply system, the climate control system, and the sewage system.

At the dockyard approximately 1000 employees work in different departments. The RNND is responsible for a highly variable work package: it ranges from the repair of a single fire system pipe to the complete overhaul and modification assignment of a frigate (comprising approximately 150,000 man-hours). Especially the corrective maintenance tasks of RNND may be characterised as unpredictable with respect to materials and capacity needed. This requires quite some flexibility from the organisation.

As explained in the research structure, the dockyard case gave rise to this study. In particular the functionally structured organisation prevented the ability to meet agreed due dates or resulted into tremendous extra costs of overtime work and subcontracting to meet these due dates. Faced with more stringent customer requirements in terms of speed and responsiveness, a new production structure became inevitable for the dockyard.

* The Rail Freight Wagon Maintenance of the Netherlands Railways

The Wagenbedrijf Amersfoort (WBA) maintains rail freight wagons. As such, it belongs to the Netherlands Railways Maintenance Company. Due to the privatisation of the Netherlands Railways (the NS), which started in the early nineties, the WBA currently obtains an independent position within the concern structure. This also means that the operator of the freight train services (i.e. NS Cargo) is no longer obliged to assign its rail freight wagon maintenance to WBA. This changing market position urged WBA to change into a customer driven organisation, which acquires customers inside and outside NS.

WBA is located in Amersfoort and owns an annex in Duisburg (located in Germany). Approximately one hundred and sixty employees are employed in Amersfoort, while the Duisburg site employs approximately fifty employees. The technique of a rail freight wagon is relatively simple and comprises hardly any innovation in the design. Even the high level contracts on the maintenance of a series of rail freight wagons, concern well-known activities in general. The uncertainty with respect to the activities within WBA mainly concerns the individual workload of each rail freight wagon.

* The Mechanical Workshop of the Royal Netherlands Army

The Mechanisch Centrale Werkplaats (MCW) provides maintenance, repair, overhaul, and modification of Royal Netherlands Army equipment. The main location of MCW is in Leusden (near Amersfoort). A second establishment is located in Utrecht. The workforce of MCW comprises approximately three hundred employees.

Due to changing international politics, MCW has undergone a major redesign process. The old bureaucratic maintenance organisation could no longer cope with the changing needs of the army. This inability was reflected by uncontrollable stocks, an inadequate due date performance, long lead times, quality problems,
inefficiency, low employee satisfaction, and finally a high absence due to illness. The new organisational structure within MCW is characterised as process-oriented, with a high emphasis on the delegation of control competencies and responsibilities to the lowest possible level. As in the WBA case, MCW agrees with its customer (i.e. the Netherlands Army) on the number of vehicles to be maintained in a particular period. In addition, MCW only carries out high-level maintenance tasks. The customer carries out the smaller preventive and corrective maintenance operations. However, also within MCW uncertainty exists, caused by the unknown work contents of each vehicle. The maintenance of army objects has changed from a standardised approach to a condition-based one. This demands a highly flexible organisation that is able to anticipate and handle the workload of each individual vehicle.

- **The Norfolk Naval Shipyard**
The Norfolk Naval Shipyard (NNS) is one of the four USA Naval Shipyards. The yard is located in Norfolk Virginia, a city just south of Washington DC. NNS employs approximately seven thousand people. In 1993 NNS changed its organisation from a functionally oriented one into a customer focused one. This was caused by the changing political situation in the world and its consequences for the military forces.

The work package of NNS mainly comprises the large overhauls of the US Navy ships. For this purpose, NNS developed a strong project management approach. For each overhaul, NNS assigns a project team responsible for the complete process from order acquisition till order completion (which includes a six months warranty period). The uncertainty within NNS is caused by the work contents of each overhaul, the technical complexity of US warships, and the multi-project situation.

- **Smit Transformatoren BV**
The last case study comprises the ETO company ‘Smit Transformatoren BV’. Smit employs approximately three hundred and twenty people and is located in Nijmegen, in the eastern part of the Netherlands. Smit is an important player on the market of large power transformers and reactors. Smit’s customers mainly consist of electricity distributors and electricity producing companies. Due to the liberalisation of companies in the electricity market, the position of Smit changed drastically. Smit could no longer rely on a high quality product alone, but was also urged to pay attention to lead time reduction, an excellent due date performance, and low prices. In particular during the order acquisition and initial engineering phases, Smit faces a relatively high uncertainty with respect to specific product characteristics and, as a result, needs estimates to predict the various resource leads. In such companies, a quick product configuration mechanism may be helpful [see e.g. Begelinger (1998)], next to a planning and control structure that reduces uncertainties during the actual project execution.

When we consider the main case study and the additional smaller cases, the following similarities become apparent:

- the change to an unstable market environment;
- the uncertainty in the manufacturing process;
- the emphasis on the engineering and work preparation phase;
- the need for flexibility.

The differences between the cases concern:

- the size of each company (varies from approximately two hundred to seven thousand employees);
- the domain (four LSMO’s and one ETO organisation);
- three companies operate within a government-owned structure, while two others operate in a commercial environment.
It is important to emphasize that the additional case studies should indicate whether the general design model may be applied to a broader range of LSMO and ETO companies. The result therefore will be at best a reasonably generic structure, and not a single universal planning and control structure for all LSMO’s and ETO organisations.

1.5 Outline of the thesis

Figure 1.10 depicts the reflective cycle and the corresponding chapters of this thesis. The present chapter deals with an observation and description of the problem area. Chapter 2 describes the theory selection for the design process and the design process itself. In Chapter 3 we apply this design process to redesign the organisation and control structure of the Royal Netherlands Dockyard. First, we describe the dockyard’s history, the current process structure, and the problems regarding its process control. Next, we step-wise come to a redesign of the process structure. As the dockyard has already implemented parts of the new structure, we discuss the achieved results as well as expectations on future developments at the end of this chapter.

In Chapter 4 we evaluate the design approach and generalise the results of the RNND case study. The result is a generic design model that consists of seven essential technological rules.

To test this design model for a class of LSMO’s we discuss in Chapter 5 the four follow-up case studies. At the end of each case study, we compare the company’s process structure with the essential features of the design model. The conclusions of Chapter 5 concern the extent to which the design model is applicable to a broader environment (i.e. may be considered as a design model for a specific class of LSMO’s).

The last chapter contains an evaluation of the design process and the test in real-life cases. By comparing the results of the different chapters with the research goals, we end with some conclusions and recommendations for further research.

In each chapter, we repeat the regulative cycle of Figure 1.10. In this way, the reader may keep track of the thesis’ outline.
1.6 Summary

This thesis considers the control problems within Large Scale Maintenance Organisations. An important characteristic of these organisations is the uncertainty factor in both the preparation and execution phase of their manufacturing processes. In addition, changing markets and especially the increasing customer demands regarding flexibility, response and lead times, quality, and low costs have urged LSMO's to reconsider their production and control structure. In view of the characteristics of LSMO's, the development of a design model seems to be most appropriate. However, to our knowledge such a model is not available. Therefore, we develop in this thesis such a model with the use of a multiple case study. First, we construct a design process that consists of elements from existing redesign approaches. The application of this design process to a primary case (i.e. the Royal Netherlands Navy Dockyard) yields a design model. Subsequently, we generalise this model for a class of LSMO's. To test the model, we perform four follow-up case studies. Finally, we reflect on the results of these tests and discuss the level of 'theoretical saturation'.
Chapter 2

2. A design process for Large Scale Maintenance Organisations

2.1 Introduction

In this chapter, we describe a (re)design process (i.e. an approach for the re-engineering process) for the RNNRD case, which we will use in the next chapter (see Figure 2.1). First, we briefly consider the history and development of industrial organisations, to explain why functionally oriented organisational structures have played (and still play) such a dominant role. Next, we explore several process-oriented redesign theories in order to select useful tools for the development of the (re)design process.

![Diagram](image-url)
Subsequently, we combine these tools in the design process for the RNNF case in the next chapter. This design process is mainly based on the Dutch Sociotechnical approach. We explain this approach by successively discussing the phases investigation/diagnosis, goal setting, design, and finally implementation. For the development of an operational and management structure, only the first three phases are relevant. Therefore, we subsequently discuss in three separate sections the contents of these phases. In the last section, we summarise the (re)design approach.

2.2 Selection of organisational redesign theories

Before discussing the process (re)design in detail, we select in this section the underlying organisational redesign theories. In Chapter 1 we mentioned the limitations of functionally oriented organisational theories. Because of the great influence these theories had and still have on our way of organising, we first consider the history and development of industrial organisations that led to the present problems in the structure of LSMO’s. Since many LSMO’s are still organised around the principles of labour division and Scientific Management, we start our historic overview by Adam Smith, who was the first to describe the advantages of labour division, then move to Frederick Taylor, the father of Scientific Management, and from there to the modern approaches in organising and managing industrial organisations. In this way, we gain insight in the basis of the problems in our field of research. We do not pretend to give a complete historical survey: this is beyond the scope of this thesis. The mere meaning is to provide knowledge on the logic behind and the drawbacks of traditional organisational structures. Next, we eclectically select alternative theories for the functional approach, which we use in the development of the design process (i.e. the approach of the re-engineering process). The result of this selection is summarised at the end of this section.

2.2.1 History and Development of Industrial Organisations

Many management and organisational problems of LSMO’s originate from a functionally oriented structure (i.e. a grouping of similar skills into functional groups). In this section, we start a discussion on this structure and its alternatives by giving a brief survey of the historical development of organisations and the development of organisational theory.

In 1776, the Scottish economist Adam Smith described the division of labour in a pin-manufacturing firm:

One man draws out the wire, another straightens it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head; to make the head requires two or three distinct operations; to put it on is a peculiar business, to whiten the pins is another; it is even a trade by itself to put them into the paper; and the important business of making a pin is, in this manner, divided into about eighteen distinct operations [Smith (1993)].

Nowadays, we have automated the pin-making process, but the principle of division of labour Smith described is still present in many modern organisations. The development that enabled the principle of Smith to be put into practice was the invention of the steam engine. In 1776, James Watt sold his first steam engine in England, an event that marked the start of the First Industrial Revolution. Following these developments, two fundamental steps were taken to develop manufacturing industry. The first one primarily took place in American industry, which chose to vertically integrate many previously disparate operations under a single roof [Wallace et al. (1996)]. This formed the basis for the integrated mass production facilities in the 20th century.

The second step was the production of interchangeable parts. This principle originates from the 15th century when the Arsenal of Venice used some standard parts in the manufacture of warships (1436). It lasted till 1785 as the French gunsmith Horace LeBlanc showed Thomas Jefferson muskets manufactured by using interchangeable parts. Whitney and North further developed the concept in America. Its implication has been
enormous: prior to this innovation, the making of complex machineries was still a bit of an art. Constructors fabricated and fitted every required piece. The uniformity of the interchangeable parts method made it possible to mass-produce individual parts to sufficiently tight tolerances, such that they could be used in any finished product. It is without doubt an essential idea in the development of modern society that made the use of Smith’s division of labour principle on a large-scale possible. The implementation of this principle greatly reduced the need for specialised skills on the part of the workers: workers, like parts, became interchangeable. This development was the start for the distinction between planning (by management) and execution (by workers).

In the second phase of the Industrial Revolution, starting roughly in the 1850s and 1860s, the factory system diffused into specialised branches (e.g. clothing and food manufacturing, engineering, and chemical, iron, and steel processing), all of which depended upon complex production processes [Hatch (1997), p.23]. Burns (1962) states that this growth and the increased technical complexity of manufacturing operations demanded parallel growth in systems of social organisation and bureaucracy, with their emphasis on control, routine, and specialisation.

Henry Ford was the first one who made high-speed complex mass assembly possible, by using the principle of interchangeable parts and introducing the moving assembly line. He abandoned the practice of skilled workmen assembling substantial subassemblies and workers gathering around a static chassis to complete assembly. Instead, he sought to bring the product to the worker in a non-stop, continuous stream [Wallace et al. (1996)]. This made it possible to mass-produce cheap, reliable automobiles.

The first person who generated sustained interest, active following, and a systematic framework necessary to proclaim management as a discipline, was Frederick W. Taylor (1856-1915) [Wallace et al. (1996), p.30]. He proposed the application of scientific methods to discover the most efficient working techniques for manual forms of labour. This approach became known as Taylorism or Scientific Management [Hatch (1997)]. He strongly emphasized efficiency by specialising labour through the close supervision of employees carrying out highly specific physical work. Management defined the tasks, which had to be performed by the workers, and also determined how they should approach these tasks. This approach shifted control from the workers to the management: planning and doing became distinct activities, placed in entirely separated jobs. It resulted in a situation where the production function is limited to the execution of tasks whereas the supportive tasks are the responsibility of staff departments. An organisation with a Scientific Management approach may be characterised as hierarchical functionally structured and has a strict adherence to rules and procedures.

Scientific Management is seen as an American invention [Wallace et al (1996), p.30]. It had a strong influence on all American industrial organisations and its extreme effectiveness in producing products and services in high quantities at low cost levels formed the basis of the American industrial and economic power [Van Breukelen (1996), p.16]. After World War II, the European and Japanese industries were largely destroyed. The rebuilding of these industries started energetically with American aid. Naturally, the successful Scientific Management principles formed an example of the way industries in these areas should be modelled. This resulted in the sixties in America, as well as in Europe and Japan, in industrial organisations, which were largely based on Scientific Management principles.

In a large and stable market, an organisation with a Scientific Management approach is able to serve its clients very well. In a so-called sellers market, these organisations can provide efficiently made products. In the sixties, however, the first cracks in the Scientific Management hegemony appeared while the market changed from a seller’s to a buyer’s market. One main cause was the liberalisation of international trade. This so-called globalisation was inspired on the one hand by politicians, who were convinced that intensive trade between nations would reduce the chances on war, and on the other hand by industrial organisations, which began to experience the protected national markets as a limiting factor for their future growth. However, globalisation of the market led to more competitors, often operating under different circumstances (e.g. low wage levels). Also,
the increase of competition led to a much wider product variety. Combined with the fact that Western consumers had become wealthier, this led to a situation in which it was no longer sufficient to make a good standard product; the market demanded for a wide range of products, in many variants and with a high quality standard. The immediate consequence was a drastic shortening of the commercial product life: an innovative strategy was needed to satisfy customer demands. Besides efficiency, the concepts flexibility, quality, and innovative power became leading principles in manufacturing industry.

The flexibility concept meant in particular a capability to produce a large variety of products with short lead times. Production control techniques like Material Requirements Planning (MRP), Just-in-Time production (JIT) and KANBAN were used to achieve the flexibility goals. MRP consists of a large, relational database, centred around a fixed Master Production Schedule (MPS) and is meant to control the total goods flow, including all logistic aspects such as purchasing, inventory control, and shop floor scheduling [Van Breukelen (1996), p.25]. JIT [Bertrand et al. (1992), p.341-p.348], initiated by the Japanese, is an approach to deliver parts as well as finished products just when they are needed, in order to minimise work-in-process inventory levels. A special implementation of JIT is a KANBAN system [Bertrand et al. (1990), p.348-p.353], which uses cards to authorise the start of the production of parts to replenish a just demanded quantity. JIT and KANBAN require a relatively stable, repetitive, manufacturing flow, as well as an extremely reliable production process; therefore it is often referred to as a 'zero defect' policy. Around the same time as the flexibility concept gained attention, quality was introduced as an important market-competitive product aspect. Juran (1988), Deming (1982) and others made organisations aware of the relevance of quality in the entire organisation. This approach is known as Total Quality Management (TQM).

As in the seventies Japanese industries are often functioning better than the Western ones, the virtues of Scientific Management are questioned [Van Breukelen (1996), p.30]. A new type of organisations, referred to as Lean Production organisations [Womack et al. (1990)], was introduced. It drew attention to the Japanese strong points in organizing manufacturing processes, like concern management, integration of planning and doing, multidisciplinary teamwork and their orientation towards markets. When comparing Western and Japanese companies, the attention of Japanese management to, and interest in, the production function simply did not exist in Western management. The consequence was superior management of manufacturing operations by the Japanese managers. Another interesting difference between the Western and Japanese attitude is the approach of the production process. Western organisations often adopt a reductionistic approach: a system is analysed by breaking it down into its components, which next are studied in isolation. The Far Eastern societies on the other hand, often use a more holistic or systems approach. They view individual components much more in terms of their interactions with other subsystems, and make the overall goals of the system the main theme [Wallace et al. (1996), p.17]. This attitude explains the Japanese choice for approaches such as JIT and KANBAN, which focus on the improvement of the entire production process. The Western organisations on the other hand chose for the high-tech, integral and complex MRP computer systems focusing on the improvements of the different elements of the production planning process.

In the eighties and nineties, the major manufacturing goals have become efficiency, quality, flexibility, and due date reliability. This has led to new concepts in production design in which product flow analysis played an important role. These developments overcame us with new concepts in production control like Concurrent Engineering [Jo et al. (1993)], capacity oriented control systems such as Optimised Production Technology (OPT) [Goldratt (1984)], and improved material co-ordination systems like MRP II [Wight (1984)]. The growing awareness of the bankruptcy of the Scientific Management approach and the need for an integral process-oriented redesign of manufacturing processes led to four basic redesign approaches [Den Hertog et al. (1995)]; the already mentioned Lean Production [Womack et al. (1990)], Business Process Re-engineering [Hammer et al. 1993], the Scandinavian Sociotechnical approach [Den Hertog et al. (1995)], and the Dutch Sociotechnical approach [De Sitter (1994)]. All these approaches have in common that they derive the functional demands for redesign from the
company strategy, adopt a process-oriented and integral approach, give attention to the creation of willingness for change, and finally point out the need to establish convincing leadership for a successful turnover. In the next section, we briefly explain each approach and eclectically select appropriate tools from these approaches for the development of our design model.

2.2.2 Alternatives for the functional approach

In this section, we consider the alternatives of functionally oriented organisations. We first motivate our choice for a process-oriented approach and discuss the corresponding issues. Next, we move to a selection of theories we use to design this process-oriented organisation.

The shortcomings of a Scientific Management organisation makes it highly unsuitable to meet the demands in an environment with a high degree of uncertainty. To manufacture a large variety of products and/or services, to frequently manufacture new products and/or services, to quickly implement new technologies, and finally to continually improve quality, basically contradicts Scientific Management principles. To achieve these goals, it is necessary to focus on a process-oriented organisation, based on three major pillars [Kidd (1994)]:

1. innovative management structures and organisations,
2. a skill base of knowledgeable and empowered people,
3. flexible and intelligent technologies.

An essential underlying dilemma in a process-oriented approach is to obtain a proper balance between differentiation and integration. After all, as soon as two people are involved in a production process, some kind of relationship is established. When a process becomes complex, with many different tasks and special skills needed, differentiation is inevitable. Differentiation is necessary to enable an organisation to accomplish goals that cannot be achieved by a single individual. However, as differentiation continues within an organisation, it becomes difficult for organisational members to perform both their primary activities and co-ordinate with the work of their colleagues. This need for co-ordination is called integration. It is a challenge of process-oriented design to maintain such a balance between differentiation and integration, such that it will lead to an organisation with optimal conditions for achieving its goals in terms of flexibility, efficiency, quality, and due date reliability. It is important to realise that it is not possible to design an organisation with no disadvantages in its structure at all.

![Figure 2.2: Differentiation and de-differentiation (De Sitter (1994), p.227).](image-url)
According to Hatch [Hatch (1997), p.183]:

Every social structure has conflicts and contradictions built into it, which result from the practical impossibility of perfectly integrating a differentiated organisation.

So we should aim for a solution with the fewest possible drawbacks. The lesson learned is that a Scientific Management view upon organisational structures with a high uncertainty level, is a basically wrong starting point: integrating tasks takes much effort and the management complexity is too high.

This conclusion calls for the need for a process-oriented approach in which the functional structure is de-differentiated (see Figure 2.2), in other words: different activities have to be integrated, to reduce both complexity and the need for co-ordination. The balance between differentiation, integration, and the call for de-differentiation will be a bottom line in this thesis.

Thus, we adopt a process-oriented approach to accomplish an optimal balance between differentiation and integration. At the end of the historical outline we listed four basic process-oriented redesign approaches: lean production, business process re-engineering, the Scandinavian sociotechnical approach, and the Dutch sociotechnical approach. In the following subsections, we briefly survey the essential elements of each approach. Since the Scandinavian and Dutch sociotechnical approach are based on the classical sociotechnical approach, we also include in this survey a short description of the latter one.

- **Lean Production (Womack et al. (1990)).**
  American researchers of the Massachusetts Institute of Technology (MIT) have carried out an extensive research program at a hundred automobile manufacturing companies. They concluded that Japanese companies work differently compared to European and American companies. They work cheap and decisive and deliver qualitatively good products. This is caused by a constant process of improvement, which is incorporated in the manufacturing process, instead of in big staff sections outside the manufacturing process. The improvements aim for an elimination of all forms of waste; in this respect, a lot of attention is given to stock control. This approach is not a sudden invention by Japanese companies, but the result of a long learning process that started at the end of the Second World War. Unfortunately, when observing the Japanese successes, many Western companies started with pruning their functional organisational structure, without implementing the logic behind the lean production philosophy, i.e. incorporating staff tasks in the manufacturing process [Den Hertog et al. (1995), p.78].

- **Business process re-engineering (BPR) (Hammer et al. (1993)).**
  Hammer et al. (1993) claim that the survival of a company is nowadays only possible by means of a drastic redesign of the manufacturing process, aiming at an integral process-oriented organisational structure. Information technology (IT) plays an important enabling role in the BPR-philosophy. Modern IT should enable the streamlining of the organisational structures, bridge geographical distances, and finally eliminate certain functions. The cross-functional perspective (integration of functional parallel activities which aim at the same customer), the integral and process-oriented approach, the knowledge that management layers, staff sections, and control systems are derived from the primary process (and not the other way around), and finally the enabling function of information technology, are the strong points of the BPR-approach. Drawbacks are the lack of an integral redesign policy and the drastic element in the redesign process. In addition, a systematic approach is missing for the actual redesign process. Combined with the fact that the authors suggest that a drastic change should be undertaken, in which an existing process should be completely eliminated, unfortunately many companies failed when following the BPR-approach.

- **The classical sociotechnical approach**
  The advantages of using the knowledge and skills of the work force in controlling manufacturing processes have been the subject of many studies, starting in the fifties. For instance, Trist et al. (1951) observed a
significant improvement of the mine's output in a case where mineworkers were able to influence their own manufacturing process. After this study, many similar experiments in different countries in Europe, the United States, and Canada have been carried out. This approach is generally referred to as the classical sociotechnical approach; it originated at the Tavistock Institute in England [Van Dijk (1989)]. This approach had a marginal influence on the way companies were organised. One reason was the lack of urgency to change; after all in this period companies could still depend on a relatively stable market with a more or less guaranteed sales volume. The second reason is the very strong practical orientation of classical sociotechnical researchers. They did not focus on the development of a well-considered sociotechnical theory and design method. Besides this, they also omitted a systematic evaluation of the different experiments [Fruytier (1994), p.16]. In the eighties, under the influence of the need for theoretical and practical foundations of a structural design policy, different ‘modern’ sociotechnical approaches developed, based on this classical approach.

- **The Scandinavian sociotechnical approach**
  In Sweden, a group of researchers developed a theory that was based on the self-organising capacity of employees. They state that structures and processes that are developed by experts, and imposed upon an organisation by higher management, will never get full acceptance. Therefore it is necessary to create a democratic dialogue, in which the work force and management search for solutions for organisational problems. This approach aims for the change process and the democratic way in which this change should take place. There is little attention for the design method of organisational structures. Sometimes the attention for active work force participation in the design and decision processes has driven the actual design and change of organisational structures and processes to the background.

- **The Dutch sociotechnical approach**
  In the Netherlands, a modernistic sociotechnical approach developed, based on a system of design principles and procedures, which have to be applied in a fixed sequence. The search for parallel flows and segments in the primary process, the design of a production structure by a top-down approach, and of a control structure by a bottom up approach, are leading principles in this approach. The greatest advantage of this approach is the systematic design of a process-oriented organisational structure [De Sitter (1994)].

The fundamental guideline in all approaches is the need to put decisions at the lowest possible organisational level. Meale (1984) calls this approach ‘putting production decisions where they belong, by establishing self-management as a fundamental condition of organising’. We adopt this view by aiming for a hierarchical production management structure, which allows for the use of aggregated data for top-level decisions and detailed data for shop-floor decisions. The plan at each level serves as a constraint for the decisions to be made at the next lower level and gives this level the room to manage its own process within these constraints. To realise such a management and operational structure we have selected the following redesign approach.

For the design of a management and operational structure for non-flow LSMO’s we use the systematic approach of the Dutch Sociotechnical School. We include in this approach the importance of the information technology’s enabling function from the BPR-approach, thereby acknowledging that the possibilities of modern IT should be used as an ‘enabler’ in the design of organisational structures.

In the next section we describe the design process that emerges from this selection.
2.3 Set-up of the design process

In this section we present the set-up of the design process, which is mainly based on the Dutch sociotechnical approach [see e.g. De Sitter (1994) and Van Ewijk-Hoeveraars et al. (1995)]. In addition, we use elements from the systems approach for organisational redesign [see In ’t Veld, (1998)]. The approach is called Integral Organisational Change (IOC) and comprises four steps: diagnosis, goal setting, design, and finally implementation (see Figure 2.3). The four steps can be described as follows:

1. **Investigation/Diagnosis**
   A diagnosis of the environment (i.e. the market and customer demands) and a determination of the characteristics of the organisation.

2. **Goal setting**
   Based on the diagnosis of step 1, the development of a strategy and vision of what the organisation should be.

3. **Design**
   The design phase comprises the definition of the activities that have to be performed to produce the desired products (the production structure). This task has to be performed top-down and from outside to inside: starting at the customer's wishes (surroundings) and the strategy level (the result of step 2), and ending at the detailed production level. Next, we have to define the control structure. The design of the control structure follows a road opposite to the definition of the production structure: it is defined bottom up, starting at a detailed level. The leading issue in this phase is a reduction of the complexity in an organisation. In the last step, we design the supporting information structure.

4. **Implementation**
   In this phase the production and control structure is implemented in the organisation.

The centre of Figure 2.3 contains the phrase ‘tell and educate’, indicating that a successful application of this model in a real life organisation can only be achieved if the employees are involved, trained and educated in each of the four steps. When we apply the design process to the RNND case the result should be a design model (i.e. a design of what the organisational structure should be). Therefore we focus on step 1 (Investigation/Diagnosis),

![Figure 2.3: The IOC-model (Van Ewijk-Hoeveraars et al. (1995), p.26).](image-url)
step 2 (Goal Setting), and step 3 (Design). In the remainder of this chapter we describe the contents of these steps.

### 2.3.1 The environment: Investigation and diagnosis

The essence of the first phase is to determine the market and customers demands for a specific LSMO. Subsequently, we consider whether the LSMO is able to fulfill these demands. When examining an LSMO and its environment, the most common perspectives are: an interorganisational network perspective, a more general environment perspective (including social, cultural, legal, political, economic, technological, and physical views), and an explicit international/global environment perspective [Hatch (1997, p.64). Because of the explicit interest this thesis places on the organisational structure of non-flow LSMO's, we have selected the interorganisational network perspective, centred around our object of study (see Figure 2.4). Where necessary, we will borrow appropriate elements from the other perspectives.

The gathering of data to accomplish the environmental diagnosis and the diagnosis of an LSMO, may be done in several ways. For the environmental diagnosis suitable instruments are for example: the measurements of customer satisfaction, surveys on customer complaints, and comparisons with competitors (i.e. benchmarking).

The diagnosis of the organisation may be done by a survey of the organisational structure, the measurement of employee satisfaction, and a performance measurement (i.e. a diagnosis of the internal and external performance indicators). The data collected in this way must be sufficient to enter the second step of the IOC process: the goal setting phase.

![Figure 2.4: The interorganisational perspective (Hatch (1997), p.66).](image)

### 2.3.2 Strategy: Goal setting

In the second step we consider the strategy of the LSMO. This should provide the basis for the design of the organisational structure. A possible definition of strategy is:

> The pattern of choices within an organisation concerning the goals, and the way and the resources needed to achieve these goals [Van Aken (1994), p.118].

Formulating and communicating a strategy should provide the organisation with clear goals, ambitions and business logic. For the use in the design process, we formulate a general strategy for LSMO's that expresses a high ambition level. This general strategy comprises a mission statement, the ambitions, and the business logic of this class of organisations. In the mission statement we sum up the products and services and the proposed
target groups, the ambitions comprise concrete goals, and finally the business logic comprises the way to achieve these goals [Van Aken (1994), p.118]. This trio forms the basis for the re-engineering process.

### 2.3.3 Design of the organisational structure

We redesign the organisational structure in a three-step-model: the Production structure, the Control structure, and the Information structure, respectively (also called the PCI-model). The production structure contains all the primary activities necessary to properly satisfy a customer's demand. The control structure comprises all activities needed to manage the production structure. Finally the information structure denotes the architecture that contains the information flows and automated systems for the support of the production and control structure. In the next subsections we discuss the design of each element in detail.

#### 2.3.3.1 The production structure

In the design of the production structure we want to minimise complexity. To realise a structure as simple as possible we group activities around the flow of orders through the company, based on the strategy of the previous step. For the design of this process-oriented production structure, three design questions have to be answered [De Sitter (1994), p.227]:

1. Which order flows can we define?
2. Do we have to split the flows into segments and how are these segments related?
3. How can we design tasks, within these segments, in such a way that they mobilize human resources, shorten lead times, satisfy quality conditions, and finally contribute to process and product innovation?

These three design questions resemble the macro, meso, and micro level of design. First we define the parallel order flows at macro level. The starting point is determined by the result of the goal setting phase. At the intermediate meso level (i.e. between the macro and micro level) we analyse the order flows. The result of this process is the definition of segments. Finally we consider the contents of each segment at the micro level. The essence of this design is a top-down approach in which logically connected activities are integrated. Therefore a clear awareness of the different phases in a manufacturing process is essential. We have adopted the following five phases (see Figure 2.5) in the design of the production structure [see De Waard (1995)]:

![Figure 2.5: Production phase model.](image)

1. **Order acquisition and functional specification**

   The first step in this phase contains an active search for customer orders (acquisition). When a customer is acquired, the functional specification (the features of the desired product or service) is made up. Based
on these functional specifications a so-called Rough Cut Capacity Plan (RCCP) is defined for each capacity group. This RCCP is the basis for the final contract with the customer.

2. **Technical specification (process planning)**
   In this phase the functional specifications are translated into detailed process plans, which contain all the data needed to perform the job. These data include for example: the different activities in the manufacturing process, the precedence relations between these activities, a bill of material, the technical specifications, etc. One of the important outputs of this phase is an uncapacitated network with precedence relations.

3. **Resource planning and scheduling**
   The uncapacitated network is scheduled in time, given the limited availability of resources. In addition, the different materials are ordered such that they are available when needed in the manufacturing process.

4. **Execution**
   The activities are executed in accordance with the network planning. Monitoring and accurate time registration of work in progress is essential in this stage for the timely completion of the order.

5. **Evaluation and Service**
   In the last step the experience gathered has to be used to improve and maintain working standards. This is of utmost importance for the quality of the process planning system.

Having defined these different production phases in the design of the production structure, we now start with determining so-called parallel homogeneous production flows at the *macro level*, beginning at *order acceptance* and ending at *evaluation and service* (see Figure 2.6). These flows are defined as:

- A parallel flow is a chain of manufacturing activities starting at order acquisition and ending at evaluation and service, which depends as little as possible on other flows or functions within the organisation.

An important goal in designing parallel flows is to reduce control complexity. This complexity arises from the variability in elements of the manufacturing process. On the macro level we distinguish on the output side: the variability in product functions, products, product types, and finally product appearances.

![Figure 2.6: Designing parallel flows.](image)

The input side often shows a high diversity in the requests for maintenance (with respect to the time an order occurs, the size of an order, and the desired due dates) and the supply of materials and spares. The grouping of manufacturing activities with a similar variability may lead to feasible parallel flows. A flow is feasible if the
workload is sufficient, if a resource division is possible, and finally if the product demand is sufficient and reasonably stable. However, very often restrictions will occur in the workload and possible divisions of resources. When it is not possible to create feasible flows for one product or product types, the next step is to combine as much as possible similar products into a flow. Also the market differentiation in so-called customer groups may help to detect possible parallel flows. However, a pure product-market combination (one product with one specific product function that is to be delivered to only one customer group) is a rare phenomenon.

An essential issue in the design of parallel flows is to decide whether we want to reduce internal or external complexity. The internal complexity is defined as the number of interfaces between the different product flows within a manufacturing process. The external complexity is the number of different product flows within a manufacturing process that serve the same market segment. A choice for external complexity reduction is generally based on market segments. However, this prevents an internal complexity reduction by grouping similar products into one flow. In almost every case it is necessary to make a choice between a reduction of the external or the internal complexity. A guideline is that the chosen option should establish the best possible customer oriented production structure. This may also be achieved with an internal complexity reduction. This is for example the case in an unstructured production function, where customers are incapable to determine what kind of product they desire. A definition of complete in-out flows is then not possible, so an internal complexity reduction is the best alternative.

At the 'macro level' we examine each parallel flow separately. In most LSMO's the flows are so voluminous that it is not possible to put one group in charge of the entire flow. We will then divide the parallel flow into segments. A segment is defined as:

A segment is a part of a parallel flow, which contains a complete set of clearly defined activities constituting a measurable piece of work.

Figure 2.7 depicts this segmentation. In Chapter 1 we characterised the LSMO's as a job shop/small batches/project manufacturing process. This kind of process is labelled as 'criss-cross streams', while it incorporates many different product and services, a high variance in the combination, contents, and sequence of manufacturing tasks, and finally hundreds of different routings. The IOM-methodology provides four subsequent segmentation options for this 'criss-cross streams' process structure: the product group, the module group, phase groups, and finally component groups. An outline of each solution is presented below.

1. **Product group**

A 'product group' is a group that fully controls the manufacturing equipment to independently manufacture a product within one stream. The main difference with a group that is responsible for an entire flow on macro
level is related to the process planning and supporting services. A product group is not independent with respect to these services. Criteria for creating a product group are again the workload and the distribution of this workload in time. In addition, the existence of so-called indivisible resources is an important criterion. Figure 2.8 depicts an example of a layout of a product group.

![Figure 2.8: Example of a product group.](image)

2. **Module groups**
   The next possible solution is a 'module group'. If product groups are regularly under- or overloaded, then a group, which is responsible for the complete manufacturing of modules, may be a feasible option. These modules are next assembled into one finished product. Figure 2.9 displays an example of module groups.

![Figure 2.9: Example of module groups.](image)

3. **Phase groups**
   If also a module group is not a feasible option then we consider 'phase groups'. For example due to high investments needed for manufacturing equipment, it may be necessary to introduce shared resources between groups. Figure 2.10 depicts an example of phase groups due to indivisible resources. It is important to keep the tasks before and after the indivisible resource integrated within one group.
4. Component groups

The last possible solution is 'component groups'. In these groups we create parallel segments based on the similarity of the tasks and sequences of tasks needed to manufacture components. The main difference with the previous solutions is the creation of a parallel segment based on the manufacturing technology and not on the product characteristics (i.e. functional oriented groups).

After the meso level, the last design task concerns the 'micro level' structure. This structure determines the actual way in which employees have to carry out the manufacturing tasks. Recall that the aim of our redesign process is to improve the flexibility, promptness, product quality, and due date reliability of LSMO's. In view of the characteristics of LSMO's (i.e. a high uncertainty in the product specification and manufacturing phase and many different orders with different routings in execution) we argue that the basic solution at micro level is to let multi-skilled people work in groups with a high level of self-co-ordination. A well-defined hierarchical structure of planning and co-ordination should enable these multi-disciplinary groups to control and innovate their own products and processes. The control limits for such a group are defined at the next higher level. This concept empowers the work force by improving the work contents tremendously, which enables the organisation to achieve its goals. The task of these all-round manufacturing and control groups demands a well-considered mix of people with a variety of skills. We use so-called flex-matrices to define these skills. On one axis we outline the different manufacturing and control tasks needed and on the other axis we place the different employees. In the matrix we create a view of the present group tasks and the desired group tasks. In this way we are able to assign manufacturing and control tasks in harmony with the group's abilities. In addition, we can define a training program to achieve the desired group level.

The choice for multi-disciplinary teams concludes the production structure redesign process. In summary, we obtain the following survey:

1. Search for parallel flows at the macro level;
2. If one manufacturing group cannot handle a flow: create segments at the meso level;
3. Assign product, module, phase, or component groups to these segments;
4. Create multi-disciplinary teams at the micro level.

We now enter the second phase of the organisational structure redesign process: the design of the control structure.

2.3.3.2 The control structure

The design of the control structure uses a bottom up approach (i.e. from micro to macro level) by first allocating control cycles, then determining the control cycle scope, and finally, due to necessary adjustments between control cycles, by coupling the different control cycles (see Figure 2.11, see also In 't Veld (1998), p. 238).
Before we consider seven basic design principles, we note that the quality of the control structure is largely determined by the quality of the production structure design. It is the production structure and its environment that determine the process failure rates and its sensitivity. This cannot be changed by the control structure. Consequently, deficiencies in the production structure will be duplicated in the control structure. So a preliminary condition for a useful application of the following principles is a qualitatively good production structure.

1. The aspects *thinking, planning, controlling*, and *doing* should be integrated in a control cycle.
2. There has to be unity of *time, place, and action*.
3. An employee should be able to develop and change goals.
4. He should have the necessary information regarding the input, output, internal structure, and state of the system.
5. He should have an understanding of the environment (a model) and knowledge about the state of the environment.
6. He should have the ability to change operations and transformations (i.e. flexibility as a result of the production structure design).
7. He should use control measures based on the contents of actual information.

<table>
<thead>
<tr>
<th>Control Cycle:</th>
<th>Level:</th>
<th>Domain:</th>
<th>Aspect:</th>
<th>Process range:</th>
<th>Standards:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduling of the process with respect to:</td>
<td>Operational</td>
<td>Incoming stream</td>
<td>Quality</td>
<td>Local and Outside group limits</td>
<td>Act, measure, compare, and an integral local judgement.</td>
</tr>
<tr>
<td>In time delivery; Quality; Efficiency; Process planning; Logistics; Maintenance.</td>
<td></td>
<td>Adding value to the stream</td>
<td>Quantity</td>
<td>Time</td>
<td></td>
</tr>
<tr>
<td>Adjust the process with respect to:</td>
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<td>Incoming stream</td>
<td>Quality</td>
<td>Local and Outside group limits</td>
<td>Act, measure, compare, and an integral local judgement.</td>
</tr>
<tr>
<td>In time delivery; Quality; Efficiency; Process planning; Logistics; Maintenance.</td>
<td></td>
<td>Adding value to the stream</td>
<td>Quantity</td>
<td>Time</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 2.11: Diagram of organisational control cycle [De Sitter (1994), p.94].*
A design process for LMO's

<table>
<thead>
<tr>
<th>Solve process disturbances with respect to:</th>
<th>Operational</th>
<th>Incoming stream</th>
<th>Quality</th>
<th>Local and Outside group limits</th>
<th>Act, measure, compare, and an integral local judgement.</th>
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</thead>
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<td>Quality;</td>
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<td>Outgoing stream</td>
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<tr>
<td>Efficiency;</td>
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<td>Process planning;</td>
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<td>Logistics;</td>
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<td>Maintenance;</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Guard, maintain and improve performance with respect to:</td>
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<td>Production Structure;</td>
<td>Planning</td>
<td>Local and Outside group limits</td>
<td>Participating in choosing between design alternatives for local level.</td>
</tr>
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<td>Control Structure;</td>
<td>Supporting</td>
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</tr>
<tr>
<td>Work management;</td>
<td></td>
<td>Information Structure.</td>
<td>Manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finance;</td>
<td></td>
<td></td>
<td>Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machines and supporting Means;</td>
<td></td>
<td>Contents and nature of the transactions with the environment</td>
<td>Quantity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel;</td>
<td></td>
<td></td>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training;</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Safety, Working, and Environmental conditions.</td>
<td>Strategic</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 2.1: Selection of control cycles.

A simple and flexible control structure that recognises 'uncertainty' as a fundamental aspect should be the result of these principles. We now briefly discuss the contents of the allocation, selection, and finally coupling of control cycles.

- **The allocation**
  
  We allocate the control tasks bottom up, starting at the micro level. The guiding principle is to place a control task at the lowest possible level. A control task is only transferred to the next higher level when it requires a more central co-ordination.

- **The selection**
  
  We select in this step for each control cycle its level, domain, aspects, range, and its standards. Table 2.1 lists a group's scheduling, adjustment, problem solving, and process improvement control cycle, with the selections for each cycle.
The coupling

We externally couple the various control cycles in the last design step. This external coupling is concerned with cycles that belong to different process segments. We do not consider internal couplings since they are the responsibility of one controller within one process segment. The external coupling of control cycles to one subsystem is called ‘integration’: one subsystem is responsible for several control cycles.

Ultimately the bottom up use of these design steps (i.e. from micro to macro level) should result in a control structure in which the operational, organisational, and strategic levels are integrated (see Figure 2.12). This should yield a basis for a continual renewal and improvement process through the entire LSMO.

We now enter the final phase of the organisational design: the information structure.

2.3.3.3 The information structure

The information structure is the subject of the last organisational design step. We define the information structure as follows:

The information structure denotes the contents and shape of the information needed and the way in which this information is stored and transferred (the information architecture).

The essence of this structure is how the information needed in the control structure is being perceived, gathered, recorded and dispatched. We design this structure by first drawing up an inventory of all information needs and flows. This survey is the basis for the development of a coherent structure of information systems. Here, we note that throughout the design of the production and control structure it is essential to take into account the possibilities of modern information systems. For instance, if an information system enables the controllers of different groups to simultaneously obtain an updated schedule, than a different content and coupling of the scheduling control cycles is facilitated.
2.4 Summary

We first eclectically selected a process-oriented design model, primarily based on the Dutch sociotechnical approach. Next, we developed in three steps a design process that we will use in the next chapter for the RNND case. The first step comprises the diagnosis and investigation of the environment. In the second step we consider the strategy. Based on this strategy we discuss in the third step a design approach for the organisational structure. This approach comprises a production structure design at the macro, meso, and micro level, by searching for parallel flows, dividing them into segments, and creating multi-disciplinary teams. Subsequently, a control structure is defined bottom up, starting at micro level. A clearly defined hierarchical planning structure, self-management, and ‘putting production decisions where they belong’, are important features of this approach. The design of the information structure completes the organisational structure.
Chapter 3

3. A design model for the Royal Netherlands Navy Dockyard

3.1 Introduction

In this chapter we describe the design of a new organisational structure for the Royal Netherlands Navy Dockyard (RNND), leading to a design model for this dockyard (see Figure 3.1). First we give a general introduction of the dockyard, with its main characteristics and changing objectives. Next we move to the design of an organisational model with the use of the design approach outlined in Chapter 2.
The first step is the investigation and diagnosis phase, in which we consider the specific environmental conditions for the dockyard and pay special attention to the customer’s needs. Subsequently we formulate the dockyard’s mission statement in the goal setting phase. This statement is the starting point for the organisational model design in the third step. We successively go through the design of the production structure, the control structure, the corresponding work breakdown structure, and finally the information structure. We conclude this chapter with the results from the implementation of elements of the new structure and expectations for the future.

3.2 The Royal Netherlands Navy Dockyard

King William I established the Royal Netherlands Navy Dockyard (RNND) in 1822, under the name of ‘Willemsoord’ [Bakker (1993)]. This was the result of a long process, which started in 1776 when J.E. Witte formulated the first plan to create a harbour in Den Helder. He was inspired by the unique position of Den Helder, which would make a direct accessible sea harbour possible. The actual construction of Willemsoord’s basic infrastructure started in 1824. This marked the starting point of the dockyard, which from that time on developed itself into one of the largest enterprises in the Netherlands. In view of its work area and the innovative technologies within the navy’s fleet, the dockyard has always been on the front of technological developments.

In the seventies of this century a dry dock was built in the harbour complex for the new navy frigates. The old infrastructure at Willemsoord (near Den Helder’s town centre) was not able to take in and maintain the new generation of warships. This created the unfortunate circumstance that the dockyard’s workforce was spread over two locations: the old Willemsoord facilities and the new dry dock facility. In the eighties the Netherlands Ministry of Defence (MOD) commissioned a consultancy agency to perform a study in which various future scenarios for the dockyard were examined, including a privatisation option. Due to strategic reasons it was decided that the navy had to keep its own repair and maintenance facilities at its disposal. This meant that the RNND continued to exist; however due to the proven inefficiency in its processes MOD decided to implement some major changes. The dockyard had to downsize from 1800 to approximately 1000 employees, a new organisational model had to be developed and implemented, and finally, to enable the dockyard to establish an efficient and effective repair and maintenance process, a new infrastructure around the dry dock facility in the navy harbour had to be built. These changes took place in the period from 1988 till 1994.

**NOT AVAILABLE IN THIS VERSION**

*Photo 3.1: The new infrastructure of the RNND.*

In 1994 the entire dockyard was located at the new infrastructure in the navy harbour complex. This resulted into one of the most modern and well-equipped maintenance and repair facilities in Western Europe (see Photo 3.1).

The main task for the RNND is to maintain, repair, and modify the ‘platform’ systems of the RNN ships. These ships can be roughly classified into capital ships (i.e. the frigates, the supply ships, and an amphibious assault ship), mine combat ships (i.e. the mine hunters and sweepers), and submarines. The platform systems comprise roughly the hull, the propulsion system, the energy supply systems, and all the supporting systems (e.g. the sewage system, the climate control systems, etc.). All the sensor (e.g. radar equipment, scanners and communication equipment) and weapon systems are repaired and maintained by the SEWACO company, a second maintenance facility owned by the navy. In addition to the repair of platform systems, the RNND
maintains shore facilities, provides engineering knowledge, and has responsibilities regarding the logistic supply chain (i.e. for platform spare parts) within the navy.

Next we turn to the maintenance and overhaul activities of the dockyard. Within maintenance we may distinguish various categories. A possible classification by Van Duivenvoorden et al. (1993) and Pintelon (1993) is:

- **Time Based Maintenance**
  (TBM: maintenance performed due to an expired specified period of use)

- **Condition Based Maintenance**
  (CBM: maintenance due to the deterioration of an object’s condition)

- **Failure Based Maintenance**
  (FBM: maintenance due to the occurrence of a failure)

- **Opportunity Based Maintenance**
  (OBM: maintenance, which can easily be performed simultaneously with other maintenance tasks)

- **Performance Improving Maintenance**
  (PIM: maintenance, which improves the availability, maintainability, and/or reliability of an object, as compared to its initial performance)

These different maintenance categories call for an appropriate maintenance policy. For example in the case of FBM the reaction time of a maintenance company in general has to be short and the repair urgency may be high. On the other hand the predictability of TBM is in general high, assuming that the future use of a system in a specific period is known. The PIM category comprises the modifications of systems or the installation of complete new systems. This classification of maintenance leads within RNNND to the following categories:

1. **Long Term Maintenance (LTM)**
   An LTM-period takes place once every six years. In this period the dockyard carries out a major overhaul and modification program. The duration and size of this period depend on the ship’s age and condition. For example for an S-class frigate this period lasts approximately one year, in which 180,000 man-hours are spent on average.

2. **Between Time Maintenance (BTM)**
   A BTM-period takes place every six years, halfway between two LTM’s. In this period the ship undergoes a moderate overhaul and modification program.

3. **Appointed Incidental Maintenance (AIM)**
   A ship undergoes several AIM’s every year. In each AIM of usually several weeks, the dockyard carries out corrective, preventive, and condition based maintenance. Only in rare cases modifications are carried out (i.e. only if the modification is necessary due to safety reasons or urgent operational needs).

4. **Urgent Incidental Maintenance (UIM)**
   A ship undergoes UIM whenever defects arise which cannot wait to be corrected until the forthcoming AIM. In general these defects affect the crew’s and ship’s safety, as well as the ship’s operational readiness.

The actual maintenance interval and lead time of a specific maintenance period may vary for each ship type. In addition to the capital ships, submarines, and mine-counter measures ships, the dockyard also maintains small ships, like harbour tug boats, water boats, etcetera. These ships undergo similar maintenance approaches.

This classification of the various maintenance categories indicates a process with a high variety and complexity. Unfortunately, in the eighties the dockyard again chose to establish a functionally based organisation. Figure 3.2 shows a simplified representation of this organisational structure.
The Chief Executive Officer (CEO) is responsible for the entire process. Three functionally oriented departments are situated below the CEO. The finance and organisational department is a supporting organisational unit, which is responsible for the dockyard's financial management and justification. In addition it provides support on information technology and organisational issues.

![Diagram of dockyard's functional organisational structure]

The dockyard's actual manufacturing process (i.e. the primary process) is accommodated in the production department and the engineering department. The first one repairs, maintains, and modifies objects of the RNN. For this purpose it is divided into four functional production units: ship construction I (steel construction), ship construction II (wood, synthetics, and preservation), electrical systems, and mechanical systems. Each production unit is divided into several functional expertise groups. For example within the mechanical systems unit there exist a hydraulic, a piping, and a fitters group. The external contacts with the dockyard's customers are maintained by the division organisation. They conclude contracts with the customers and make internal agreements with the functional units.

The manufacturing process of the production department is divided into nine steps: long-term forecasting, medium-term forecasting, short-term forecasting, establishing an external contract (with the dockyard's customer), formulating an internal contract (with the various functional units), making up main activities (a functionally split-up of the order), dispatching and execution of the activities, handing over finished work to the customer, and finally evaluation. Each of these nine steps is delegated to more or less different functions. So each order has to pass several steps and employees before it can be executed.

The engineering group is responsible for the assistance of the maintenance process, the engineering of modifications, the development of maintenance concepts, the improvement of the maintenance process, and the assistance of ship building projects. These tasks are in accordance with the EUT-maintenance philosophy outlined in Chapter 1.

The dockyard's structure is supported by a huge information system called the Business Planning System (BPS). This system has been developed in the late seventies and eighties. It consists of three major subsystems: the material subsystem (MATSUB), the production subsystem (PRODSUB), and finally the financial subsystem (FINSUB). The MATSUB is intended for the dockyard's inventory and material management. The PRODSUB has to control the manufacturing process from the order acquisition phase to the evaluation and service phase. To this end, it distinguishes five levels in its work breakdown structure: 'main projects', 'projects', 'main orders', 'work orders', and 'operations'. However, capacity planning is only allowed at the work order level, in which it does not take precedence relations into account. This one level planning makes a hierarchical capacity planning
impossible. Also the quality of the scheduling capabilities is poor. It is based on some restricted priority rules. In addition the system’s data are updated through a weekly batch processing cycle. This implies that only once a week an accurate survey of the resource loads is available. In the circumstances of a highly dynamic and by times erratic environment this is undesirable. Another shortcoming is the storage of maintenance data standards. The ambiguous storage criteria and the cumbersome data accessibility make an efficient storage and use of these data impossible. The last BPS module, FINSUB, is intended for finance and accounting purposes.

To overcome parts of the BPS-inadequacies the production department has implemented two additional information systems: a Work Forecasting System (WFS) and a Shop-Floor Control System (SFCS). The first one is a system which only registers and in this way provides graphical views of the expected workload and the free space in resource utilisation. However it incorporates no intelligent planning facilities. The main purpose of the SFCS is to provide the functional expertise groups with schedules, in which the inter-group precedence relations are incorporated. It provides the meso and micro organisational level with useful overviews for activity assignments. However it does not provide finite scheduling capabilities.

Compared to the dockyard’s dynamic environment this view on the current organisational structure with the automated systems shows some major drawbacks. The first one is the rigid separation of production and engineering in two departments. This makes it hard to fully exploit the surplus value, as meant in the EUT-maintenance model (an integral view on the design, the execution, and the feed-back of maintenance). A second drawback is the rigid division of the production department into functional units and groups. This calls for a work split-up into small functional packages, which need a lot of co-ordinating efforts from the higher levels (see Chapter 2). In addition the process is divided into nine steps which are more or less delegated to different functions. This implies a long preparation phase, with a lot of slack, a rigid single manufacturing flow for all orders (despite the facts that orders differ significantly on aspects such as the complexity, the urgency, the size, etcetera), and the tendency of employees to avoid responsibility whenever things go wrong. The last drawback is the insufficient support of the automated systems. The batch-processing limitation, the absence of hierarchical planning facilities, the poor scheduling features, and finally the insufficient data storage, strengthen the shortcomings of the organisational structure.

The drawbacks of the organisational structure and the automated systems negatively influenced the dockyard’s performance. However after the major changes in the late eighties and the beginning of the nineties, the dockyard and its customers expected a major performance improvement. It lasted till 1994 before the dockyard’s management prudently acknowledged the insufficient performance and the major drawbacks. Therefore the management formulated the following problem:

The controllability of the Royal Netherlands Dockyard is absolutely insufficient with respect to the customers’ demands. The dockyard is not capable to provide its customers the desired products within the time, costs, and quality constraints.

The sense of urgency in this problem statement led to the willingness of again carrying out a major restructuring process. The aim of this process was to improve the dockyard’s controllability, which would ultimately reduce lead times, raise the level of flexibility and promptness, and provide a better due date performance. The redesign process started with the design of a new organisational structure, which is described in the next section.

### 3.3 Designing a new organisational structure

In this section we use the design approach of Chapter 2 for the dockyard’s re-engineering process. The contents of this section is the result of a design process, which took place at the dockyard in 1996 and 1997. We subsequently discuss a diagnosis of the RNNID environment, the formulation of a mission statement, and finally the design of the organisational structure.
3.3.1 A diagnosis of the RNND environment

For a diagnosis of the RNND environment we analyse its customers. For a clear understanding of the customer’s demands, it is necessary to elaborate on the different customer groups (see Figure 3.3).

![Figure 3.3: Survey of the RNND’s customers.]

At a strategic level, the management of the dockyard and the Commander Material Department (CMD) agree on the dockyard’s performance for the coming year. During and after this year the dockyard management has to report to the CMD on its performance and achieved results. Within the Ministry of Defence (MOD), the Commander in Chief of the RNND and CMD together settle the material budgets. Parallel to the agreement between the CMD and the dockyard’s management, the Commander in Chief of the RNND agrees with the Operational Commander on the annual performance of the operational task groups. On the tactical level the different actors detail these strategic agreements into frameworks for the different operational customer groups. Finally at the operational level, the Operational Task Groups and the Sections of the Ministry of Defence bring concrete work assignments into the dockyard.

This survey of the dockyard’s environment implies a variety of customers on the different levels and especially within the operational level. To give a short impression of the customer’s demands regarding the dockyard’s product, we first discuss one group of customers, the Operational Task Groups (left-hand side of Figure 3.3). Next, we move to the different sections of the MOD. This section concludes with a short-list of customer’s demands.

- **The operational Task Groups**

  The operational task groups are the primary customers for all maintenance, overhaul, and modification programs. They are primarily served by the production department, and, indirectly, by engineering when needed. With respect to the dockyard’s performance, the operational customers classified the inability of dockyard management to have a clear view on the future workload and the utilisation of its resources as an essential shortcoming. This leads to the unsatisfactory situation in which new assignments are rejected at the dockyard’s ‘counter’ (i.e. the Division Organisation), while employees on the shop floor may be under-utilised. In addition, the dockyard has problems to fulfil the agreed planning milestones. Sometimes these milestones are altered without any customer consultation. These changes are highly inconvenient for a ship’s crew. Compared to commercial dockyards, especially the lack of promptness has been blamed. The customer experiences in general a considerably faster and accurate problem solving process at a commercial yard. A final remark concerns the tendency within engineering to decide which solution for a maintenance
problem is implemented. The customer is hardly able to influence this process. It must be obvious that the customer ultimately should decide which solution is chosen.

- *The MOD setting*
  The MOD sections basically act as a 'knowledge' customer, primarily interested in the design of new ships and different systems, including the monitoring and control systems. As the dockyard is the primary maintenance facility of these ships and systems, it can play an important role in this design process. In addition the dockyard is, due to its experience in the maintenance area, the authority that is capable of improving the performance of existing systems (e.g. when an existing system is malfunctioning due to errors in the design phase; this concerns the Performance Improving Maintenance). With respect to the dockyard’s performance in this area, the customers experience the division between the maintenance department and the engineering department as an important shortcoming. It diminishes the important synergetic effects of performing maintenance and using the obtained knowledge to contribute to the system’s improvement, the design of maintenance strategies, and ultimately the design of new ships.

As we summarise these remarks of the dockyard’s customers we obtain the following list. The customers of the RNND expect:

- a reliable planning;
- a flexible employment of the dockyard’s workforce;
- a clear view on the availability of the dockyard’s resources;
- prompt action whenever unexpected events occur;
- a short response time to customer demands;
- an improved pre-calculation of scheduled work and account for work done;
- an integral view on maintenance (not only performing the actual maintenance but also putting the installations into operation);
- a high level technical consultancy product regarding the performance improvement of existing systems, the design of maintenance concepts, and the design of new systems and/or ships (This knowledge should be based on aggregated knowledge regarding clusters of systems of the entire fleet, e.g. aggregated knowledge regarding diesel-engines of frigates, submarines, and mine-hunters).

With this list and the organisational shortcomings of Section 3.2, we enter the second phase of the IOG-model, in which we determine a strategy and vision of what the dockyard should be.

3.3.2 The RNND mission statement

In co-operation with our re-engineering project team, the dockyard’s management formulated the following mission statement, which is primarily based on the customer’s demands and the determination of what the RNND wants to be:

*The Royal Netherlands Navy Dockyard should be the unique and self-evident maintenance facility within the RN, which delivers technical and logistic support for the RN (RNND (1996a)).*

Three terms are essential in this mission statement: 'unique', 'self-evident', and 'technical and logistic support'. We give a short explanation of each term.

- *unique*
  The term 'unique' points out the fact that the dockyard does not only carry out maintenance, but also wants to organise the maintenance process. The dockyard wants to play an important role in realising a cheaper maintenance process and optimising the reliability of systems. The knowledge gained in this
process should be used as the basis for participation in new ship-building projects. In this way the
dockyard distinguishes itself from other (commercial) yards.

- 'self-evident'
The term 'self-evident' implies that the dockyard strives to be the one and only ship maintenance facility
within the RNN. Within - and outside - the Netherlands there exist other yards, which are capable to
maintain the RNN's ships. However, by providing an unique integral maintenance concept, in which high
quality maintenance, low costs, short lead times, and high due date reliability are essential characteristics,
the dockyard should be the natural supplier of maintenance services.

- 'technical and logistic support'
The term 'technical and logistic support' indicates the enlargement of the dockyard's product from
merely the execution of maintenance, towards the maintenance control and result analysis, the control of
material supplies, the maintenance concept design, and finally the technical system design. This goal is
supported by the EUT-maintenance model. The realisation of this goal ultimately leads to a situation in
which the dockyard is responsible for an optimal availability of RNN ships, during their entire
operational lifetime, against the lowest possible costs.

Together with the shortcomings of the dockyard's current structure and the customer's demands, the mission
statement was translated into the following policy notes:

- increase the creativity and flexibility within the organisation, leading to a higher problem-solving
capability;
- be customer-oriented;
- put high emphasis on due date reliability;
- provide every level with a clear relevant insight on the due date reliability;
- put the responsibilities and competencies as low as possible in the organisation;
- create a dialogue in which every employee should gain knowledge about the 'what, how, and why'
question;
- decrease the need for vertical co-ordination by increasing the multi-functionality of individual employees
and teams.

These policy notes were the guidelines, along which a new organisational structure was designed.

3.3.3 The organisational structure
We describe in this section the design of the dockyard's new organisational structure. In three separate
subsections we successively discuss the design of the production structure, the control structure, and finally the
information structure.

3.3.3.1 The production structure design
The design of the production structure is a top-down activity, starting from the results of the goal setting phase.
The primary activity from the mission statement, which includes every manufacturing activity at the macro level,
is called 'providing technical and logistical support'. In this thesis we focus on the primary activities and do not
include the supporting processes. With the use of the IDEF-methodology we unravelled the primary activity into
the production model phases outlined in Section 2.3.3.1. For a clear understanding of the IDEF-diagrams we
first briefly explain this methodology. From there we move to a survey of the manufacturing activities at the
various levels and the search for homogeneous order flows. Finally we consider the production structure at the
macro, meso, and micro level, respectively.
3.3.3.1.1 The IDEF-methodology

The Integrated Definition (IDEF) methodology [Marca et al. (1998)] provides a structured way to describe a production system from macro to micro level. It is based on the definition of the various activities, needed to transform a certain input (= what is to be transformed in the process) into a certain output (= the result of the transformation process). These activities are processes or tasks, with a specific duration and a tangible result. Controls (= information which co-ordinates and controls the activity) and mechanisms (= enabling facilities which are not consumed) are entities which enable the activity's execution. Figure 3.4 displays the interaction of an activity with its environment.

![Diagram of activity interaction](image)

Figure 3.4: Interaction of an activity with its environment.

To use the IDEF-methodology we describe an activity with a verb (which expresses the action) and a subject. Each activity should have a substantial result that adds value to the overall process. In the top-down definition process the overall activity is numbered 'A0', after which the activities for the different parts at the underlying levels are subsequently numbered 'A1,...,An'. In the same way a subactivity for a part of the process is split into several smaller activities. These activities are also subsequently numbered with the number of the co-ordinating predecessor (e.g. subactivity k is split into (k,1),(k,2),..., (k,m)). The structure that originates from this methodology can be presented in a tree and in context and decomposition diagrams. The tree structure provides insight in the breakdown of the overall activity 'A0' into several sub-activities at different levels. The context and decomposition diagrams depict the inputs, controls, and mechanisms of the different activities and their mutual dependencies.

3.3.3.1.2 The RNND's activities

For each production phase (order acquisition, technical specification, resource planning and scheduling, execution, and evaluation and service) we define different activities at the various levels of the manufacturing process. This results in a tree of the activity breakdown structure and a survey of the different context diagrams [RNND (1996b)].
<table>
<thead>
<tr>
<th>1st LEVEL DECOMPOSITION</th>
<th>2nd LEVEL DECOMPOSITION</th>
<th>3rd LEVEL DECOMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquire orders through</td>
<td>Adjudge operational schedules</td>
<td>Retrieve information (including</td>
</tr>
<tr>
<td>customers consultations (A1)</td>
<td>(A11)</td>
<td>an object survey) (A211)</td>
</tr>
<tr>
<td></td>
<td>Make global work break down</td>
<td>Analyse obtained information (A212)</td>
</tr>
<tr>
<td></td>
<td>structure (A12)</td>
<td>Make activity networks (A213)</td>
</tr>
<tr>
<td></td>
<td>Schedule global work break down</td>
<td></td>
</tr>
<tr>
<td></td>
<td>structure (A13)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consult at portfolio level (A14)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consult the customer (A15)</td>
<td></td>
</tr>
<tr>
<td>Prepare the technical</td>
<td>Investigate order (A21)</td>
<td></td>
</tr>
<tr>
<td>specifications (A2)</td>
<td>Specify technical details</td>
<td></td>
</tr>
<tr>
<td></td>
<td>modifications (A22)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prepare repair / modification</td>
<td>Update activity networks (A231)</td>
</tr>
<tr>
<td></td>
<td>approach (A23)</td>
<td>Make work descriptions (A232)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Take stock of required materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and spare parts (A233)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Take stock of required resources</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A234)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Put together work definitions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A236)</td>
</tr>
<tr>
<td>Prepare resource planning</td>
<td>Order materials and spare parts</td>
<td></td>
</tr>
<tr>
<td>and scheduling (A3)</td>
<td>(A31)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Go through planning information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and resource availability (A32)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Go through planning information</td>
<td></td>
</tr>
<tr>
<td></td>
<td>skills (A33)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Integrate planning data (A34)</td>
<td></td>
</tr>
<tr>
<td>Execute work assignments</td>
<td>Prepare work execution (A41)</td>
<td></td>
</tr>
<tr>
<td>(A4)</td>
<td>Examine work assignments, check</td>
<td></td>
</tr>
<tr>
<td></td>
<td>availability employees, materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td>, materials, spare parts, and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>resources (A411)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Order materials and spare parts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(A412)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Claim resources (A413)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distribute work packages (A414)</td>
<td></td>
</tr>
<tr>
<td>Supply materials, spare parts,</td>
<td>Support Royal Netherlands Navy</td>
<td></td>
</tr>
<tr>
<td>and services (A43)</td>
<td>and other Navy Maintenance</td>
<td>Support new ship building projects</td>
</tr>
<tr>
<td></td>
<td>Companies (A42)</td>
<td>(A421)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Analyse and improve upkeep</td>
</tr>
<tr>
<td></td>
<td></td>
<td>strategies (A422)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supply general technical support</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(A423)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Support break-up phase (A424)</td>
</tr>
<tr>
<td>Execute order (A44)</td>
<td>Manage operational supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>activities (A431)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purchase materials, spare parts,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and services (A432)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manage Navy Stores (A433)</td>
<td></td>
</tr>
<tr>
<td>Evaluate and deliver service</td>
<td>Evaluate and deliver service</td>
<td></td>
</tr>
<tr>
<td>(A5)</td>
<td>(A51)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Settle project (A51)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manage internal information data</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(A52)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manage information data for</td>
<td></td>
</tr>
<tr>
<td></td>
<td>external customers (A53)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1: Survey of context diagrams.

Appendix 1 of this thesis contains this tree structure, while Appendix 2 contains the first level decomposition diagrams for the different production phases. Table 3.1 surveys the context diagrams. The context diagrams
show a complex set of linked activities for each production phase. The first step in the production structure design is to reduce this complexity. For the design of homogeneous order flows (flows of orders with a highly similar structure) we consider three dimensions:

- **the order lead time** (= time spent between the start of the order processing [i.e. after obtaining an assignment in the order acquisition phase] and delivering a finished product which satisfies the customer);
- **the order size** (= the resource requirements of an order expressed in man hours needed for the different production phases)
- **the order complexity** (= the amount of different skills needed in the execution phase [= execution complexity] and the repetitiveness of a product [= resource complexity]).

The choice of the first dimension is based on a clearly expressed customer wish. The result of the phase ‘investigation and diagnosis’ revealed that the customers put a high emphasis on due date reliability.

<table>
<thead>
<tr>
<th>Description work packages by customer group</th>
<th>Size:</th>
<th>Complexity</th>
<th>Lead time:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Term Maintenance (LTM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Ships Section</td>
<td>± 120,000 hour</td>
<td>+++++</td>
<td>± 1 year</td>
</tr>
<tr>
<td>Submarine Service</td>
<td>± 180,000 hour</td>
<td>+++++</td>
<td>± 1 year</td>
</tr>
<tr>
<td>Mine-Counter Measures Service</td>
<td>± 25,000 hour</td>
<td>+++++</td>
<td>± 6 months</td>
</tr>
<tr>
<td>Between Time Maintenance (BTM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Ships Section</td>
<td>± 25,000 hour</td>
<td>+++++</td>
<td>± 3 months</td>
</tr>
<tr>
<td>Submarine Service</td>
<td>± 10,000 hour</td>
<td>+++++</td>
<td>± 3 months</td>
</tr>
<tr>
<td>Appointed Incidental Maintenance (AIM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Ships Section</td>
<td>± 5,000 hour</td>
<td>+++</td>
<td>± 4 weeks</td>
</tr>
<tr>
<td>Submarine Service</td>
<td>± 2,000 hour</td>
<td>+++</td>
<td>± 4 weeks</td>
</tr>
<tr>
<td>Mine-Counter Measures Service</td>
<td>± 2,000 hour</td>
<td>+++</td>
<td>± 3 weeks</td>
</tr>
<tr>
<td>Urgent incidental maintenance (UIM) all groups</td>
<td>Vari</td>
<td>Vari</td>
<td>Vari</td>
</tr>
<tr>
<td>Maintenance of landing craft assault Marines</td>
<td>± 50,000 hour a year</td>
<td>++</td>
<td>Vari</td>
</tr>
<tr>
<td>Maintenance of ‘small’ ships</td>
<td>± 16,500 hour a year</td>
<td>++</td>
<td>Vari</td>
</tr>
<tr>
<td>Maintenance of shore facilities</td>
<td>± 80,000 hour a year</td>
<td>+</td>
<td>Vari</td>
</tr>
<tr>
<td>Maintenance of interchangeable parts Navy Stores</td>
<td>± 60,000 hour a year</td>
<td>++</td>
<td>Vari</td>
</tr>
<tr>
<td>Supply of parts and services</td>
<td>± 60,000 hour a year</td>
<td>+</td>
<td>Vari</td>
</tr>
<tr>
<td>Maintenance engineering</td>
<td>± 60,000 hour a year</td>
<td>+</td>
<td>Vari</td>
</tr>
</tbody>
</table>

Table 3.2: Survey of the values size, complexity, and lead time.

By selecting a primary dimension that is closely related to the market, we realise a process-oriented structure (see Chapter 2) that is capable to satisfy customer demands. Next, we have selected the order size and the order complexity as secondary dimensions to incorporate the efficiency goals. An efficient order execution should be possible by joining orders of equal size and complexity.

In the search for parallel flows, we estimate the value of these three dimensions for each customer group. For the large customer groups we present these values according to the maintenance types (i.e. LTM, BTM, AIM, and UIM). Table 3.2 presents a survey of these values. Based on the contents of this table, we create seven more or less homogeneous order flows based on similar lead times, size, and complexity:

1. **Largely Overhauls**
   Orders ranging in size from medium to large, and in lead time from 3 months till approximately one year. The complexity for these orders is high. This flow is applicable for the LTM, the BTM, and sometimes the UIM, for the Capital Ships Section, the Submarine Service, and the Mine-Counter Measures Service.
2. *Service Maintenance*
   Orders with a relatively small size, a lead time varying between 1 to 6 weeks, and an average complexity. This flow is applicable for the AIM, and sometimes the UIM, for the Capital Ships Section, the Submarine Service, and the Mine-Counter Measures Service.

3. *Fast Repairs*
   Urgent orders that have a small size, a lead time varying from a few hours to several days, and a low complexity. The urgency of these orders is caused by the influence of the defect on the ship’s and/or crew’s safety, or on the ship’s operational availability.

4. *Maintenance of Small Objects*
   Orders which have a size varying from small to medium, a lead time varying from a week to several months, and a low to medium complexity. In this flow objects are maintained for the Netherlands Marine Corps, the ‘small ships’, and the shore facilities.

5. *Maintenance of Reparable Spare Parts*
   Orders which have in general a small size, a lead time varying from one day to several weeks, and a low to medium complexity. This flow concerns the repairable item circuit for the Navy Stores.

6. *Supply of Parts and Services*
   Orders which have a small size, a short lead time, and a low complexity. This flow is concerned with the supply of spare parts and services to the operational and maintenance services within the RNN. This work is performed both in- and outside the dockyard.

7. *Engineering Services*
   Orders which have a relatively small size, a lead time varying from a few days to a few months, and a low complexity. This flow comprises both the technical support and design.

Except for the urgent incidental maintenance (UIM) all the work packages of Table 3.2 are clearly placed in one of the flows. The reason that UIM is both part of the flows 1, 2, and 3, stems from its unpredictable character. So the classification of an UIM-order depends on its actual characteristics.

<table>
<thead>
<tr>
<th>Order flow</th>
<th>Name:</th>
<th>Estimate of capacity required each year (in man hours):</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Large Overhauls</td>
<td>582,000 (45%)</td>
</tr>
<tr>
<td>2</td>
<td>Service Maintenance</td>
<td>314,000 (24%)</td>
</tr>
<tr>
<td>3</td>
<td>Fast Repairs</td>
<td>16,500 (1%)</td>
</tr>
<tr>
<td>4</td>
<td>Maintenance of ‘Small’ Objects</td>
<td>215,000 (15%)</td>
</tr>
<tr>
<td>5</td>
<td>Reparable Item Circuit</td>
<td>66,000 (5%)</td>
</tr>
<tr>
<td>6</td>
<td>Supply of Goods and Services</td>
<td>60,000 (5%)</td>
</tr>
<tr>
<td>7</td>
<td>Engineering Services</td>
<td>57,000 (5%)</td>
</tr>
</tbody>
</table>

*Table 3.3: The size of each order flow in man-hours per year.*

For example the repair of a major engine-room fire will be part of flow 1, whereas a simple pipe repair is part of flow 3. The contents of Table 3.3 indicate the size of each flow.

As we have defined these seven order flows, the next step is to investigate each flow on successively a macro, a meso, and a micro level. We first consider both the macro and the meso level and subsequently go into the micro
level. At the macro level we search for strategic production units: groups which are strategically, organisationally, and operationally responsible for an entire flow. These units may be interpreted as self-supporting business units. Next, we move to the production structure at the meso level. Four options may be considered in succession: a product group, a module group, a phase group, and finally a component group. At the lowest level multidisciplinary teams are created within the process structure of the upper levels.

3.3.3.1.3 Review of the order flows on the macro and meso level

The dockyard's context diagrams show a production process that is highly integrated at the macro level. The strategic input for the A0 activity is equal for all seven order flows. Also the order acceptance phase can, due to the customer's structure (i.e. the different levels within the Royal Netherlands Navy, see Figure 3.3, never be fully integrated in the production units. Following the arguments of Chapter 2 we therefore conclude that for none of the seven flows, the formation of a strategic production unit (a unit responsible for the strategic, organisational, and operational management on every level) is possible. The highest possible level of order flow independence is to be found at the meso level. Therefore, we next consider the process structure options at the meso level.

<table>
<thead>
<tr>
<th>The characteristics</th>
<th>• Many different products</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Orders vary in the combination and the sequence of process steps</td>
</tr>
<tr>
<td></td>
<td>• Hundreds of routings</td>
</tr>
<tr>
<td>The possible process structures</td>
<td>1. Product groups</td>
</tr>
<tr>
<td></td>
<td>2. Module groups</td>
</tr>
<tr>
<td></td>
<td>3. Phase groups due to indivisible capacity</td>
</tr>
<tr>
<td></td>
<td>4. Component groups</td>
</tr>
</tbody>
</table>

*Table 3.4: The possible meso level process structures for criss-cross streams.*

The characterisation of the dockyard shows a process with many different products, a high order variation, and many different routings: so-called criss-cross streams. Table 3.4 presents the possible process structures, as well as the main characteristics of criss-cross streams.

In determining the best possible process structure for each flow, the first option is to create product groups. A product group incorporates all necessary skills and resources to manufacture a product or a set of products. Such a group is a feasible option if the workload for the group as a whole, and for each skill and resource, is sufficient and reasonably stable during a year. If this is not possible, a division of the order flows into segments, such that groups are responsible for the semi-products within a segment, may be feasible. Again, these so-called module groups must have a sufficient and stable workload. If within a flow, due to for example large investments, resources have to be shared between groups, then a phase group is a possible third option. In this case the product leaves the group for the shared resource and returns to the group for the final manufacturing activities. The last option is a component group in which similar operations and operations sequences are grouped. The fundamental difference with the previous groups is a selection based on operations and not on products. Chapter 2 provides a comprehensive description with graphical views of the different group structures. We now discuss each individual flow at the meso level.
**The large overhaul**

The objects that are subject to the overhaul process (i.e. the LTM, the BTM, and sometimes the UTM) are the high-tech warships. These ships are generally equipped with state-of-the-art propulsion, control, and computer systems, which are often installed in higher numbers than needed (to provide redundancy). Due to the high and diverse demands placed on a warship’s capabilities (e.g. with respect to the ship’s speed, size, weapon systems, and action radius) the available space for the ship’s equipment is limited. In addition, the ships are equipped with many different water-tight compartments. These characteristics make the ships difficult to access for large overhaul activities, in particular since these activities have in general far-reaching consequences for the ship’s structure and systems. This makes the manufacturing process of the ‘large overhaul’ flow highly complex.

To determine a suitable process structure at the meso level, we first consider the workload and the number of skills needed. If these variables are reasonably stable, then a product group is an applicable process structure. However an integral survey of the workload for an LTM-assignment of an S-class frigate indicates a highly unstable workload (see Figure 3.5). In addition, the maximum size of the workload can never be delegated to one group (see, for instance, the 9000 man hours required in week 627). Also the nature of the overhaul process calls for a wide variety of different skills. Therefore a product group is not a realistic option within the large overhaul flow.

![Resource Load LTM-period S-Frigate](image)

*Figure 3.5: Example of the resource load for an LTM-assignment.*

A division of the overhaul process into smaller segments may lead to a feasible process structure. Research at the dockyard showed the feasibility of the module group option. With the use of zone technology (which we discuss in the next section) segments with a stable and sufficient workload can be created. The manufacturing process of these segments may be assigned to various module groups.

In addition the research showed the importance of the ‘on-site-maintenance’ aspect within large overhauls. These activities on board the ship increase the complexity of these overhauls. The creation of module groups, each responsible for their own segments, reduces this complexity and therefore provides a powerful control mechanism.
The service maintenance
This order flow is mainly concerned with the appointed incidental maintenance (AIM). Ships undergo a maintenance period of approximately 4 weeks, as scheduled in a yearly contract. Mainly periodic and corrective maintenance activities are executed in these periods. Sometimes the incidental unexpected maintenance is part of this flow (UIM). Research on the nature of service maintenance showed that the different activities within one assignment have hardly any dependencies. This is explained by the less rigorous nature of the maintenance activities, as compared to the large overhaul flow. A production group does not provide a feasible process structure due to the unstable workload and wide variety of skills needed. The creation of module groups on the other hand is an applicable structure. In order to establish a sufficient workload for these groups, it may be necessary to simultaneously assign activities from different service maintenance periods to one module group.

The fast repairs
This order flow is concerned with the urgent defects, which directly influence a ship’s safety and/or operational availability. The nature of these defects should make a fast repair possible; i.e. a small order size and a low complexity (only one or two skills and no complicated materials and/or resources needed). As soon as the order does not fulfill these demands, it is upgraded to the service maintenance or large overhaul flow. An important characteristic of a fast repair is the high unpredictability of the moment of appearance and the skills needed. This makes the formation of any completely dedicated group impossible. However, a process structure in which the module groups of the large overhaul and the service maintenance flow carry out fast repairs is an applicable structure.

The maintenance of ‘small’ objects
This order flow contains the smaller objects of the RNN. Examples of these objects are the landing craft, assault, harbour tugboats, and dive operation ships. These ships are small indeed, but comprise the same essential mechanical and electrical systems as their larger counterparts. An investigation of this flow showed a relatively stable workload and a limited number of different skills needed. This observation enables us to create a product group which contains almost any skill and resource needed.

The repairable item circuit
The repairable item circuit is characterised by an open cycle process in which the items flow from the store to an object (e.g. the ship), from the object to a reservoir with defective items and from there to the maintenance facility. The maintenance facility repairs the item or disposes the item in case of irreparable damage. A schematic drawing of this process is given in Figure 3.6.

Within this flow a stable workload exists for the mechanical and electrical items. These items provide a yearly workload that enables the formation of a product group. However this flow also incorporates items which are related to the ship’s hull, as well as specific items which require a specialised employee (e.g. hydraulic components). In such a case we consider a process structure with the module groups from the other flows.
The supply of goods and services

The RNN has chosen to integrate all the maintenance, engineering, and logistic processes for its platform systems within the dockyard. This is expected to lead to a considerable efficiency improvement. The basic argument is to employ the dockyard’s maintenance knowledge when designing new planning and control structures for the logistics of both consumable and reparable items. For the ‘supply of goods and services’ flow, this policy has led to an integral responsibility for the platform items for all possible clients within the Netherlands Defence Organisation. Hence, not only the dockyard’s manufacturing process is a client but for example also a frigate or the Navy Base barracks.

We distinguish three segments in this flow: material planning, procurement, and storage (i.e. the Navy Storage). The most important argument to select this segmentation is that one ‘supply of goods and services’ group would become too voluminous. Another argument is related to the RNN regulations that prescribe a separation between the requirement function, the purchasing function, and the intake and storage function. Figure 3.7 depicts their mutual and external relations (in and outside the dockyard).

Figure 3.6: The reparable items circuit [Clusine (1995)].

Figure 3.7: The different segments within the Supply of Goods and Services flow.
The material planning is responsible for the availability of the right items at the right time and in the right quantities. To determine which items, and in what quantity, should be stored, a close contact with the engineering service is essential. The procurement is responsible for the actual purchasing of the different items and services. The storage stores and distributes the items.

In view of the clearly defined flow with a sufficient workload for each segment, a product group is a suitable process structure.

**The engineering service**

The engineering process consists of three mutually related processes: the support of shipbuilding projects (i.e. the building of new navy ships at a private yard), the support of maintenance assignments (including the modifications), and the technical maintenance control. The last process consists of the maintenance design, preparation of maintenance and modifications, configuration control, data management, and analysis of the stock’s composition (the interaction with the material planning).

Within the engineering services a strong orientation exists towards the ship types and classes. Based on this orientation and the associated steady workload, we create the following four product groups: the capital ships, the submarines, the mine counter ships, and the small ships. In addition a module group is created for the specific knowledge areas and a phase group for the information and documentation area.

The creation of module and product groups concludes the production structure design at meso level. Table 3.5 depicts a survey of the different groups for each flow.

<table>
<thead>
<tr>
<th>Order flow:</th>
<th>Segment:</th>
<th>The process structure at meso level:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Large Overhauls</td>
<td></td>
<td>Module Groups</td>
</tr>
<tr>
<td>2. The Service Maintenance</td>
<td></td>
<td>Module Groups</td>
</tr>
<tr>
<td>3. The Fast Repairs</td>
<td></td>
<td>Module Groups</td>
</tr>
<tr>
<td>4. The Maintenance of 'Small' Objects</td>
<td></td>
<td>Product Group</td>
</tr>
<tr>
<td>5. The Reparable Items</td>
<td></td>
<td>• Product Group</td>
</tr>
<tr>
<td>6. The Supply of Goods and Services</td>
<td>Material Planning</td>
<td>• Module Groups</td>
</tr>
<tr>
<td>7. The Engineering services</td>
<td>• Procurement</td>
<td>• Product Group</td>
</tr>
<tr>
<td></td>
<td>• Storage</td>
<td>• Product Group</td>
</tr>
<tr>
<td></td>
<td>• Capital Ships</td>
<td>• Product Group</td>
</tr>
<tr>
<td></td>
<td>• Submarines</td>
<td>• Product Group</td>
</tr>
<tr>
<td></td>
<td>• Mine Counter Ships</td>
<td>• Product Group</td>
</tr>
<tr>
<td></td>
<td>• Small Ships</td>
<td>• Product Group</td>
</tr>
<tr>
<td></td>
<td>• Specific Knowledge Areas</td>
<td>• Product Group</td>
</tr>
<tr>
<td></td>
<td>• Information Documentation Area</td>
<td>• Module Group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Phase Group</td>
</tr>
</tbody>
</table>

*Table 3.5: The process structure at the meso level.*

### 3.3.3.1.4 The design on the micro level

In this section we create, within the constraints set by the process structure design at the meso level, so-called multi-disciplinary teams for the different flows. In the previous section we concluded that there was a need for synergy between the execution of the order flows 'large overhaul', 'service maintenance', and 'fast repairs' (the module groups). We first consider the formation of multi-disciplinary teams within these module groups. Next we move to the product groups for the other flows.
To make a survey of the different skills needed for the execution of these order flows, we use the Standard Materials Classification (SMC) of the RNND ships. This SMC comprises every ship's platform construction and system. For each element of the SMC we have determined which skills are needed. To give a complete survey of the results is beyond the scope of this thesis. Table 3.6 gives an impression of the results, by listing the skills needed for the propulsion system.

<table>
<thead>
<tr>
<th>SMC Items:</th>
<th>Description:</th>
<th>Skills needed:</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 PROPULSION SYSTEM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>121. Main Engines</td>
<td>Gas-turbines Diesel Engines</td>
<td>• Basic Mechanical Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Basic Constructional Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Gas-turbines Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• DieselEngines Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Platform Control Systems Skills</td>
</tr>
<tr>
<td>123. Transmission Systems</td>
<td>Transmission Gear Shearing Variable Pitch Propeller System</td>
<td>• Basic Mechanical Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hydraulic Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Revisions of Appliances Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Platform Control System Skills</td>
</tr>
<tr>
<td>125. Supporting Systems</td>
<td>Fuel Systems Lubricating Oil Systems Cooling Water Systems</td>
<td>• Basic Mechanical Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Basic Constructional Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Piping Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Revisions of Appliances Skills</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Platform Control System Skills</td>
</tr>
</tbody>
</table>

Table 3.6: Propulsion system and skills needed [RNND (1997b)].

Based on the skills needed for each SMC element, we combined the workload of related systems into work packages for several multi-disciplinary teams (see Table 3.7). The teams within a module or product group may have different fields of interest. For example within the module group 'platform supporting systems', a multi-disciplinary team for pneumatic maintenance may be present. This process of group development depends on the actual formation of the different teams.

<table>
<thead>
<tr>
<th>Meso Level</th>
<th>Multi-disciplinary Teams:</th>
<th>Number of multi-disciplinary teams:</th>
<th>Total strength (in employees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Groups for:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Large Overhauls</td>
<td>Hull (steel)</td>
<td>4</td>
<td>00</td>
</tr>
<tr>
<td></td>
<td>Hull (wood and Polymer)</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Hull Preservation</td>
<td>3</td>
<td>55</td>
</tr>
<tr>
<td>2. Service Maintenance</td>
<td>Hull</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Hull (miscellaneous)</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Sail Loft</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Propulsion, including transmission, excluding diesel engines</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Combustion Engines, excluding Gas-turbines</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Platform Supporting Systems</td>
<td>6</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>Hydraulics</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>3. Fast Repairs</td>
<td>Maintenance of Light and Small Vessels</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>Product Group 'Maintenance of Small Objects'</td>
<td>Maintenance of Components</td>
<td>6</td>
<td>120</td>
</tr>
<tr>
<td>Product Group 'Mechanical and Electrical Components Maintenance'</td>
<td>Tank Group Ship's Class Management of Hull Capital Ships</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Product Group 'Engineering of Capital Ships'</td>
<td>Tank Group Ship's Class Management of Platform Systems Capital Ships</td>
<td>1 or 2</td>
<td>22</td>
</tr>
<tr>
<td>Product Group 'Engineering of Submarines, Coast Guard and Caribbean'</td>
<td>Tank Group Ship's Class Management of Hull Submarines, Coast Guard and</td>
<td>1</td>
<td>11</td>
</tr>
</tbody>
</table>
This is also a dynamic process; whenever for example the navy demand changes or experiences in the work field show that a different team composition is beneficial, it is essential to be able to change the team structure.

At the dockyard special attention is needed for the workforce’s flexibility. The larger part of the activities in the large overhaul flow takes place on board the ship. The maintenance of specific systems is delegated to the appropriate multi-disciplinary group. Examples are the maintenance of hydraulic systems by the hydraulics team and the maintenance of a diesel engine by a team of the combustion engines group. These groups have an integral responsibility for the work on board the ship and in the shop. We call such a team a ‘specific’ multi-disciplinary group. In addition to these specific maintenance jobs, also more general maintenance tasks exist. An example is the maintenance of the general piping system in an engine room. These tasks are delegated to a ‘temporary’ group. This group is responsible for any general maintenance task in a ship’s segment. In addition the group plays, within its segment, a role in co-ordinating the activities of the specific teams on board the ship.

The temporary groups are not included in Table 3.7. The hired employees from the specific teams form these groups. The temporary characteristic requires special attention for the coherence in the temporary group. In addition, a smooth return of the employee to its own specific task group must be guaranteed. For the specific teams it is also important to sustain the coherence within the team, despite the exchange of a few employees. This leads to an upper bound on the number of exchange workers. This upper bound depends on the team’s size and on the maturity level. There is no need for temporary teams in the service maintenance and fast repair flow. The tasks within these flows are delegated to the specific groups.

For the Maintenance of ‘Small’ Objects and the Mechanical and Electrical Reparable Item Circuit we form product groups, which are entirely responsible for the maintenance process of their work package, within the higher level agreements. For the Engineering Services we distinguish the hull and platform systems. In each of these two areas, task groups are created for the Capital Ships, the Submarines, Coast Guard and Caribbean Ships, and the Mine-Counter Measures Services, Small Vessels, and Marines, respectively. A phase group handles the system and process management of the platform systems. For the Supply of Goods and Services flow, product groups are arranged around the material planning, the procurement, and the storage. The material planning group is split up in a general, mechanical, electrical, and hull group. The last group is concerned with configuration and codification issues. Table 3.7 presents a complete overview of the different groups and the multi-disciplinary teams.

<table>
<thead>
<tr>
<th>Ships’</th>
<th>Caribbean Ships</th>
<th>1 or 2</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Task Group Ship’s Class Management of Platform Systems Submarines, Coast Guard</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>and Caribbean Ships</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Task Group Ship’s Class Management of Men-Counter Measures Services, and Small</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Vessels, and Marines</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Task Group Ship’s Class Management of Platform Systems Men-Counter Measures</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Services, Small Vessels, and Marines</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Task Group System and Process Management Platform Systems</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Phase Group Engineering</td>
<td>Task Group General Section</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Product Group Material Planning</td>
<td>Task Group Platform Systems</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Product Group Procurement</td>
<td>Task Group Hull</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Product Group Storage</td>
<td>Task Group Store Management</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Product Group Information, Supply, and</td>
<td>Task Group Data Management</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Data Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product Group Configuration and</td>
<td>Task Group Configuration and Identification</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Identification</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.7: The multi-disciplinary teams at the micro level.
This concludes the design at the micro level. The different module and product groups with their multi-disciplinary teams form the basis for the control structure definition.

3.3.3.2 The control structure design

We develop the control structure through a process of allocation, selection, and finally coupling of control cycles. This process starts with a survey of the different control cycles for each flow. Next we move to the coupling of control cycles for the various levels. We conclude this section with a survey of the corresponding breakdown structure.

3.3.3.2.1 The control cycle survey

In this section we survey the control cycles for each flow.

- **The large overhaul**

  The objects that are subject to the overhaul process (i.e. the LTM, the BTM, and sometimes the overhaul order flow) are partly handled by multi-disciplinary teams, which belong to the co-ordinating module groups at the meso level. These mainly system-oriented multi-disciplinary teams manufacture modules, which subsequently have to be assembled to a ready-for-use installation or system. In addition, we have chosen for temporary teams to execute and co-ordinate the activities on board the ship.

  For the control of this order flow the project management approach appears to be the most suitable option. The following arguments support this decision:

  - many teams (specific and temporary) are involved in the execution process;
  - the activities comprise many different maintenance and modification jobs, which are in general complex in both the planning (e.g. due to many precedence constraints) and the execution phase;
  - the large overhaul assignment has a clearly defined finite duration;
  - each large overhaul assignment is specific with respect to the nature and composition of the work packages;
  - many maintenance and modification jobs have to be performed in small, difficult to access rooms;
  - for the planning and execution of these complex assignments a limited time is available.

  Based on the dimensions 'job size' and 'job complexity' a process selection diagram can be designed (see Figure 3.8), similar to the product-process diagrams as proposed by Hayes et al. (1984). This projection clearly indicates a project management approach with a zone-based planning (zone technology) for large overhauls. In this approach the integral project team's responsibility from order acquisition to evaluation and service is essential [Nelissen (1995)]. This so-called 'plan and do philosophy' must prevent the danger of responsibility shifting whenever problems occur.
The zone oriented approach matches perfectly with the team concept, which has been selected as the most suitable production structure at the micro level. Project management can plan and control the integral progress of the project without getting lost in too much detail. A zone (i.e. a segment) can be a ship compartment, only a part of that compartment, a group of compartments, a system, a part of a system, a group of systems, or a prefabricated unit being built in a shop [Storch et al. (1995), p.373]. Any zone definition is possible as long as it facilitates project progress and control. The zone concept enables an early project-wide task grouping, resource allocation, and interdependent decision-making. The project leader defines the work packages and recruits specific employees for each project phase. Depending on the project phase, employees join or leave the team. 'Specific' work is subcontracted to specific teams in the shops (cf. the definition of specific groups in Section 3.3.3.1.4). There is no need to incorporate these teams into the project team.

In the order acquisition and technical specification phase the project team mainly consists of employees from the engineering and material planning teams. In the technical specification phase the project management turns over from a system oriented to a zone oriented approach. The resource planning and scheduling is based on this zone oriented approach. The composition of the project team changes from mainly process planning and planning and scheduling employees towards operational employees in the work execution phase. Based on the zone classification, temporary teams are set to work on board the ship. Specialised teams maintain special systems. As soon as the work is finished the evaluation and service phase starts. To put the various systems and installations into service and make up a system-oriented customer account, the project team returns to a system-oriented approach. Figure 3.9 depicts this process.

This description of the large overhaul process leads to the following external control cycles (as seen from the project team's viewpoint):

1. Project team - customer

The consultation process with the customer starts as soon as the project team is installed. The ultimate result of this process should be a mutual agreement on the work contents of the overhaul assignment, with respect to the dimensions time, quality, and costs. The project team also consults the customer in all other maintenance phases whenever necessary. Obviously, the team is obliged to keep the customer informed on all important aspects of the project execution progress.
2. **Project team - material planning**
   For a timely availability of the necessary materials and spares it is essential for the project team to consult the material planning groups in an early stage. Special attention is required for the items that are not on stock and have long order lead times. Consultation of the material planning in the other process phases is necessary whenever logistic problems occur.

3. **Project team - engineering services**
   Especially in the order acquisition and technical specification phase the consultation of the engineering services product groups is intense. Topics include the ship's survey, the engineering of modifications and the assistance in the technical specification process. Engineering is involved in the
work execution phase whenever unexpected problems occur, which cannot be solved within the teams.

4. **Project team - module groups**

   A consultation of the module groups comprises two objectives. The first one is to hire employees for the various temporary teams within the project. The second objective is to make agreements on the maintenance tasks on board the ship and in the shops that are subcontracted to the module groups.

   - **The service maintenance flow**
     
     This flow mainly consists of the appointed incidental maintenance jobs. In view of the process time, size, and complexity of these jobs, a system-oriented approach is in general appropriate. The service maintenance assignments are split into jobs for the multi-disciplinary teams within the various module or product groups. These teams are then responsible for the job execution. For the order acquisition phase of the customer consultation process and the specification and distribution process of the various jobs, an unambiguous entry-point is essential. This customer relation point serves as a counter, where on the one hand agreements with the customers are made, and on the other hand the job's execution and progress is ensured and observed. An 'account manager' fulfils these tasks. Just as in the large overhaul process the account manager and his team have relations with the customers, the material planning, the engineering services, and the module groups. The various control cycles are basically similar, however the account manager does not create temporary teams.

   - **The fast repair flow**
     
     The high unpredictability of this flow does not justify the creation of a separate team. Execution of these repairs is delegated to the various module groups. Again, an account manager maintains contact with the customer. This gives the customer an unambiguous entry-point and serves for the dockyard as a review-point. The account manager must be able to judge whether the customer request fits within the fast repairs flow conditions (small in size, minimal technical specification needed, and materials and spare parts in stock). This implies that the major control cycle within this flow is between the account manager and the module groups.

   - **The maintenance of 'small' objects**
     
     For this flow we created a product group which comprises three multi-disciplinary teams (see Table 3.7). These groups have a direct relation with the dockyard customer at the meso level since they manufacture an end product that needs no higher level co-ordinating efforts. The account manager is responsible for the necessary embedding of this flow in the dockyard's entire process. He agrees on an annual contract with the various customers, which contains the entire workload for one year. The product group is involved in this consultation process. Next, the group is responsible for the detailed agreements and work execution at the meso and micro level. The following control cycles are important in this flow (from the group's point of view):

   1. **Product group maintenance of small objects - account manager**
      
      The group is involved in the making of the annual frame contracts. Major changes occurring at the macro level usually lead to interim consultations between the product group and the account manager.

   2. **Product group maintenance of small objects - other groups**
      
      In the creation of this product group we aim to accommodate all necessary skills within the group. However due to some unique equipment and facilities, the group may have to hire services from other groups. The group is responsible for the planning and scheduling process with the other groups.
3. **Product group maintenance of small objects - engineering**

From a terotechnology point of view, consultation of the engineering services is necessary on a regular basis. In addition, the occurrence of serious defects may require the experience of engineering.

- **The maintenance of repairable spare parts**

A product group is responsible for all the maintenance of mechanical and electrical repairable items. The material planner presents these items to the product group. Depending on the type of item to be repaired, an agreement is made on the due date. This working method requires a close consultation process with the material planning function.

In a normal case a 'repair by replacement' strategy is applicable for the repairable item circuit. In some cases, however, a 'repair by repair' strategy may be preferred. If for example in an LTM-period all fire pumps need maintenance, a repair-by-repair strategy may be recommended. In such a case, a repair by replacement strategy will cause a low availability of spare pumps in store, which ultimately may lead to insufficient spare items for the operational fleet on the short term. The ultimate responsibility for the repair strategy lies within the material planning.

The following control cycles are applicable for the electrical and mechanical repairable items:

1. **Product group repairable items - material planning**

   The material planner presents the items to be repaired within the framework agreements. This framework indicates the total amount of repairable items to be handled in a certain period. In addition, agreements are made for the lead time for each item category. These framework agreements at the meso level are made for example for a one-year period. A quick feedback from the product group is essential. Obviously, whenever the material planning is fed with poor information, this will lead to a low availability and an incorrect purchase policy.

2. **Product group repairable items - other groups**

   For some skills, assistance from other groups is needed. An example is the surface cleaning facility. Horizontal group to group consultation leads to internal due date agreements.

3. **Product group repairable items - engineering**

   Consultation of the engineering services, as a norm fixing facility, is a necessity.

The repairable items for the hull section will be forwarded to the related module group. For this flow, analogous control cycles are applicable.

- **The supply of parts and service**

Three groups are distinguished within this flow: material planning, procurement, and storage. These groups are responsible for the re-supply process, the stock control, the purchase process, and finally the storage management.

The important question is how the material planning (MP) can timely fulfill all requests for materials and spares, from both external and internal customers. The internal customers are the various groups within the dockyard; the external customers comprise all others, such as the operational ships. To this end, MP determines which spares should be kept in stock, and in what quantities. These decisions in turn are based on agreements with the external and internal customers on service levels (here, the desired delivery times for certain spares and materials). In addition, MP seeks for solutions in case of shortages. Also in this case, a close contact with the customers is essential. The stock control tasks aim for an optimal size and composition of spare parts packages [see Rustenburg et al. (1998)]. Therefore MP consults the engineering, the maintenance execution function (product and module groups), and the operational users.
Procurement purchases the different spares and materials, based on indications of the material planning group. In addition, procurement establishes contracts on external services (for example a contract for the hiring of painters). Procurement must have the commercial knowledge to select the appropriate supplier. A close contact with the material planning group and a good insight in the suppliers market is required.

Storage takes in the delivered spares and materials and then checks and stores these goods. The goods are delivered on customer request. For these purposes storage is closely related to the material planning.

*The engineering services*

The design of technical systems, the maintenance concept design, the technical support during a system’s use, and the maintenance control and results analysis belong to the engineering services’ work area. For each task we may distinguish different control cycles.

The feedback from the operational use of systems is essential in the design of new technical systems. As the dockyard’s engineering is involved in the support of the operation of existing systems, it can employ this knowledge in shipbuilding projects. These projects are co-ordinated by the Navy Headquarters at the Ministry of Defence. Consultations between these shipbuilding project teams and the relevant engineering groups are essential for this feedback.

Engineering designs the maintenance concepts for new objects and systems. The shipbuilding project team assigns these tasks to engineering. As maintenance concepts have a high impact on the logistic supply policy, participation of material planning is necessary.

Whenever a system reaches the operational use phase, technical support is needed to solve problems that occur, for the design of modifications, and, possibly, the design of an upgrading program (fitting the ship with new systems to extend its life). Support is also needed when a ship is put out of service.

By analysing the effects of maintenance on the operational availability of objects and systems, engineering attempts to improve the maintenance process. This improvement should lead to a higher operational availability against the same costs, or to the same operational availability against lower costs. This process requires consultations with the different module and product groups, the operational users, the material planning, and the shipbuilding project teams. This analysis and improvement process may result in a modification proposal. On approval of the Ministry of Defence or the operational users’ organisation, the proposal is further detailed into a set of drawings, work instructions, and a bill of materials.

This concludes the discussion of the different control cycles for the individual order flows. Figure 3.10 presents an outline of the various relations between the dockyard’s customers and its order flows.
3.3.3.2.2 The work breakdown structure

In the previous sections we have considered the production structure and thereupon the control cycles for each individual flow. The next step is to allocate, select, and couple the different control cycles. The planning hierarchy is an important element in the emerging integral control structure. For a correct use of this hierarchy it is essential to match the work breakdown structure (WBS) with this design. Therefore, we discuss in this section the WBS.

A WBS is basically a tree structure that divides the work into packages. In this way it enables the work specification, scheduling, execution, control, and evaluation at the different organisational levels. To this end, we have created the following four levels:

1. **project/order/framework agreements**

   A project, order, or framework agreement comprises all jobs that have to be performed to fulfil the customer demands, with respect to timeliness, quality, and cost. Projects or orders are assignments in the order of 10,000 man-hours or more. If an order has a high capacity complexity, a large size, and a restricted lead time, it is treated as a project. A maintenance assignment that consists of a frame, in which smaller assignments are executed, is called a framework agreement.

2. **main activity**

   At the first decomposition level, a project, order, or framework agreement is divided into logical units, which contain all the work for a system, a cluster of systems, or the geographic location of an object. This

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*Figure 3.10: Diagram of relations between the various segments.*
definition allows for different split-ups of the work. The choice for a split-up depends on the nature of the work. An important guideline is that it should ease the specification, scheduling, execution, and control of the work. The main activity size should vary between approximately 1500 and 5000 man-hours.

3. **activity**
   Main activities are divided into activities of approximately 300 to 600 man-hours. These activities are work packages that are, as a whole, allocated to the multidisciplinary teams. Agreements are made with the team on the execution of an activity. The composition of the activities should allow for feedback, to provide a reliable insight in the main activity progress.

4. **operations**
   Activities are divided into tasks for the individual employees, which are called operations. The size of these operations varies between a few hours and approximately a hundred man-hours.

The quoted sizes of the different WBS elements should be considered as guidelines. In some cases it might be necessary to deviate from these numbers. For example a very complex but relatively small maintenance assignment might be labelled as a project. However, to obtain a well-balanced WBS, this should be an exception.

The WBS elements defined in this section will play an essential role in the design of the integral control structure in the next section.

3.3.3.2.3 **Allocation, selection, and coupling of control cycles**

Now that we have gained a global insight in the different relations and control cycles for the various order flows, we take a closer look at these cycles. In this section, we discuss the allocation, selection, and coupling of control cycles at the micro, meso, and macro level, respectively.

- **The micro level**
  For the module and product groups we have selected the following local (within the group or team) or external (with the group's surrounding) control cycles:

  - goal setting (internal and external);
  - tuning with other groups (external);
  - tuning with order acquisition at meso level (external);
  - determination and improvement of work methods (internal and possibly external);
  - introduction of process improvement (internal and possibly external);
  - performing routine maintenance on production resources (internal);
  - work distribution (internal);
  - order, neatness, and safety control (internal);
  - reviewing the team's productivity (internal);
  - reviewing individual productivity (internal);
  - determination of need for training (internal);
  - scheduling of free days (internal).

These control cycles are present in all teams within the module and product groups of Table 3.7. In a module group a co-ordinator is responsible for the consultation of the operational controllers at the meso level. The different teams within the group are involved in the related scheduling process. However, a group co-ordinator is in general not licensed to fill up the teams with assignments independently. The vertical internal order acquisition process at the meso level is a regular activity in module groups. In a product group
the co-ordinators have a direct relation with the external customers. Their agreements are limited by the framework agreements made by the account managers on the meso level. These agreements comprise limits on the macro level for the amount of man-hours and materials to be spent during a certain period (e.g. during one year) and do not specify all underlying activities. As long as the product groups and customers remain within these limits, they may realise these agreements in a direct horizontal consultation on the meso and the micro level. Hence, within product groups the order acquisition process may be a more horizontal activity. Obviously, also in the product groups the teams must be involved in the scheduling process.

- **The meso level**

  At this level we group the different module and product groups in manageable units. Starting points are:

  1. integrate the execution of maintenance, the engineering service, and the material planning (this originates from the mission statement);

  2. bring groups together of which the products or semi-products are strongly related.

A few options are available in this grouping process. The first possibility is based on the traditional distinction between the mechanical, the electrical, and the ship building skills. However this conflicts with the nature of the multi-disciplinary teams concept and the starting points of the integral organisational change approach. Therefore this is not a real option.

The second option is to copy the technical organisation of a navy ship. Here, we distinguish a propulsion section, an energy section, and a hull section. The separation of the propulsion and the energy section however may cause problems. Both sections incorporate for example diesel engines, which would split up the multi-disciplinary team 'diesel engines'. The creation of a section 'hull' seems promising. It is possible to arrange a hull section that comprises groups with a natural cohesion.

In the third option we combine the energy and propulsion systems in a platform systems group. This enables us to create a section with the same natural cohesion as in the hull section. In view of the strong synergy that emerges from this option, we choose for a hull and a platform systems section. Table 3.8 shows the division of the module and product groups into the two sections.

The account or project managers acquire work from external customers at the meso level. By means of a meso level technical specification phase, an activity list originates that enables a meaningful consultation of the two sections. For the co-ordination of the operational consultation process within the two sections, we introduce a section manager. He is responsible for the match on macro and meso level, between the maintenance capacity demand of the project and account managers on the one hand and the available resources in his section on the other hand.
<table>
<thead>
<tr>
<th>Section:</th>
<th>Module- or Product Group:</th>
</tr>
</thead>
</table>
| **Hull** | • Module Group Hull Steel  
• Module Group Hull Wood and Polyester  
• Module Group Hull Preservation and Paint  
• Module Group Hull Rigging  
• Module Group Hull Various Skills  
• Module Group Hull Sail Loft  
• Product Group Maintenance of 'Small' Objects  
• Task Groups Class Management HULL  
• Task Group Material Planning HULL  |
| **Platform Systems** | • Module Group Propulsion including transmission, including Gas-turbines, excluding Diesel Engines  
• Module Group Combustion Engines, excluding Gas-turbines  
• Module Group Platform Systems  
• Module Group Hydraulics  
• Product Group Reparable Items 'Platform System'  
• Task Groups Class Management Platform Systems  
• Task Group Material Planning Platform Systems  |

Table 3.8: Division of module and product groups into the two sections.

*The macro level*

At the macro level an integral co-ordination of the workload and new assignments is performed. For this process we use the principles of the portfolio management methodology. The essentials of this methodology are explained below.

Suppose that we have created several organisational units at the meso level in which the different resources of the company are sheltered. Whenever capacity is needed by one of the orders, agreements with these groups have to be made. The project teams or work package attendants raise this demand for capacity. At the highest level (the macro level) a fit between capacity demand and availability has to be made. This model is known as a matrix organisation: on one axis we find the resource departments and on the other axis the units which need these resources.
Figure 3.11: The LSMO matrix structure [based on Hatô (1997), p.188].

Figure 3.11 shows this organisational structure. It depends on the kind of job that has to be executed (size, lead time, specialised skills needed, etcetera) whether members of production units are actually, on a temporary basis, transferred to project or work package teams. In general the work package attendants will bring work into the production teams (because the size of their assignments is in general small), while project teams may demand members from a production unit for assignment to the project team. To sustain the benefits of production groups, we must attempt to bring complete production groups into the project teams.

In addition, the project team will also have assignments that have to be handled by production units; the size of these jobs does not justify the transfer of production unit members into the project team. The actual process of transferring production unit groups or members to projects and the assignment of work to the production units depends fully on the actual project.

Naturally, in such a structure conflicts may arise between the demand for capacity and its availability. In any multi-order organisation, project leaders and management of work packages use production units that have limited capacity. Leaving the balancing of projects, work packages, and production units to bilateral consultations may lead to ambiguity. Therefore, a clear solution should be defined at the macro level of operations planning and control.

This level of planning is based on the principles we used to create the micro and meso level: delegate all responsibilities to the lowest possible organisational levels, whereas bilateral communication is made explicit through the control cycle definition. Based on these principles, higher management (at the macro level) is restricted to setting priorities, authorising the distribution of resources over the different projects and work packages, and resolving conflicts which cannot be managed at lower levels. At an intermediate level called portfolio management, the bilateral contacts between general management, managers of work packages and projects, and finally managers of production units are made explicit (see Figure 3.12).
This portfolio management methodology results in an unambiguous priority setting between projects, work packages and capacity groups [see Platje et al. (1993)]. At portfolio level, feasible portfolios are constructed, trade-offs between conflicting interests of the participants are made, and finally an integral communication between department heads, project leaders and managers of work packages is supported. Through the involvement of all parties in an integral view on feasible portfolio's the urge to favour a single project, work package, or unit decreases. By making trade-offs explicit and priority setting explicit, the overall company interest becomes clear for all participants.

![Diagram](image)

**Figure 3.13: The dockyard's operational management structure.**

At the RNND we find on one side the two sections with their module and product groups and on the other side the project teams and account managers. Figure 3.13 depicts this operational management structure, including the WBS elements. At the macro level we find the enclosing portfolio management, which defines the constraints for operational management at the lower levels. We estimate the portfolio management meetings to be held once every two weeks, for the specific case of the RNND. In this meeting the account managers, the project managers, and the two section managers are present to perform macro level
operational management, based on aggregate capacity views. Interim meetings are necessary whenever unexpected major changes occur that cannot be solved at meso and micro level within the agreed frameworks.

The chairman of the portfolio meeting is the manager platform maintenance. He and his staff are responsible for the portfolio management process. The basic idea behind portfolio management is to breed mutual understanding, by providing an integral resource load and a company portfolio plan. However, when individual interests coincide and there is no prospective of a mutual agreement, the portfolio manager decides which plan is authorised.

The quality of this meeting highly depends on the accuracy of the information regarding the resource loads and the project and account plans. The manager of a project, account, or section is primarily responsible for the accuracy of the information for his work area. However in view of the dockyard's size and its dynamic surroundings, an automated supporting tool is indispensable. This system should be capable to integrate the different information surveys, be based on aggregate capacity, and assist in scheduling operations by providing different scenarios. Finite capacity scheduling and due dates accounting are essential in this decision support system methodology. The construction of this system is discussed in the information structure design.

This concludes the design of the production and control structure. In the next section we discuss the supporting information structure.

3.3.3.3 Information structure design

The last step in the design process concerns the dockyard's information structure. The information structure has to support the entities in the various process phases. These entities are the groups that take part in the control structure. To develop a proper information structure for these groups, we first discuss a general information architecture. Next, we customise this general architecture for the RNND. From there, we move to the features of supporting information systems needed at the macro level, meso level, and micro level, respectively. In view of their significance for the design model we pay special attention to the database prototype and the Decision Support System.

3.3.3.3.1 The general information system architecture

We developed in the previous sections a planning hierarchy for the micro, meso, and macro level. In designing the information structure we combine this planning hierarchy and the general information structure. For the development of the information structure we use the general architecture by Bertrand et al. (1990). Figure 3.14 presents this architecture which consists of four concentric circles, each representing a layer in the information structure.
The first element of Figure 3.14 is the inner circle that comprises the systems software: a platform that, dependent on the hardware, enables the functioning of user applications. The actual shape of this software depends on the real-life environment that it is supposed to support. Software in this circle may include 4th generation languages and Windows NT structures, to enable a proper performance of the application programs in the other circles. In view of the great number of applications available and the rapid developments in this software, an extensive survey of systems software is beyond the scope of this thesis [for such an extensive survey, see De Boer (1998)].

The circles around this inner circle represent the different user applications. The first layer comprises the application programs that support the state-independent data. These data are independent of the actual state of the maintenance process. For example different standard maintenance products, bills-of-materials, standard networks and routings, resource capacities, technologies, and standard throughput times are incorporated in this layer. State-independent data may refer to product data as well as to process data. It provides a basis to develop the state-dependent data, which are related to the actual state of the maintenance process.

In the third circle we find the application programs for the state-dependent data. These data outline the actual state of the maintenance process; it describes the actual states of orders, resources (human and technical), and materials. Examples of state-dependent data are the actual customer orders, work orders, material orders, job assignments, etc. The last circle contains the application programs that support human decision making in the maintenance process.

3.3.3.3.2 An information structure for the RNND

To obtain a clear picture of the information requirements at the various levels an information planning process was carried out [RNND (1997a)]. Figure 3.15 depicts an impression of the result of this process. It presents a survey of the various information flows for every production phase, the supporting mechanisms, and the customers. The production and control structure of the previous sections are easily recognized in this figure.

Based on this diagnosis of the information flows we developed a scenario for the dockyard's information structure in the near future. An important constraint on the development of this structure is the requirement that it should interact with the existing navy-wide information systems. This requirement also applies to the Business
Planning System (BPS). This BPS is also used by other navy maintenance organisations and the units of the Ministry of Defence in The Hague. Obviously, the BPS needs planning data as input.

We now consider the elements of this scenario in depth by discussing the state-independent data, the state-dependent data, and the structured decision systems, respectively. As the standards database and the decision support system are essential elements of this information structure that have been developed as prototypes in our research project, we discuss these two systems in more detail.

![Information model dockyard](image-url)

**Figure 3.15: Information model dockyard.**
A standards database (state-independent data)

A standards database is essential for the state-independent data. A material breakdown structure should provide for each standard object the basis for storage of the different standards. Figure 3.16 represents a basic structure for this database.

![Material breakdown diagram](image-url)

Figure 3.16: The Material breakdown Structure [Graenebelt (1995)].

Each object in use could belong to a class of objects. For example an M-class frigate belongs to a class of eight ships. Each object (i.e. a frigate) can be decomposed into a number of installations or sub-systems. Each installation in turn can further be decomposed into standard and non-standard components (see Figure 3.17). For the standard components a number of maintenance levels are defined, ranging from minor maintenance to an extensive overhaul. For each maintenance level a sequence of processing steps is given. An example of such a sequence is given in Table 3.9.

Given a particular maintenance order, process planning selects from the appropriate maintenance level a number of steps, as listed in Table 3.9. The database contains for each step the necessary data such as the norm times, norm capacities (including special skills needed), split (maximum, average, and minimum number of workers for the job), bill of materials, and list of documents (instruction files and/or drawings).
The data stored in the database can be characterised as product data (data concerned with standard products) and process data (for example the different manufacturing skills and the size and composition of task groups). These data have to be used at various planning levels to deliver customised products. The extent to which an LSMO company is able to obtain state-independent product data heavily depends on the kind of maintenance objects.

For example, since the RNND always maintains the same frigate classes, it must be able to create a specific product database. In this case the customisation process should not take too much effort. On the opposite, an LSMO facing a large variety of customer orders will have far more difficulties in creating this product database. Nevertheless, also these companies should invest in developing and maintaining such a database, for example by defining standard maintenance operations. Our experiences in field studies show...
that the availability of these data is essential for an efficient and effective quotation and process planning phase.

- **State-dependent data**
  The state-dependent data are related to the actual maintenance process. It starts with the registration of a request for quotation and of customer orders in the order acquisition phase. This information forms the basis for the registration of the state-dependent data. During the phases 'technical specification', 'resource planning and scheduling', 'execution', and 'evaluation and service' several state-dependent data elements are recorded (e.g. the customised product structure, the customised uncapacitated network of activities, the scheduled network of activities, and the monitoring and progress data). For example shop floor control systems and project planning systems are used for these purposes.

- **Decision Support Systems**
  The outer circle comprises a Decision Support System (DSS). At the macro level this tool is essential to perform aggregate capacity planning. After obtaining a rough view of capacity and material requirements of a new customer order, we want to check whether this assignment can be completed within a requested time window, taking into account capacity constraints. In particular, we want to be able to establish a sound quotation with a reliable due date and an acceptable price. Therefore it is crucial to have insight in the utilisation of resources by both new and accepted orders, while only rough estimates of both duration and resource requirements of the new orders are available. This is the function of a Rough Cut Capacity Planning module. Once process planning has been completed, the next step is to provide a more detailed schedule. In line with these requirements a DSS serves two purposes:

  1. It should quickly provide the portfolio team with good quality plans and schedules, which are subject to a set of strict operational constraints as well as so-called soft restrictions (i.e. preferences).
  2. It should facilitate the consultation process within the portfolio team by quickly visualising different scenarios and proposals.

The latter purpose indicates that a DSS will never be an autonomous automatic decision maker: the system is simply not capable to take all possible constraints into account, let alone to anticipate random disturbances. Hence, the portfolio team still takes the ultimate decisions, with the support of the DSS. At the University of Twente a prototype DSS has been developed, which is capable to perform both the Rough Cut Capacity Planning (RCCP) and the Resource Constrained Project Scheduling (RCPS) functions [see e.g. De Boer et al. (1996), De Boer et al. (1997a), De Boer et al. (1997b), and De Boer (1998)]. The above references provide an extensive survey on the mathematical theory behind this system. In this thesis we restrict ourselves to a general survey on the scheduling capabilities of the DSS.

The portfolio management co-ordinates the Dockyard's work package at both the RCCP and RCPS levels. In this context the term project includes both orders and frame work agreements (i.e. the highest level of the work breakdown structure, see Section 3.3.3.2.2). As explained in Section 3.3.3.2.3, at the macro level the portfolio management team is involved in the order acceptance, priority setting, capacity management, material and capacity scheduling, crisis management, and finally performance evaluation. The DSS should support the portfolio management team in all of these tasks at both the RCCP and the RCPS level. De Boer (1998) addresses this problem by describing heuristic methods for solving the multi-project RCCP problem. He uses aggregate data to accomplish this task. A number of resource groups are defined (the composition of the task groups is not taken into account at the macro level). These resource groups represent either personnel with a specific skill or unique equipment. The possibility of multi-skilled personnel is incorporated in these data. This leads to the following DSS capabilities [De Boer (1998), p.120]:
• An easy access to the input data. The portfolio management team must be able to retrieve, view, and adapt necessary data in a convenient way.

• A transparent communication between the members of the portfolio team (creation of mutual understanding). Proposed changes and their results should be presented in transparent views.

• A quick generation of high quality schedules within proposed constraints to support the portfolio management team. The generating mechanism allows choosing between a number of algorithms or parameter schemes with different calculation periods and accessory schedule quality levels.

• Support in the diagnosis of a proposed schedule. This enables the team to evaluate the quality of a schedule and identify (possible) bottlenecks.

To provide these capabilities the DSS consists of the following functions and components (see Figure 3.18):

![Diagram of DSS architecture]

Figure 3.18: Functional architecture of the DSS [De Boer (1998), p.127];

• **a corporate database**
A database for all data that serve as initial planning input for the DSS. These data consist of the one hand of project, order, and framework agreements, and on the other hand of resource data. The first group comprises information on work packages and activities like the content description, release and due dates, capacity and materials requirements, related documentation, (minimum) duration left, precedence relations, percentage complete, and minimum time lags. The resource data comprise the expected amount of capacity available in the near future.

• **a local database**
This is a database for the storage of various scenarios. The DSS allows for ‘what-if-analysis’ by generating various scenarios. To evaluate and weigh the effects of various decisions against each other these scenarios must be stored in this database.
• **a model base**
A database for the storage of various predetermined parameters schemes for the adaptive search algorithms (i.e. the algorithms that the DSS uses to generate a schedule).

• **a graphical user interface (GUI)**
The graphical user interface (GUI) supports the set of actions a user needs to instruct the system, as well as the information presented to the user. For this purpose the DSS incorporates three windows: the network view, the RCCP view, and finally the RCPS view.

• **data manipulation**
The data manipulation function incorporates the entry and adaptation of input. This includes interactive network construction (see Figure 3.19) (i.e. adding and deleting resources, milestones, work packages, activities, and precedence relations, and the copying of complete networks).

• **plan and schedule generation**
The DSS incorporates three groups of algorithms: one for the resource-driven RCCP, one for the time-driven RCCP, and one to generate high quality resource-constrained schedules.

### NOT AVAILABLE IN THIS VERSION

*Figure 3.19: Network view [De Boer (1998), p.131].*

### NOT AVAILABLE IN THIS VERSION

*Figure 3.20: Rough cut capacity planning view [De Boer (1998), p.133].*

The resource driven RCCP approach supports the user in determining the earliest completion date of a project, order, or framework agreement, within prescribed capacity levels. This approach is used for instance when a customer demands a due date quotation for a new assignment. The time driven RCCP approach is used when the user has to meet prescribed due dates. The system calculates how to meet these dates with minimum resource requirements. Finally, within the capacity limits set at the RCCP level, the RCPS algorithms yield detailed work schedules. Figure 3.20 depicts a RCCP view, generated with one of these algorithms.

• **schedule and edit toolbox**
The schedule and edit toolbox provides functions to adjust a schedule. A reliable way to adjust schedules is by indirect editing, i.e. by adapting schedule input or constraints. In this way the risk of obtaining infeasible schedules by directly altering start times, completion times or the execution mode of an activity (the number of workers are assigned to an activity), is avoided.

• **analysis and evaluation tools**
After a schedule is generated, the DSS should provide insight in the quality of the schedule. The analysis and evaluation tools comprise a set of performance indicators such as time-based indicators (e.g. maximum lateness, average lateness, number of late activities, total makespan, and mean flow
A design model for the RNND

time), resource-based indicators (e.g. average capacity available, minimum, maximum, and average utilization, and percentage of non-regular capacity), and cost-based indicators (e.g. total cost of hiring, outsourcing and, working overtime).

This survey of the information structure concludes the organisational design. Before we discuss the achieved results and future developments, we underline the importance of a hierarchy of performance indicators in the next section.

3.3.3.4 A hierarchy of performance indicators

A consistent hierarchy of performance indicators is indispensable to measure process performance. These indicators justify a solid conclusion on whether the organisation is achieving its goals as formulated in the mission statement. Figure 3.21 depicts a general scheme of such a hierarchy. The bottom-line performance indicators are cost, quality, and time.

These are the variables that represent the organisation's performance. In addition, we define as intermediate variables any other organisational and contextual variable that influences the bottom-line variables. These variables are here expressed as added value and service, see Figure 3.21.

![Figure 3.21: Performance indicator variables (De Waal et al. (1995)).](image)

The actual composition of a performance indicator hierarchy depends on the actual characteristics of a particular company, including the possibility of information processing systems to generate adequate data. The dockyard management formulated the following seven indicators based on the dockyard's mission statement of Section 3.3.2 [RNND (1997c)]:

1. **response time to customer orders**
   The time needed to respond to a customer order. A customer-oriented structure should reduce the response time to customer orders. This leads to the desired level of organisational promptness.

2. **due date reliability (on macro, meso, and micro level)**
   The due date reliability denotes the degree to which the dockyard delivers a finished product within the desired delivery time. To measure the due date performance the dockyard formulated indicators for each organisational level. The results of these measurements indicate the desired due date reliability improvement.

3. **quality of the technical specification phase**
This indicator is defined as the ratio between the calculated man-hours in the technical specification phase and the actual amount of man-hours spent. The result of this measurement represents the quality of the work preparation phase.

4. **amount of control tasks, related to the direct production hours**
   This indicator comprises the ratio between the direct production man-hours (i.e. man-hours related to the actual preparation and execution tasks) and the indirect man-hours (i.e. man-hours related to the various control tasks). This indicator relates to the desired reduction of control tasks.

5. **resource idle time**
   The resource idle time is defined as the total number of ineffective production hours (i.e. scheduled man-hours that were lost due to for example unavailable spare parts and control problems between resources). The new organisational structure should lead to a reduction of resource idle time.

6. **Multi-disciplinarity level**
   The multi-disciplinarity level of employees is defined as the level to which employees incorporate two or more skills. An increase of the multi-disciplinarity level should lead to an increase of desired capacity flexibility at micro level.

7. **Level of absence due to illness**
   This indicator is defined as the total amount of man-hours wasted due to employee illness. As the team concept aims for an improvement of workers satisfaction, ultimately a reduction of absence due to illness is expected.

These indicators constitute the dockyard’s planning hierarchy. The dockyard used these indicators as much as possible in the execution of the pilot projects. However, as outlined in the next section, inadequate support of automated systems and the scale of the pilots limited the use of these indicators. A full implementation of the new organisational structure and the introduction of the appropriate planning systems will enable the use of these indicators.

3.4 Achieved results and future developments

Before starting a full implementation of the process-oriented organisation model the management decided to test the concept on a small scale. Pilots were run with respect to: the multi-disciplinary teams, a project management approach with the use of zone-technology for a major overhaul of a mine hunter, the portfolio management methodology, and finally the testing of automated systems. We will briefly discuss the results of each pilot.

- **Multi-disciplinary teams**
  The results of the multi-disciplinary teams are promising. Four teams were put together, each with their own workload. People tend to respond positively to the increase of responsibilities and competencies. A lot of effort has to be spent on training and education. The first results show that employees have to learn to work in a team, where it is essential to make arrangements with direct colleagues. Special attention has to be paid to the co-ordinating management layers. They have to change their directive approach into a coaching role. Practice shows that this is a rather difficult transformation process. Another important conclusion is the need to solve existing problems, which could easily spread and kept hidden in a functional organisation. For example the formation of a team with both wood and polyester processing skills showed the need for carpenters to become multi-skilled. This need is caused by the fact that the Netherlands Navy has put its last wooden mine sweepers out of service. Hence, there is not a full workload for a person who is only trained as a carpenter. In the former functional organisation it was possible to postpone the required additional training on the basis of figurative arguments. Employees for example claimed that all carpenters should work on the
basis of their status within the functional structure, thereby avoiding additional training in polyester processing. In a multi-skilled team with a clearly defined work package, such an attitude is no longer possible, given the total work contents and the team responsibility.

Concrete results were measured with respect to customer satisfaction and due date reliability. Both performance indicators show a continuous improvement since the start of the multidisciplinary teams. For some groups the due date performance increased with 10% to approximately 95% on work order level.

- **Project management with zone technology**
  A major overhaul period of a mine hunter is prepared with a project management approach. The five planning phases will be executed under the integral responsibility of a project team. For the execution phase, zone technology is used. In this concept zones are defined to be geographically, system, or geographically and system oriented. All tasks within a zone are assigned to a group of workers. In this way work packages are created which will be executed under the responsibility of a team. The integral approach of the process planning phase and execution phase showed undeniable advantages: a faster translation into work definitions, a better insight in the total work package and its consequences for the capacity needed, and finally qualitative better work definitions. In addition, problems in the work execution phase were solved much faster. Also in these pilots we have measured an increase in due date reliability and customer satisfaction.

- **Portfolio management**
  The first cautious steps are taken to perform higher level order acceptance and planning. The aggregate information needed is derived from existing automated systems. The problem is that these systems only contain very detailed planning information, which cannot be integrated into an aggregate capacity plan in the way we defined it in the previous sections. Yet this pilot is useful while it trains middle management in 'the art of letting go'; this means that they have to realise that their objective should be to act with the use of higher level information. In this way the constraints for the lower working levels are set. The first experiences already show that this turnaround of middle management is going to be a hard process. Middle managers at the Dockyard tend to derive their status from their involvement in the detailed planning and execution processes. A lot of training and coaching must result in the necessary cultural change.

- **Test results of automated systems**
  A prototype of the database is developed at the Dockyard. Five standard maintenance levels, ranging from minor maintenance (inspection tasks) to an extensive overhaul, are incorporated in this prototype. The equipment of a ship is categorised by a navy coding system called Basic Standard Material Classification System. By addressing ship class, equipment code and desired maintenance level, a user can easily retrieve work standards and a list of materials needed. In this way a significant shortening of order acceptance and process planning procedures is expected. First experiences are available with a Mine-hunter class of ships.

  The prototype of the DSS is now tested at the dockyard. Planners who work with the system report to be impressed by the user-friendly design and the technical capabilities. A full evaluation is possible when a significant part of the dockyards work package is brought into the system.

The results of these pilots resulted in a managerial decision to fully implement the new organisational structure. This decision was based on the actual improvement of the controllability (the aim of the redesign process) in the various pilots. For example, multi-disciplinary teams show an improved performance regarding due date reliability, reaction times, flexibility, and problem-solving capabilities. By the end of the year 2000, the basis of the new organisational structure is to be implemented.
Chapter 4

4. The elements of the LSMO design model

4.1 Introduction

The elements of the LSMO design model, outlined in this chapter, are extracted from the results of the RNND-case (see Figure 4.1). Both the design process and the essential design model elements are discussed. The design process concerns the approach of the re-engineering process. The design model elements comprise the essential characteristics of an LSMO within the research domain. In this chapter, we first consider the design process consisting of the four steps of the IOC-model. Subsequently, we deal with the mission statement (i.e. what should a non-flow LSMO aim for?) and an outline of the essential design model elements: the production, the control, and the information structure. These elements are used to test the design model in the next chapter.

Figure 4.1: Reflective cycle for LSMO problem solving.
4.2 A design process for LSMO re-engineering

To develop an organisational design for a specific LSMO we follow the steps of the IOC-model (see Figure 4.2). In this way we can reasonably ensure that all the specific company and environmental characteristics are taken into account. For one LSMO, for instance, it may be beneficial to reduce the internal complexity by grouping similar products and services, while another LSMO seems to benefit more from an external complexity reduction by grouping according to customer segments. For the sake of completeness we briefly repeat a comprehensive definition of each of the four steps of the IOC-model.

1. **Investigation / Diagnosis**
   The first step comprises a diagnosis of the characteristics of the environment and the LSMO. First we analyse the environment by determining the market and customer demands. Next, we consider the characteristics of the LSMO. An essential LSMO characteristic, particularly for non-flow LSMO’s, is the uncertainty in the composition of the work package, the work preparation phase, and finally the work execution phase. In addition, the market imposes tight demands on the product delivery and quality. These characteristics are essential in the application of this design model.

2. **Goal setting**
   The strategy and vision are subject of the second step. Here, we formulate what the LSMO wants to be. In addition, also the concrete goals and the way to achieve the goals are part of the strategy and vision formulation. The contents of these statements should comply with the environmental conditions and market demands referred to in step 1, and constitute the basis for the design of the organisational structure in step 3.

![IOC-model](attachment:image.png)

*Figure 4.2: The IOC-model [van Euijik-Hovenaar (1995), p. 26].*

3. **Design**
   The third step comprises the actual design of a new management and operational structure. Essential in this design approach is the wish to reduce complexity by grouping related activities and delegating the execution and control of these activities as much as possible to one group. The emerging process oriented structure has to be as simple as possible with a maximum problem solving capability. To achieve this goal we first define the company’s overall primary activities. Next, we unravel this overall stream top-down into parallel flows and segments. In this way we either find product groups, module groups, or phase groups. Second, we have to define the managing activities by establishing a clear planning...
hierarchy. Each control task is placed at the lowest possible level. For the highest macro operational control level we establish a portfolio management structure. This structure unambiguously matches resource demand and resource availability. In designing the production and control structure we continually take into account the possibilities of innovative information systems. These new systems should enable the desired complexity reduction and support and increase the company's problem solving capabilities. The last step in the design phase is the actual design of the supporting information architecture.

4. Implementation

The final step of the IOC-model contains the implementation of the organisational structure. The application of the first three steps in a specific case provides us with a customised organisational structure. In the next section, we consider a general outline of this LSMO organisational structure.

4.3 Outline of the LSMO design model

In the outline of the design model, we first discuss a general formulation of the strategy and vision of an LSMO. Next, we consider the essential elements of the LSMO design model.

4.3.1 The general strategy and vision

Based on an evaluation of general market developments (see Chapter 2), we conclude that also for LSMO's customers become more and more interested in a high flexibility level, short lead times, high quality products, and reliable due dates. In addition, we found that concepts like 'life cycle costs' and 'integrated logistic support' open new possibilities for LSMO's (compare the EUT-maintenance model, Geraedts [1991]). In agreement with these concepts, LSMO's may aim for business approaches in which they are integrally responsible for the design, manufacturing, use, and finally the disposal of a system.

The following general LSMO mission statement is based on the changing environmental conditions and the new opportunities:

An LSMO should aim for an outstanding performance regarding flexibility, short lead times and time-to-market intervals, low costs, high quality, and delivery reliability. In addition, it may distinguish itself by not merely generating technical services but also logistic services, leading to an integral customer support.

Subsequently, from this general mission statement a set of ambitions may be derived. The ambitions describe the organisation's concrete goals. The following paragraph contains the general ambitions.

- All products and services should be delivered against low costs, with high quality, and within agreed time windows;
- The lead time should be as short as possible;
- The reaction time to customer demands should be minimal, resulting in a short time-to-market interval;
- The response to unexpected customer demands, not foreseen maintenance tasks, changes in system design, and any other possible disruption that affects the manufacturing process, should be prompt and flexible;
- The company's product is based on an integral concept, in which the life cycle support for an object is incorporated.

The last element of the organisational strategy is the business logic. The business logic comprises the way to achieve the defined ambitions. Based on the general ambitions we obtain the following short-list of necessary actions.

- Establish a clear planning hierarchy, which is customised to each organisational level. This hierarchy should provide each group with its own margins for process control. The result should maximise the
problem-solving capabilities, by allowing decision making at the problem source if possible [i.e. 'putting production decisions where they belong', cf. Meal (1984)], which ultimately leads to short lead times and a reliable due date performance.

- A flexible response should be maximised through a process-oriented organisational structure. By organising the manufacturing activities around the processes, illogical barriers are removed and a quick response to changing needs or disturbances is enabled.

- Create an integral model from order acceptance until evaluation. In view of the fact that almost every order is relatively unique, the technical specification phase plays an important role in the manufacturing process. Therefore, it is highly recommended to plan and schedule also the execution of the preparation phase and to avoid barriers between preparation and the actual work execution. The resulting integral structure that incorporates both non-physical and physical transformation processes is capable to support integral maintenance concepts.

- Aim for a stimulating and motivating work environment and create for each employee the possibility to fully exploit his or her potentials. This is the only way to mobilise the creative and problem-solving capabilities of human resources, which are indispensable in an LSMO.

The general strategy and vision (i.e. the mission statement, the ambitions, and the business logic) form the basis for technological rules with respect to the operational and management structure.

### 4.3.2 The technological rules

The design approach is based on a top-down design of the production structure, a bottom up design of the control structure, and finally the design of the information structure.

Following the line of reasoning in the preceding chapter, we define a number of elements (i.e. technological rules) that form the basis for the design model. Figure 4.3 depicts a general outline of the corresponding management and operational structure.

The following seven elements constitute the basis for an LSMO design model, aiming at an improvement of the organisation's performance and controllability.

1. The establishment of a process-oriented organisation
2. The integration of non-physical and physical activities;
3. A three level organisational structure;
4. A clear coherent planning hierarchy with a distinction between aggregate and detailed capacity;
5. The use of the portfolio management methodology;
6. The use of multi-disciplinary teams at the micro level;
7. The use of information technology as an enabler.

In the remainder of this section we discuss each element in detail.
The establishment of a process-oriented organisation

Functional structures strive for maximising output for a limited range of usually high volume products, by dividing the manufacturing department in highly efficient functional units and by a strict separation between planning activities and physical work execution (separation of 'planning' and 'doing'). This structure is highly efficient as long as the environment of the organisation remains stable. However, we have characterised the market of LSMO's as highly unstable with erratic demands. Therefore, the most important drawbacks for a functionally oriented LSMO structure are:

1. If the maintenance process is split up in several departments and functions, which are all managed through co-ordinating management layers, the organisation is not able to respond quickly to new or changing demands. The co-ordinating management layers would have to address all departments and functions through vertical communication to cope with these demands.

2. The separation between 'thinking', 'planning', and 'doing', and between the non-physical and physical transformation processes, and an execution function that is based on simple and repetitive jobs, leads to low work contents and, in general, to low job satisfaction. This has a negative impact on the quality of the manufactured product. Especially in maintenance, a creative and highly motivated work force is essential for an effective and efficient response to market demands.

These drawbacks make a process-oriented structure (i.e. a structure in which all activities in the primary process are organised around the product flow) in an LSMO a necessity.

The integration of non-physical and physical activities

An essential part of the LSMO process regards the non-physical activities, such as engineering and technical specification. As we have noticed, the uncertainty level within LSMO's is high: the greater part of the maintenance process is customer driven. The non-physical activities (like rough-cut capacity planning, specification of customer requirements, process planning, and engineering activities) generate the essential information needed for the physical transformation process. Thus, not only the barriers inside the manufacturing process but also a strong separation between non-physical and physical activities may seriously hamper a transparent work structure. Therefore, we aim for an integral process-oriented approach for the subsequent process phases (i.e. from order acquisition until evaluation). Although we already made a
plea for a process-oriented approach, we included the integration of non-physical and physical transformation processes in a separate rule because of its extreme importance in improving an LSMO's controllability.

- **A three level organisational structure**
  A control task should preferably be placed at the lowest possible organisational level, i.e. where the work to be controlled occurs. Higher organisational levels are only created when an employee is unable review the consequences of a control decision. In this way we create a three level structure that comprises a micro, meso, and macro level, and avoid the absorption of control tasks into unnecessary additional organisational levels. The latter phenomenon has a negative influence on the organisation's flexibility and promptness, due to the inevitably occurring time delays in decision-making. Worst case scenarios include for example too late decision-making, avoidance of responsibilities, and incompetent decisions.

- **A clear coherent planning hierarchy with a distinction between aggregate and detailed capacity**
  To establish a flexible and prompt organisation with a high problem-solving potential a clearly defined planning hierarchy is essential. This hierarchy provides each organisational level with clear margins to deal with unexpected events. We define the following planning hierarchy:
  - **strategic resource planning (macro level);**
    This level comprises the determination of the nature and amount of resources that are needed to fulfil an LSMO's ambition.
  - **rough cut capacity planning (meso and macro level);**
    Rough cut capacity planning is concerned with a rough estimation of required resources to execute a customer order within specified time, cost, and quality constraints.
  - **resource constrained scheduling (meso level);**
    This meso level control task comprises the top-down assignment of resources to a specific customer order and the timing of tasks, based on high level process planning.
  - **detailed scheduling (micro level).**
    The assignment of the actual resources (manpower, machines, and facilities) to perform all operations needed to manufacture the desired product is the essential control issue at micro level.

We use slack to realise the margins at the various levels. Slack is defined as a quantitative measure that indicates how much a task can be delayed, without delaying the completion of the whole order. As long as the completion time of a task remains within the defined slack margins, the responsible employee or group is entitled to independently decide what kind of actions are to be taken. In this way the various levels of the organisation (micro, meso, and macro) have the potential to act flexibly. To create a robust planning hierarchy it is essential to establish a proper fit between the margins (i.e. slack) of the different levels. A sufficient robustness should prevent that every little change is shown at all organisational levels. As a general guideline we use mainly mix flexibility as the primary steering instrument at the lower organisational levels; for the higher levels volume flexibility is a more appropriate steering instrument. Mix flexibility reflects the possibility to re-allocate operations from one specific resource to another one, without changing the total number of working hours. For instance, the introduction of multi-skilled workers creates mix flexibility. Depending on the actual demand and on disturbances of the manufacturing process, workers can be employed for different tasks. Volume flexibility denotes the possibility to vary the total amount of produced products or working hours. This can be achieved through subcontracting or by contracting workers on a temporary basis.

In this planning hierarchy we define two different capacity views: aggregate capacity for the top-down approach and detailed capacity for the bottom-up approach. Aggregate capacity is defined as the total number
of working hours available for the different skills. Here, we do not differentiate to the different groups we have created at the meso or micro level, we purely focus on the reservoirs of skills within the company. Detailed capacity is based on a summation of all the different tasks of individual members of the working force. A common problem in a multi-order environment is the mix-up of aggregate and detailed capacity. This leads to a troubled view of the available capacity while it is not clear anymore which part of the resource load is aggregate and which part is detailed. The solution is to keep the two views separated. At the portfolio level the assignments are made on the basis of a reservoir of skills. The assignment of work to teams is done within the resource departments (as much as possible, complete jobs are assigned to one team). The detailed capacity view is only used within a department to verify whether the different jobs still fit within the time window that is generated by the aggregate overview. It is the responsibility of the manager of a department to match aggregate and detailed capacity

- **The use of the portfolio management methodology**
  The portfolio management methodology (see Figure 4.4) is used to obtain an unambiguous priority setting between projects, work packages, and capacity groups at macro level [see Platje et al. (1993)]. At this level feasible portfolios are constructed, trade-offs between (often conflicting) interests of the participants are made, and finally an integral communication between department heads, project leaders, and managers of work packages is supported. Through the involvement of all parties in an integral view on feasible portfolio’s and through the participation in comparing the pro’s and cons of the different portfolio’s, the urge to favour the interest of one’s own project, work package, or unit, decreases. By making trade-offs and priority setting explicit, the company’s overall interest becomes clear for all participants. The use of a supporting DSS is essential in portfolio management. This tool should visualise and quickly calculate the different scenarios.

![Diagram showing the hierarchy from general management to portfolio management, then to projects and work packages, and finally to production units.](image)

*Figure 4.4: Macro level priority setting [based on Platje et al. (1993)].*

- **The use of multi-disciplinary teams at the micro level**
  To cope with the high uncertainty level and the need for flexibility and promptness, we have selected the multi-disciplinary team concept at the LSMO micro level. The work contents and the maturity level of the employees both influence the responsibilities and competencies of such a group. Apart from the kind of team we have created in a particular situation, it is essential that every group has its own responsibilities regarding certain tasks, and the ability to execute, measure, evaluate, and react with respect to these tasks. The product, module, phase, or component groups may comprise several production groups. The multidisciplinary group performs the necessary internal and external adjustments and agreements with other multidisciplinary groups. Only tasks that cannot be managed at a multi-disciplinary group level are handled by a group co-ordinator. This person is charged with the vertical consultation of several multi-disciplinary groups within a meso level group. The integral view on resource surplus and shortage, for instance, is the responsibility of a group co-ordinator. The different multidisciplinary groups supply him with the necessary
information to establish such a view. This enables the group co-ordinator to address the right multi-disciplinary group for the acceptance of new orders. Based on the contents of the order the group co-ordinator and the multi-disciplinary group representative make agreements on due date, quality, and costs. We do not wish to give the group co-ordinator a directive approach towards the multi-disciplinary groups. The consultation between the group co-ordinator and group representatives should be on an equal basis, whereas the multi-disciplinary group accepts work based on its scheduled workload. As these agreements have been set, and the multi-disciplinary group is supplied with the necessary documentation and materials, the group is primarily responsible for executing the order and possible adjustments with other groups. As long as these adjustments remain within boundaries set in the negotiating process with the group co-ordinator, there is no need for vertical consultation. As soon as disturbances cannot be solved within these boundaries, consultation of the group co-ordinator is necessary. Hence, the group level represents the lowest level of the planning hierarchy. This management structure is visualised in Figure 4.5. In Figure 4.5 a ‘supporting multi-disciplinary group’ is depicted with a dashed line around it. This means that, depending on the selection of control cycles, it may be necessary to establish a multi-disciplinary group with supporting services. Process planning, for instance, might be a task of such a group. The goal is to integrate planning, supporting, and executing tasks within the multi-disciplinary group as much as possible. However, due to high workloads, the need for specialised skills, and the maturity level of multi-disciplinary groups, it may be necessary to establish supporting multi-disciplinary groups on a more or less permanent basis. In a real case, careful thought whether such a group should be established is necessary.

![Figure 4.5: Management structure at micro and meso level.](image)

- **The use of information technology as an enabler**
  Although the information structure is the last step of the organisational design (i.e. the production, control, and information structure design model), we should already take the possibilities of modern technology into account in the first steps. It is even advisable to already use the enabling function of information technology in the formulation of strategy and vision. The goals and business logic of an LSMO may be enlarged with the use of information technology. The exclusion of modern information technology until the entire design of production and control structure is finished is in this view a short-sighted option.
Figure 4.6: A general architecture for information structure (Bertrand et al. (1990)).

Figure 4.6 shows a general structure for an LSMO’s information architecture. Essential are the state-independent data that should comprise a standards database. The information of such a database plays an important role in the order acquisition and process-planning phase. It enables an LSMO to shorten its time-to-market intervals and to react quickly whenever unexpected changes occur. Besides the need for adequate shop planning systems, at the highest level there seems to be an urgent need for an adequate macro/meso level scheduling tool. These decision support systems should enable decision-making in a multi-order environment based on different high quality scenarios. These scenarios should be calculated against finite capacity constraints, take due dates into account, use intelligent, state of the art, scheduling methods, and require only short computation times (i.e. a few minutes as a maximum). The prototype built at the RNNED has shown the feasibility of such a system. The tests have shown an LSMO may benefit significantly from such a system (De Boer (1998)).

4.4 Summary

In this chapter we briefly reconsidered the design process for LSMO re-engineering and presented a design model that consists of a number of essential elements in an LSMO’s operational and management structure. The design process is based on an eclectic selection of management theories in Chapter 2, while the design model is based on the results of the RNNED case in the previous chapter.

The design process starts with an investigation of the environment and a diagnosis of the LSMO. The next step comprises the formulation of the strategy and vision. The actual design of the new structure is based on these statements. It starts with a top-down design of the production structure, it continues with the control structure design, and the last design phase considers the information structure. The final step of the process design contains the implementation of the new organisational structure.
The design model is based on the following elements:

1. The establishment of a process-oriented organisation
2. The integration of non-physical and physical activities;
3. A three level organisational structure;
4. A clear coherent planning hierarchy with a distinction between aggregate and detailed capacity;
5. The use of a portfolio management methodology;
6. The use of multi-disciplinary teams at the micro level;
7. The use of information technology as an enabler.

These rules are derived from the essence of the new operational and management structure developed in the RNND case. In the next chapter we test these rules by studying three LSMO's and one ETO company. We test the presence or absence of the rules of the design model and subsequently discuss whether parts of the model might work in the particular case.
Chapter 5

5. The Follow-up Case Studies

5.1 Introduction

This chapter contains four short case studies. Three studies concern LSMO companies and one is related to an ETO company. The purpose of these follow-up cases is to test whether the essential features of the organisational model of Chapter 4 are present or might be useful in the particular company (see Figure 5.1). The results of the investigations presented in this chapter may indicate whether the design model is useful in a broader context. We discuss in succession the rail freight wagons maintenance section of the Netherlands Railways, the mechanical workshop of the Royal Netherlands Army, the Norfolk Naval Shipyard (NNS), and finally the ETO company Smit, a manufacturer of transformers. In each case we first describe the general characteristics of the company. From there we move to the company's market and its mission statement. Next we discuss the production structure, control structure, and information structure, respectively.

Figure 5.1: Reflective cycle for LSMO problem solving.
We conclude each case by comparing the essential elements of the design model with the existing management and operational structure. This includes the following topics: the process-oriented organisation, the integration of non-physical and physical activities, a three level planning structure, a coherent planning hierarchy, the use of portfolio management, the use of multi-disciplinary teams, and finally the use of information technology as an enabler. For each element we consider whether it is present in the specific case. If it is not present we indicate the expected benefits of the use of this element. At the end of this chapter we perform a cross-case analysis and discuss the general applicability of the design model.

5.2 The ‘Wagenbedrijf Amersfoort’ (WBA)

5.2.1 Introduction
The first case study concerns the ‘Wagenbedrijf Amersfoort’ (WBA), which maintains rail freight wagons. This company is a part of the Netherlands Railways Maintenance Department. As the Netherlands government decided to privatise the NS (i.e. the Netherlands Railways) in the beginning of the nineties, WBA was confronted with changing requirements. To understand the impact of these changing circumstances, we first consider the structure of NS as a whole, with special emphasis on the maintenance section (NS Materieel BV). Next we turn to the rail freight wagon maintenance section (WBA). We discuss the market developments and the mission statement of WBA, as well as its organisational structure. Finally we compare the characteristics of our design model with the structure of the WBA organisation.

5.2.2 Structure of the Netherlands Railways (NS)
The decision to privatise NS led to a major reorganisation that started in 1994. This resulted in a commercial and a non-commercial group. NS Passengers (exploiting the passenger train services), NS Cargo (exploiting the freight train services), NS Railway Stations, and NS Real Estate form the core of the commercial group. NS Materieel BV (i.e. maintenance of the railway rolling stock), NS Security Services, and NS Facility Services support these so-called business units. These supporting units also carry out work for clients outside NS. In addition to these activities, NS (jointly) owns a number of companies that are not directly related to the transport market, such as Telfort (a telecommunication company), the Strukton Group (a builder of railway infrastructure), and Holland Railconsult (management of large building projects).
The non-commercial group comprises units which, on behalf of the Netherlands Government, are charged with the use and management of the railway infrastructure in the Netherlands. These units are Railned, NS Rail Infrastructure, and NS Traffic Control. Figure 5.2 shows the organisational structure of NS. In the sequel, we focus on the business unit 'NS Materieel BV'.

In 1993 the units 'NS Passengers' and 'NS Cargo' became the owners of the rolling stock (i.e. the passenger trains and the rail freight wagons, respectively). This changed the position of the maintenance section (NS Materieel BV) dramatically. Until that time, NS Materieel decided when a train had to come in for maintenance; however, from now on the customer (i.e. NS Passengers and NS Cargo) determined when and what kind of maintenance a train should receive. So NS Materieel became an independent business unit, faced with the need to acquire customers instead of obtaining a certain budget. In view of this fundamentally different market position, a change program has been initiated which is still in progress at this moment. The organisational structure, shown in Figure 5.3, is therefore an instantaneous view of a transitional structure.
The NS Materieel Division has formulated a mission statement in which it aims to be a leading provider of maintenance and service for railway rolling stock. Besides it does not wish to limit itself to the role of a pure maintenance provider, but, instead, to act as a total service provider to the customer. In this concept NS Materieel delivers a clean train, which is ready for use, whenever the customer needs one. For this purpose the maintenance section is split up in a 'maintenance and service' section and an 'overhaul' section.

The 'maintenance and service' section provides technical, cleaning, and logistical services. Six maintenance departments perform the relatively small preventive and corrective maintenance tasks. These maintenance departments are located throughout the Netherlands. Besides these six maintenance departments, three service departments provide cleaning, shunting, and fault clearing facilities. Each service department provides this service throughout its entire region.

The overhaul department consists of four major departments. The departments in Haarlem and Tilburg provide extensive overhauls of the passenger trains and the locomotives, respectively. A passenger train may obtain a full refit in which for example a complete new interior is installed. Besides the NS Passenger trains, these departments maintain trains and metros of local transport companies. The EMATECH department revises the electrical motors, generators, transformers, and all other electrical equipment of a train’s electrical installations. For strategic reasons this department was incorporated in the NS Materieel Division.

The fourth department is the object of our case study: the 'Wagenbedrijf Amersfoort' (WBA). It maintains and services the rail freight wagons of different Rail Freight Companies, like NS Cargo (see Photo 5.1). After World War II WBA comprised 750 employees. Currently, the workforce counts no more than 160 employees. These figures illustrate that during the last fifty years WBA had to downsize several times. Due to this more or less continuous struggle to survive, the employees of WBA quickly realised that a privatised department could only continue to exist, if it would become self-supporting by gaining a significant part of the market. Besides the site in Amersfoort, WBA owns an annex in Duisburg (Germany). Approximately 160 employees work at the

Figure 5.3: Organisational structure of NS Materieel BV (January 1998).
Amersfoort site, while the Duisburg site employs approximately 50 people. The turnover of WBA in 1997 was 29.7 million Netherlands Guilders (NLG), while the goal for 1998 is a turnover of 31 million NLG.

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Photo 5.1: Rail freight wagon maintenance at WBA

A third subdivision of NS Materieel contains an engineering department and an industrial projects department. NS Engineering provides European railway companies with technical expertise on rolling stock and technical systems. It has designed almost the entire rolling stock of NS. In addition, NS Engineering also contributes to important international projects, such as the development of the high speed train ‘Thalys’. The industrial projects division specialises in knowledge regarding the equipment and infrastructure of the NS Materieel maintenance and overhaul departments. They advise and assist in the redesign of shops whenever for example new rolling stock is to be maintained.

Currently, approximately 3500 employees work within the NS Materieel Division. After completing the redesign process this number will be reduced to 2500 employees. The total turnover of NS Materieel is 500 million Netherlands Guilders (NLG). In the future, a decline in market share is expected for NS Passenger, due to the Netherlands government policy to allow private companies to take part in passenger transport. As a result, this may lead to a severe reduction in required maintenance capacity at NS Materieel. For every maintenance and overhaul department such a decrease in demand requires an active search for new customers (for example new regional railway companies). The main objective for NS Materieel is the daily maintenance and service of railway rolling stock. After all, extensive overhauls can in principle be performed in France or Germany. However, for the daily maintenance and service a local provider is necessary.

This general survey of the NS Materieel division illustrates the change from a stable to a dynamic market and the inevitable redesign process of the maintenance organisation. In the next sections we concentrate on the ‘Wagenbedrijf Amersfoort’ (WBA) department. First we discuss the market developments for WBA and the originating mission statement. Next, we review the production, the control, and the information structure. Finally we compare the WBA organisational structure with the essential features of the design model.

5.2.3 Market Developments and Mission Statement of WBA

With the privatisation of the Netherlands Railways, NS Cargo and RailPro became the owners of the freight rolling stock. NS Cargo owns the rail freight wagons for the transport of all kinds of cargo (e.g. container wagons, oil wagons, and general cargo wagons). The RailPro company manages all the rail freight wagons for the construction and maintenance of the railway infrastructure (e.g. sand and gravel wagons). Before 1993 WBA was the ‘owner’ of all freight wagons of the Netherlands railways. In particular WBA determined when a freight wagon should receive maintenance. The change of ownership implied that from 1993 onwards, WBA turned into a customer driven organisation, instead of following its own freight wagon maintenance plan.

This new situation also opened new perspectives: it allowed WBA to acquire other customers than just NS Cargo and RailPro. In view of the workload due to NS Cargo and RailPro, and a capacity of 160 employees, the acquisition of new customers was even a necessity. Already in 1997 49% of the entire turnover (including the Duisburg section) was realised through ‘third party’ customers. The urge for new customers and the desire to obtain an independent position in the maintenance market of freight wagons, led to the following mission statement:

WBA wants to deliver products and services for the maintenance of freight wagons, against the ruling market prices with high service levels and the quality that the customer desires.
The important clauses in this statement are 'the ruling market prices' and 'the quality that the customer desires'. The first clause indicates that WBA wants to work against competitive prices for all customers (including NS Cargo and RailPro) and not against the standard prices it used to charge before 1993. The second clause states that WBA performs the maintenance and service the customer desires. Before 1993 WBA used to bring back a freight wagon to 'new building conditions'. However, from 1993 on, a customer organisation only pays for the maintenance and service level it desires. For instance, customers who use freight wagons in large and complicated infrastructural projects or military transports, demand a high maintenance level as their services depend on a trouble-free availability of the wagons. Other customers, for example a regional transport agency that operates some regional lines in a highly competitive and low-margin market, often attempt to minimise maintenance costs.

Both elements required a drastic change at the various WBA management levels. In discussing the organisational structure we will take a closer look at these changes.

5.2.4 The organisational structure of WBA

WBA wrote a business plan based on the mission statement of the previous section. This plan consists of four main elements:

- the redesign of the organisational model;
- the introduction of new information systems;
- the reduction of overhead;
- the entry of the international market.

These elements formed the starting point for the development of the production, control, and information structure. We describe these structures in the following subsections.

5.2.4.1 The production structure

The start of the production process is constituted by the acquisition of maintenance orders. WBA used to have an annual work plan, which comprised all the maintenance of all NS freight wagons. As a result of the described changes it was necessary to establish a marketing and sales organisation, to approach potential customers, to acquire work, and finally to commit the customer to WBA. WBA attempts to achieve this long-term commitment by providing, amongst other things, special bonuses and discounts. In the beginning WBA used to have a so-called 'right of last refusal' agreement with NS Cargo. This meant that whenever NS Cargo preferred the bid of another maintenance company, WBA had the right to revise its offer as well. Since the middle of 1998, however, this advantage is abolished and WBA is subject to full market competition. This is a harsh competition since rail freight companies have downsized the number of wagons, the demand for maintenance has decreased due to the introduction of modern maintenance systems, and the available maintenance capacity has increased due to the entrance of East European companies in the freight wagon maintenance market. Because of these developments, the German railway company ("Die Bahn") for example is equipped with an excessive resource capacity for freight wagon maintenance.

In the production process WBA concentrates on the actual maintenance and service of freight wagons. A freight wagon comprises a relatively simple technology and hardly any innovation in the design takes place. The depth of the Bill of Material, which contains only three to four levels, illustrates this. In most cases WBA agrees with the customer on maintaining a series of freight wagons in a certain period. This agreement incorporates an estimated workload and price for the entire series. However the individual workload of each freight wagon is unknown. Therefore the uncertainty in the technical specification phase is mainly caused by the specific condition of a particular freight wagon. In addition the customers in general do not keep track of the use of their
freight wagons (e.g. the actual number of kilometres run from the last maintenance period). Therefore most of the preventive maintenance is based on safety regulations.

WBA developed a compact production site for the freight wagon maintenance. This led to a reduction of the old production site from 25 to 14 hectares and from 18 to 3 buildings. This was achieved by analysing and combining order flows. WBA decided to divide its process into two parallel flows:

1. the small maintenance and service flow;
2. the extensive overhaul and modification flow.

The first flow contains the jobs with a low complexity (only one or two skills and a few spare parts needed) that can be finished within a maximum of two days (including transport to and from the customer). The second flow comprises the work that needs an extensive process planning, scheduling, and execution phase. In the infrastructure of the production facility layout these two flows are physically separated (see Figure 5.4).

During the night the freight wagons are brought into the shunting yard of WBA. In the beginning of a working day the 'intake officer' inspects the freight wagon and decides what kind of maintenance or service is needed. A freight wagon that needs small maintenance is directly transported into the 'small maintenance facility'. The other wagons undergo a thorough investigation before they are moved into the 'extensive maintenance' facility.

![Figure 5.4: A schematic view on the physical layout of the WBA.](image)

Within the 'small maintenance facility' a group of approximately 20 workers is employed. WBA guarantees the customer that a 'small maintenance freight wagon' will be available for service within two working days (which means that at most one working day for the job's execution). The group that works within the 'small maintenance and service department' is a multi-disciplinary team. This team has its own responsibilities and competencies regarding its workload. As soon as a freight wagon comes in, the associated job (or jobs) is (are) scheduled with a completion time of at most one working day.

The first step in the extensive maintenance and service process is the transfer of the freight wagon to the 'inspection facility'. Here, members of the production groups carry out an extensive inspection. This results in a list of activities for a specific rail freight wagon. This list is processed by a separate planning department. A process planner determines the number of working hours and the materials required for an order. He then issues the work to a multi-disciplinary team. There exist three multi-disciplinary teams with multi-skilled employees in the extensive maintenance facility. These groups hardly have any responsibilities regarding workload determination and scheduling. The latter tasks are executed within the planning department. An exchange of employees between groups is possible whenever needed, due to surplus or shortage of resources within one
group. It is the intention of WBA to maintain a resource department (i.e. the three multi-disciplinary teams) which is able to cope with 80% of the workload. The remaining resource demands have to be filled by temporary employees. This should provide WBA with the necessary workforce flexibility.

WBA has set up a separate engineering flow that mainly assists the extensive maintenance facility. The engineering section is involved in the quality inspection and the work execution process whenever unknown deficiencies are detected. For this purpose the engineering department is split up into a maintenance and survey section, an inspection section, and a constructions section. For large conversion programs WBA calls on the NMG Materiel Engineering (see Figure 5.3). An example of such a program is the conversion of sliding side wagons into container wagons. The limited task of WBA’s engineering department leads to a relatively small section with two draughtsman/constructors, two maintenance experts, two quality inspectors, and one manager.

The Duisburg section was initially owned by the ‘Vereinigte Tanklager und Transportmittel GmbH’ (VTG) company in Hamburg. VTG is specialised in the transport of all kind of chemicals. For this purpose, it owns a wide range of tank wagons. VTG showed interest in outsourcing its maintenance capacity and establishing a long-term relationship with the resulting maintenance company. This resulted in a take over by WBA of the Duisburg production facility. Nowadays this facility maintains, in addition to the VTG wagons, also freight wagons for other companies. The production structure in Duisburg reflects the flows within WBA Amersfoort, except that it does not have its own engineering and marketing/sales section.

5.2.4.2 The control structure

The redesign of the production structure reduced the layers in the control structure from four to three. The lowest level contains the multi-disciplinary teams for the work execution phase. These teams are co-ordinated through a resource manager. The technical specification, the resource planning and the scheduling is mainly performed outside the teams and for the larger part in a separate planning department. This planning department schedules the work in consultation with the resource manager.

The WBA macro and meso management meets once a week to keep track of work progress, to discuss possible disturbances, and to accept new orders. Participants in this weekly meeting are the general manager, a marketing and sales representative, the resource manager, an engineering representative, and the planning department manager. Once a month an extensive meeting is arranged in which the tactical and strategic issues are discussed. The management of all the operational and supporting sections takes part in this monthly meeting.

The performance indicators of WBA are categorised in a ‘balanced scorecard’ for each department. These performance indicators are summarised in a macro level WBA scorecard. This card comprises indicators like the turnover for each customer, the investments, the number of employees, the financial results, etc. The different levels within WBA use these and other indicators to monitor the manufacturing process.

Figure 5.5 shows the organisational structure of WBA per April 1998. In this situation WBA employs 166 people, of which 103,5 are indirect and 62,5 direct. The indirect figure includes management, staff, supporting facilities, and direct production process support (e.g. warehouse employees).
5.2.4.3 The information structure

The software program Triton (a Dutch MRP based planning system) supports the information structure of WBA. The workload of WBA is simply registered in the Triton service module. The resource planning uses the relatively simple standard network schedules from the Triton library. These standard networks are customised for a specific job. The different standards are incorporated in this library. In almost every case the networks comprise four sequential start-finish tasks. For planning purposes a standard lead time of approximately two to three weeks is used. In this lead time a slack (idle time) of three to four days is incorporated.

5.2.5 Comparison with the design model

In this section we first consider the uncertainty and complexity within WBA. Next, we compare the structure of WBA with the technological rules of the design model.

The uncertainty in WBA’s market increased significantly during the last few years. This is due to the privatisation of NS and the resulting commercial customer-contractor relation between WBA and various rail freight transport companies. The manufacturing process is characterised by a moderate uncertainty. This is due to the relatively simple technique used within a freight wagon and the generally large contracts with customers. The simple technique enables a quicker diagnosis and a smaller chance on unexpected defects. The large contracts ensure a relatively stable workload during a longer period. Subsequently, we also classify the material and capacity complexity as average. In general a freight wagon requires only a few materials and spare parts and there are only a few skills are needed in maintenance and repair.

We now compare the elements of the design model with the WBA structure.

- The establishment of a process-oriented organisation

WBA has clearly established a process-oriented organisation. The process is divided into two parallel flows with different process times, order sizes, and complexity (regarding resources and materials needed). Due to the stable workload and the limited number of skills needed for each flow, WBA was able to create two more or less independent flows, from order intake to job completion. This is a highly favourable situation because it reduces the organisational complexity significantly.

- The integration of non-physical and physical activities

The non-physical and physical activities are completely integrated in the ‘small maintenance and service jobs’ flow. This group is responsible for the technical specification, resource planning and scheduling, and finally execution. The relatively simple process structure enables a full integration of both activities. In the extensive overhaul and modification flow non-physical and physical activities are not placed within one group.
Employees of the multidisciplinary teams carry out the inspection procedure of a freight wagon. Subsequently, the planning department processes this initial technical specification and plans and schedules the resources. However, every planner from the planning department addresses his own team. In this way WBA created a link between the planning and the resource department. A further integration of the planning tasks within the groups might well improve WBA's flexibility and team satisfaction. The engineering section is a rather small separate section within WBA. This is due to the relatively simple technique used within a freight wagon. Therefore, the groups only occasionally require engineering support. The contacts between engineering and the production groups are established in a direct horizontal way. This ensures the necessary two-way dialogue between engineering and production.

Based on these observations we conclude that WBA has an integrated physical and non-physical activities. Within all manufacturing activities there is clearly a two-way communication between technical specification (including engineering) and resource planning and scheduling on the one hand and work execution on the other hand. A further integration of specification, planning, and scheduling tasks within the groups might further enhance WBA’s flexibility.

- **A three level planning structure**
  WBA reduced its organisational levels with the corresponding planning levels from four to three. The macro level operational management communicates directly with the meso level management. In the old structure there used to be an additional management layer between the macro and the meso level. The present short operational management lines were clearly visible during our visit to WBA. This important organisational feature strongly contributes to the desired flexibility.

- **A clear coherent planning hierarchy with a distinction between aggregate and detailed capacity**
  At the macro and meso level WBA achieves a well-balanced distribution of control tasks. The meso level is in charge of the medium and short term operational management. The highest management layer is in charge of the long term operational management and the tactical and strategic management. Based on the trend within WBA to put all the scheduling and the planning activities in the planning department, we cautiously conclude that WBA seems to have opportunities in the distribution of control tasks to the lower level. In spite of the right throughput times, the delegation of more control tasks to the multidisciplinary teams seems to be possible. This may ultimately result in a more flexible organisation with a higher worker satisfaction level. In the preparation of large orders, a top-down approach is used to match the demand for capacity and the available resources. However, as soon as an order becomes more specific the planning department starts to schedule with detailed capacity. The planners take the individual employees and their skills into account when they schedule a job. In relation to the incorporation of more specification and scheduling tasks into the groups, we expect the company's planning activities to benefit from a more clear distinction between aggregate and detailed capacity. In that case the planning department might limit itself to the aggregate capacity view, while the groups perform the detailed scheduling tasks. This would enable the company to give a faster response to customer demands, and more robust control mechanisms at the various organisational levels.

As we summarise the planning hierarchy, we conclude that WBA has established a planning structure on different levels with a distinction between aggregate and detailed capacity. However, we believe there are possibilities to delegate control tasks to the micro level. Probably WBA is not pressured to incorporate control tasks in this level due to the moderate process uncertainty. Still, the use of the control abilities of the workforce might increase WBA's flexibility and promptness, thereby improving its competitive position.

- **The use of the portfolio management methodology**
  The operational steering team meeting once a week resembles a portfolio management meeting. The marketing and sales sections apply for resources, while the engineering section and the resource management
are the resource suppliers. Compared to the portfolio management methodology, the role of the planning department is somewhat ambiguous: it not only schedules the work, issued by the marketing and sales section, but also influences the resource allocation of the engineering and resource sections. In our portfolio model these tasks belong to the sections itself and not to a separate planning section. Again, the present structure may be sufficient due to the moderate process uncertainty within WBA. The portfolio management methodology is particularly useful in situations with a high uncertainty and an erratic demand. However, in line with our previous remarks on the distribution of control tasks at the meso and micro level and the incorporation of work specification and scheduling tasks in the groups, it seems meaningful to reconsider the planning structure in the future. The planning section may for example become a macro level planning (e.g. a staff portfolio planning section), while the actual meso and micro level planning is incorporated in the resource and engineering sections.

We conclude that within WBA there is not a portfolio management level such as the one proposed in Chapter 4. The need for such a level is not directly present due to the lower uncertainty level (i.e. compared to the situation at RNND). However, the use of a, perhaps simplified, portfolio management methodology might be beneficial by ensuring an unambiguous assignment of resources.

- **The use of multi-disciplinary teams at the micro level**
  WBA uses multi-disciplinary teams at the work execution level. However the control responsibilities for these teams are limited. According to the WBA management, the reason for a tight external control lies in the tight due dates which causes short lead times and product cycles. This leaves hardly any margins for a multi-disciplinary team to schedule its operations independently. However, in view of the advantages a low level micro planning has for an MSMO company, WBA might reconsider its control tasks at the micro and meso level. The argument is that daily production control practice shows that, whatever tight a due date is set, every order has a certain amount of slack. This enables the multi-disciplinary team to take part in an internal order acceptance process with mutually agreed time frames. In this case the problem solving capabilities and flexibility of the workforce will increase, while relatively small problems and disturbances are solved within these time frames. These features are certainly important when considering the customer's demand for flexibility.

- **The use of information technology as an enabler**
  WBA wants to use the possibilities of modern information technology. The company selected the Triton software to support its manufacturing process. In view of the features of its current systems and the rising customer demands, the incorporation of a macro level decision support system would benefit the order acquisition process. In addition it would provide a strong basis for the distribution of control tasks to the various organisational levels and a clear distinction between aggregate and detailed capacity.

  We therefore cautiously conclude that modern information technology is not yet used as an enabler in the WBA processes. However, the company has expressed its intentions to consider the introduction of new information systems for the support of its manufacturing process.

### 5.2.6 Conclusions

WBA maintains relatively simple technical items. This leads to a low to medium material and capacity complexity. However the unpredictability of the work package of an individual freight wagon and the changing and sometimes erratic customer demands, make the need for a flexible process clear. The challenge for WBA therefore lies in the establishment of a highly flexible process that is able to respond quickly to customer demands. Compared to the design model some essential features are present, like the establishment of a process-oriented structure, the division of the process into parallel flows, and the use of multi-disciplinary teams. Other rules, like the portfolio management methodology and the distribution of control tasks to the micro level are not
clearly present. Compared to the other cases, the need for these rules is less urgent due to the moderate process uncertainty. However, it still seems that WBA might benefit from a, perhaps partial, introduction of these rules. A reconsideration of the distribution of control tasks, a more distinct use of aggregate and detailed capacity, and the introduction of more advanced planning systems might increase the desired flexibility within the organisation.

This case study shows that most of the essential design model features are present within WBA. Due to the moderate process uncertainty, only a partial introduction is useful for some features. We therefore conclude that the design model is to a large extent applicable for WBA. In addition, the case study results confirmed that a customisation of the design model is necessary for a particular case. Due to a more moderate process uncertainty, for instance, there might be less need for some of the technological rules.

5.3 The ‘Mechanisch Centrale Werkplaats’ (MCW)

5.3.1 Introduction

The 'Mechanisch Centrale Werkplaats' (MCW) specialises in the maintenance, repair, overhaul, and modification of army equipment (see Photo 5.2). This company is the result of a merger in 1995 between the '790 Tankwerkplaats' and parts of different service units. The merger and redesign of the entire organisational structure were necessary in view of the changing tasks of the military forces, due to altering politics.

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*Photo 5.2: Maintenance of a tank at MCW.*

The main location of MCW is in Leusden (near Amersfoort), while a second establishment is located in Utrecht. The facilities of the main location will be modernised in the near future. New buildings will replace some older ones; others are modernised up to contemporary standards. Parallel to this renewal process, the Utrecht location is closed down and the activities are integrated into the main location. The order book of MCW includes the maintenance of tanks, light-tracked vehicles, special tracked vehicles, artillery, wheeled vehicles, shelters, generator sets, and engineering equipment. The maintenance of these objects comprises the following elements.

The mechanical maintenance of tanks concerns the entire tank or separate parts, like the tower (including artillery), underframe, and components. The maintenance of tanks used to be standardised; nowadays it is mostly condition based. The light-tracked vehicles family include the YPR’s (approximately 20 variants), M113’s, and similar vehicles. MCW prepares almost all light-tracked vehicles for the deployments in special United Nations missions. The special tracked vehicles section includes the armour-plated tracked vehicles against air targets, salvage vehicles, and bridge laying vehicles. In addition, MCW maintains all common pieces of artillery with a range from 20 mm (0.8 inch) until 203 mm (8 inch). A special task concerns the adjustment and control of the synchronic firing system of firing barrels. The wheeled vehicles section maintains a broad range of objects. It includes the damage repair, modification, and overhaul of plating, under-carriage, and other components. The repair and modification of shelters concern for example the electrical installation, air conditioning, and interior design. The generator sets and engineering equipment section comprise all kinds of sophisticated tools such as snowblowers and excavation equipment. MCW maintains mechanical, electrical, hydraulic, or pneumatic components for the entire range of objects.
5.3.2 The market developments of MCW

Due to the changing tasks of the Netherlands Defence organisation, the Royal Netherlands Army was reduced to approximately one third of its initial size. From this reduction process the need arose to restructure the army’s maintenance resources. The existing bureaucratic maintenance organisation was no longer able to cope with the changing needs of its customers. This inability was demonstrated by uncontrollable stocks, an inadequate due date performance, long lead times, quality problems, inefficiency, low employee satisfaction, and finally a high absence due to illness (approximately 17%). As a result of altered circumstances, MCW experienced changing demands. For instance, the batch sizes of vehicle maintenance orders decreased, the range of vehicle types broadened, and a need for more condition based maintenance instead of duration based maintenance was expressed. In addition, the attitude of MCW employees changed due to a higher level of education. For these technically skilled workers, the extensive work descriptions of the old functionally oriented organisation did not apply.

The management of MCW concluded that the old functional organisation structure lacked the flexibility needed to face these facts. This conclusion led to an integral restructuring process in which several maintenance facilities were integrated into the present MCW company.

5.3.3 The mission statement of MCW

The raison d’être of MCW within the army organisation lies in the unique ability to provide and maintain knowledge regarding the maintenance and modification of the army’s rolling stock. In addition, MCW is a resource that is directly available for urgent assignments. The preparation of vehicles for the United Nations peacekeeping operations is, for example, such an urgent task. The Netherlands defence organisation is the primary market for MCW. From this viewpoint, there is no need to strive for a market outside the defence organisation. Within the defence organisation, MCW aims for an independent position, which comprises all competencies to influence its company results. In this structure, the army organisation confines itself to judge MCW on its output, instead of interfering with the company’s management.

The knowledge of MCW concerns mainly mechanical maintenance. To perform mechanical maintenance also knowledge regarding hydraulics, pneumatics, electrical engineering, chemistry (surface processing), systems engineering, and finally connecting techniques (gluing and welding) are needed.

Based on these starting points, MCW formulated the following mission statement in 1995.

MCW develops and maintains knowledge regarding the mechanical maintenance and preservation of materials and systems. This knowledge consists of consultations of engineering, development and execution of maintenance programs, and development and execution of solutions for technical problems. MCW aims for an optimal service for its primary customer, the Royal Netherlands Army. In addition, MCW works for other military forces (i.e. the Royal Netherlands Navy and the Royal Netherlands Airforce) and other Governmental institutions. Assignments from commercial clients are only possible under strict conditions.

For these purposes MCW aims for a capacity of 350,000 man-hours in the year 2000 [NLMOD (1998)], which holds a steady workforce size of approximately 300 employees. To introduce resource flexibility, MCW aims for a complementary resource of 50,000 man-hours by hiring temporary employees. This workforce build-up enables MCW to develop and preserve the knowledge, to carry out urgent assignments for the army, and finally to run a business on an acceptable economical scale.
5.3.4 The organisational structure of MCW

To develop a new organisational structure, MCW used an approach comparable to the process design of our research project. In this section we first discuss the production structure of MCW. Next we move to the corresponding control structure. Finally, we consider the supporting information structure.

5.3.4.1 The production structure

MCW first examined the composition of its manufacturing process. Within this process it distinguished four elements:

1. **the primary process**
   (the activities directly related to the manufacturing process)

2. **the directly supporting process**
   (the manufacturing activities supporting the primary process)

3. **the indirectly supporting process**
   (the services supporting all manufacturing activities, such as procurement, stock control, and maintenance and calibration of production facilities)

4. **the supporting company process**
   (the services supporting the entire company like the personnel department)

This distinction had to clarify the essential organisational goals, establish an awareness of processes with different levels of importance, and define unambiguous decoupling points. In this case study, we mainly focus on the primary process.

MCW divides its primary process into three clearly defined parallel flows: the wheeled vehicles section, the components section, and the tracked vehicles section. Table 5.1 yields the size of each flow. In addition to their own primary process, the 'components' and 'wheeled vehicles' sections directly support the 'tracked vehicles' section with respect to the delivery of components and special services, respectively.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Tracked Vehicles</td>
<td>136.250</td>
</tr>
<tr>
<td>Component Maintenance</td>
<td>123.750</td>
</tr>
<tr>
<td>Wheeled Vehicles</td>
<td>152.500</td>
</tr>
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</table>

*Table 5.1: The workload for each primary flow.*

The directly supporting services for these three primary flows are a materials section and a facility section. The 'material section' supports the other flows by purchasing, storing, and distributing the necessary materials and spare parts. The 'facility section' is in charge of the company support. For example, the maintenance of the infrastructure and production means is co-ordinated through this section.

The production structure includes in MCW terms four levels: the management, the department, the shop, and finally the production group level. This is a reduction of three levels compared to the old functional structure. Figure 5.6 shows a simplified version of the new structure.
The lowest two levels are only shown for the ‘tracked vehicles’ department. The other departments show a similar structure. The ‘tracked vehicles’ department comprises the shops ‘heavy tracked vehicles’, ‘light-tracked vehicles’, and finally the ‘special tracked vehicles’. Within each shop, at least one production group is located. For example the ‘light-tracked vehicles’ shop consists of three production groups. Each shop is able to deliver a complete product or product family. For this purpose, employees with different skills and multi-skilled employees are incorporated within the shop. The shops in turn create the production groups in such a way that they are able to manufacture a clearly defined (partial) product or service. A production group consists in general of 8 to 12 multi-skilled employees.

5.3.4.2 The control structure

In discussing the control structure of MCW, we first consider the different planning levels. Next, we move to the control of the workload at the various control levels.

MCW uses the following three planning levels: resource planning, production planning, and detailed planning level. These three levels with their corresponding horizons are illustrated in Table 5.2. In the planning process, MCW distinguishes scheduled work, work on request, and incidental work. The maintenance of tanks, for instance, mainly belongs to the category ‘scheduled work’. This is due to the fact that the construction of a tank shows a modular structure which enables a ‘repair by replacement’ philosophy. In the ‘work on request’ category MCW makes an agreement on the number of hours to be spent on a specific range of products. At that time, the detailed contents of this agreement is not yet known. This category mainly comprises the ‘maintenance of components’ and the ‘wheeled vehicles’ flow. The component flow comprises a wide range of different items, while the wheeled vehicles constitute a broad range with hardly any modularity built in. The category ‘incidental work’ contains all assignments that were not foreseen in the long or medium term planning. This implies that the uncertainty of the MCW work package is confined to the wheeled vehicles flow, the component maintenance flow, the incidental work, and of course work related to urgent assignments (for example for United Nations peace keeping operations).

<table>
<thead>
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<th>Level:</th>
<th>Range:</th>
<th>Horizon:</th>
<th>Responsible:</th>
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<td>Resource planning</td>
<td>Long term</td>
<td>3 - 10 years</td>
<td>Company Staff</td>
</tr>
<tr>
<td></td>
<td>Medium term</td>
<td>1 - 3 years</td>
<td></td>
</tr>
<tr>
<td>Production planning</td>
<td>Short term</td>
<td>Less than 1 year</td>
<td>Production Staff</td>
</tr>
<tr>
<td>Detailed planning</td>
<td></td>
<td>Less than 6 months</td>
<td>Shop</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Less than 10 - 15 days</td>
<td>(production group)</td>
</tr>
</tbody>
</table>

Table 5.2: The different planning levels of the MCW.
The lowest control level is located in the production group (i.e. the detailed planning). A production group co-
ordinator (who is a member of the group) is in charge of the internal co-ordination process. He organises the
group’s decision-making, external communication, and external relations. In addition, he pays attention to the
group discipline, the group motivation, and the training of the individual group members. Besides these tasks,
the group co-ordinator actively participates in the group’s manufacturing process. To assist the group co-
ordinator in the in- and external consulting process, a planner (a technical administrative function) is assigned to
the production group. One planner may be assigned to several groups.

The next higher level (i.e. the production and the detailed planning) comprises the shop manager. The primary
task of this manager is to guard the development of the different groups, to stimulate the improvement of the
groups’ performances, and to accommodate the change process in the shop. The different production groups
within the shop are involved in the decision making process regarding the shop goal setting and the organisation
of the manufacturing process. To assist the shop managers in the planning process, a production staff of
approximately 10 to 15 employees is established in the departments. This group consists of schedulers and
process planners. In the future the process planners will be integrated into the different shops.

The general manager and the department heads form the highest company control level. A company staff of
approximately 10 employees assists this management level in controlling the workload. This staff section is
responsible for the acquisition and bidding phase. In addition to this ‘sales function’, it also responsible for the
engineering function (an additional nine employees). Compared to the size of MCW, the engineering function is
a small activity. MCW recognises that this activity may gain importance in the future.

Before the company staff establishes a contract with the customer, the department staff checks the feasibility. In
this acquisition process, the company staff uses a global workload as a basis for decision making in the different
shops (i.e. aggregate capacity). It does not have an actual overview of the available resource hours for each
production group. The amount of work that can be loaded is determined by previous performance results. The
company staff and the department managers constitute an ‘internal company plan’. This plan comprises the short
term planning agreements for the next year. From that time on, the department managers and their production
staff are responsible for the detailed planning. To this end, they use an actual workload overview. Once every
two weeks MCW’s general manager, the company staff, and the four department managers meet to discuss the
internal company plan progress, possible set-backs in the work execution phase, and possible occurrences of
incidental work.

Whenever a customer (i.e. in general an operational army division) brings unexpected work into MCW, the
company staff first checks whether there is any resource claim in behalf of this customer (i.e. the high level
agreements for a product range). If no such claim exists, the next step is to consult the department managers
whether it is possible to postpone jobs, subcontract certain jobs, or involve other shops in the execution of
certain jobs. Ultimately, it may be necessary to postpone orders in favour of the unexpected work. This is only
done under acceptance of both customers or on order of a high level army executive.

For monitoring and control purposes, MCW developed a system of performance indicators top-down
[Richardson et al. (1996)]. In this way each organisational level, group, and employee should have the same
understanding of the meaning of the different indicators. The indicators are incorporated in target matrices for
the different groups and levels. Examples of indicators are due date reliability, difference between bidding phase
calculations and actual costs, number of customer complaints, etc. MCW puts a lot of effort in the design and
implementation of a coherent and reliable system of performance indicators. However, daily practice shows that
due to a lack of experience with the use of indicators and a certain amount of distrust in the multidisciplinary
teams (i.e. they sometimes experience the indicators as a control system instead of an improvement tool), this is a
difficult process.
<table>
<thead>
<tr>
<th>Company:</th>
<th>574 Tank Workshop</th>
<th>790 Tank Workshop</th>
<th>MCW</th>
<th>MCW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management levels:</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of employees (Z):</td>
<td>451</td>
<td>440</td>
<td>597</td>
<td>477</td>
</tr>
<tr>
<td>Production hours realised (Y):</td>
<td>331.000</td>
<td>287.000</td>
<td>470.000</td>
<td>380.000</td>
</tr>
<tr>
<td>Production ratio (Y/Z):</td>
<td>734</td>
<td>652</td>
<td>787</td>
<td>797</td>
</tr>
</tbody>
</table>

Table 5.3: The improvements due to the restructuring process of the MCW.

To illustrate the benefits of the MCW restructuring process, Table 5.3 depicts the development of the production ratio figure (i.e. the ratio between the number of employees and the realised production hours). The companies from which MCW originated (574 and 790 Tank Workshop) are incorporated in this figure. The numbers in Table 5.3 show that the production ratio has improved significantly during the last few years.

5.3.4.3 The Information Structure

The main carrier for the information structure is a Business Planning System (BPS), comparable to the system in use at the RNN Dockyard, see Chapter 5. With respect to the main features, this BPS incorporates the same characteristics as the system used at the RNN. This BPS is also developed in the late seventies and eighties, it is qualified as user-unfriendly, and it has poor scheduling possibilities. Yet, the MCW manufacturing process allows a better use of the BPS. This is explained by the relatively smaller maintenance objects and to, a certain extent, by the higher predictability. All planning levels use the BPS as the company's primary information carrier. In addition to the BPS, some sections use their own applications.

The company staff uses Microsoft Access software to register and keep track of the different jobs and contracts. This system only registers the different jobs and matches them with the Main Production Schedule (i.e. it has no scheduling capabilities). Next, the company staff defines a maximum lead time by putting a possible earliest start and a possible latest finish date into the BPS. The actual start and finish date remains the responsibility of the department manager and his production staff. The information systems do not support them in this scheduling process. The different departments and shops use their own experience to match the workload and available resources.

5.3.5 Comparison with the Design Model

In this section we first briefly consider the general characteristics of MCW. Next, we compare the technological rules of our design model with the MCW structure. MCW faces a moderate market uncertainty. The Royal Netherlands Army is practically the only customer, which assigns all the vehicle maintenance to MCW. In addition, MCW only carries out the large maintenance and overhaul tasks. The customer is responsible for the daily and small maintenance tasks. The process uncertainty is mainly high. This is caused by the nature of the wheeled vehicles and component maintenance flow. The actual work content of these flows becomes clear when the actual object is in for inspection. The material complexity and capacity varies between average and high. Some objects only need a few reasonably standardised materials and spares. However, due to the wide range of wheeled vehicles with different materials and spare parts, the material complexity is reasonably high for this flow. The capacity complexity for MCW is moderate due to the relatively small number of different skills needed in the maintenance process.
• The establishment of a process-oriented organisation
MCW has established a process-oriented organisation with the use of a process design that is comparable with the approach discussed in Chapter 2 [Richardson et al. (1996)]. MCW distinguished four flows from the order acquisition point to the product deliverance to the customer. MCW has chosen primarily for internal complexity reduction by grouping similar products into four departments.

• The integration of non-physical and physical activities
MCW clearly aims for an extensive integration of non-physical and physical activities. Already every production group has its own planner and scheduler in the production staff. In the future MCW may integrate parts of these tasks in the groups. Also on other levels both activities are integrated in the process structure. An example at meso level is the mentioned production staff that is incorporated in the production departments.

• A three level planning structure
With the use of an integral organisational change approach MCW has reduced its organisational levels from seven to four, thereby removing redundant co-ordination layers. Within this four level organisational structure, MCW uses a three level planning structure: resource planning, production planning, and finally detailed planning. MCW is still working on the distribution of control tasks among the different organisational levels. An increase in the maturity level of the production groups opens, for example, the possibility to broaden their planning and scheduling responsibilities.

During our visits, it soon became clear that this reduction in organisational levels and the establishment of a clear three level planning hierarchy has improved MCW's promptness and flexibility. The company is for example able to respond much faster to changing customer demands.

• A clear coherent planning hierarchy with a distinction between aggregate and detailed capacity
By determining three planning levels with different ranges and assigning the corresponding tasks to four organisational levels (i.e. company staff, the department staff and the shop/production groups), MCW created a coherent planning hierarchy. The nature of its maintenance objects enables the use of this hierarchy, the highest level agrees on batches of vehicles, while the lowest level can determine and schedule the actual work package of a single vehicle. In connection with this planning hierarchy MCW considers aggregate capacity at the company staff level, while the shops and production groups look at detailed capacity. The match between the two different capacity types is made at the department staff level.

The establishment of this planning hierarchy clearly benefited MCW in delegating competencies and responsibilities. Therefore, the experiences within MCW support the conclusion that such a hierarchy is indeed an important tool in providing every level with necessary control tasks and to ensure that these tasks are incorporated in a coherent framework.

• The use of portfolio management
The bi-weekly meeting of the general manager, the company staff, and the department managers may be considered as a portfolio management meeting. However, based on the difficult accessible integral overviews of resource loads, it seems that this is a weak form of portfolio management. This is caused by the wearisome support of the existing information systems.

• The use of multi-disciplinary teams at the micro level
MCW has achieved impressive progress in the establishment of more or less self-supporting multi-disciplinary teams. Depending on the maturity level of a specific team, the control and general tasks are delegated to the group. This is illustrated by the fact that a production group independently carries out approximately 70% of the workload (i.e. the routine work). The other 30% non-routine work is carried out in consultation with the shop manager.
The use of information technology as an enabler

In spite of the coherent planning hierarchy, MCW does not use a matching coherent information systems structure. If MCW wants to take full benefit of its new structure, it is necessary to reconsider the information structure and the underlying information systems. Especially the use of appropriate intelligent resource scheduling systems would support the various planning levels tremendously by providing proper information. For example, the weak form of portfolio management is nowadays supported by information that is obtained through manipulation of detailed information systems. These views are incomplete and out-of-date as soon as they reach this management level. Besides, it is impossible to perform a scenario analysis. During our visits a clear need for such a system was observed.

5.3.6 Conclusions

MCW designed a new operational and management model that incorporates many technological rules of the design model. In addition, the company is already far on its way with a step by step implementation of this new organisational model. Besides the further development and refinement of its model, chances lie for MCW in the design and implementation of a coherent information structure. Eventually, the entire implementation process may benefit from this (e.g. through an easier distribution of control tasks to the different planning levels).

5.4 The Norfolk Naval Shipyard (NNS)

5.4.1 Introduction

The Norfolk Naval Shipyard (NNS) is one of the four USA Naval Shipyards. At NNS, approximately 7000 people are employed, of which about 4500 are blue-collar workers. In 1993 the shipyard started to change from a functionally oriented to a customer focused organisation. The introduction of a 'strong' project management approach has been an important element in this change process. In this section, we first briefly discuss the developments that urged NNS to change. From there we move to the mission statement and subsequently discuss the organisational structure of NNS. Finally, we compare this structure with the design model.

5.4.2 The market developments of NNS

Due to the changing political situation in the late eighties and early nineties, the Naval Shipyards in the USA faced a difficult challenge. Initially, there existed eight Naval Shipyards in the USA. In 1996 three of them were officially shut down (Charleston (SC), Philadelphia (PA), and Mare Island (CA)). In the next year the fourth one followed (Long Beach). So nowadays the following four Naval Shipyards remain to serve the US Navy with repair support: the Norfolk Naval Shipyard (NNS), the Puget Sound Naval Shipyard, the Portsmouth Naval Shipyard, and finally the Pearl Harbor Naval Shipyard. In this case study we focus on NNS.

Due to these drastic changes the need for a redesign process at NNS was obvious: to secure its existence NNS had to reduce costs and to be competitive.

5.4.3 The mission statement of NNS

The Naval Shipyards developed an integral view upon their strategic plan. The mission of these yards is as follows:

The Naval yards provide maintenance, modernisation, inactivation, disposal, and emergency repair of US Navy ships (US Naval Shipyards (1997)).

To achieve this mission they adopted the following set of guiding principles.
The Naval Shipyards simultaneously deliver technical excellence and quality and cost and schedule performance to their customers.

The yards proactively seek, listen, respond to, and satisfy the needs of the customers and co-workers, and base decisions on the best available information with full consideration of the impact on all concerned.

The yards treat people with courtesy and respect, provide a safe and efficient work environment, foster equal opportunity, recognise employees' contributions, and work together as labour/management partners.

The yards continually seek improvements for the customers, employees, and in business practices, while they emphasise safety, efficiency, and teamwork.

The yards empower people to take initiative, with authority and responsibility assigned to the lowest appropriate level; with relationships based on competence, trust, teamwork, employee development, and the highest standards of integrity and excellence.

The yards want to be active community members and responsible stewards of a clean and safe environment.

The mission statement and these guiding principles are for NNS the basis for its redesign process.

5.4.4 The organisational structure of NNS

5.4.4.1 The production structure

The workload of NNS mainly consists of large overhauls of US Navy Ships (see Photo 5.3). In Chapter 3 we qualified these overhauls for the RNND as 'long term maintenance' periods (LTM). NNS does not carry out the other maintenance types (i.e. BTM, AIM, and UIM). Regional maintenance facilities are responsible for these maintenance categories.

NOT AVAILABLE IN THIS VERSION

Photo 5.3: Frigate maintenance at a US Navy shipyard.

Before 1993 the large overhauls were co-ordinated and executed by thirteen functionally oriented shops resulting in a tremendous co-ordination effort. NNS introduced in its redesign process a 'strong' project management approach. A project superintendent (PS) is responsible, in NNS terms, for the project from 'cradle to grave'. This means that this project superintendent is integrally responsible for the initiating, planning, execution, and finally evaluation and service. To support the projects the original thirteen shops were consolidated into five essential shops. These five shops incorporate the workers and manufacturing facilities for the projects. In addition to the project organisation ('the operations office') and the shops ('the resource offices') NNS introduced a separate department for the engineering and corporate planning. Figure 5.7 shows an overview of the organisation structure.
NNS executes approximately seven projects simultaneously, in different stages of progress, simultaneous in execution. The size of an overhaul of for example a frigate is approximately 15,000 man-days. The overhaul of an amphibious assault ship or an aircraft carrier obviously exceeds this number significantly. The PS and his project team are held responsible for the success of the project. The team is responsible for the costs, employees, and means needed for the project. In this project structure the link between money and work is dominant. The following list is a survey of the critical factors of project management [US Naval Shipyards (1993)]:

- The PS must be the recognised shipyard official responsible for managing the project.
- The PS must place primary emphasis on the team building, empowerment and relationship management.
- The project team must be responsible for and control all funds of the project.
- The project team must be assigned early, kept intact, and located near the work site in contiguous spaces.
- The project team must oversee the development of the project management plan.
- The project team must lead the planning activity.
- The project team must take the responsibility for the project planning problems.
- The project team must be able to perform true schedule and resource load analysis.
- The project team must control the application of labour resources to the project.
- The project team must closely monitor the job planning process of developing Task Group Instructions (TGIs).
- The project team must manage the work packaging process.
- The project team must participate in the approval of changes to the work package.

From this list, a far-reaching responsibility and competency of a project team emerges. Figure 5.8 depicts the organisational structure of a project team. The different shops have to support the project in their resource needs. Manpower from these shops is forwarded to the projects. It is critical to ensure that different shops
understand and practice the support of the projects as their principal objective. This is a major shift in departmental roles as compared to the old functional management organisation. The shops are still responsible for the training, administration, and discipline. Also the technical expertise of the workers is a shop's responsibility.

The shop workers may stay within a project for only a relatively short period or for the entire duration. The workforce within the projects is accommodated in working groups. A 'working group' consists of approximately 18 to 25 persons, depending on the size of the project. As a common rule, the generally skilled workers are assigned to the projects, while workers with specialised skills, such as welding and instrument calibration, only come to a project for a specific task and return to the shop after the its completion. It would be inefficient to assign these workers full-time to a project, where they would have to perform also common skills, whereas another project might need their specialised skills.

![Diagram of project team organisation](image)

**Figure 5.8: The organisational structure of a project team.**

### 5.4.4.2 The control structure

In the new project management approach, NNS puts a lot of attention on bare bones estimations. A project team has to calculate an overhaul with no anticipated delays or disturbances. In consultation with the Shipyard Commander, the PS adds a risk assessment to this estimation. It has become apparent to the workforce that the development of realistic estimates is essential to achieve the necessary reduction in ship overhaul and repair costs. In addition, estimating on bare bones provides the opportunity to benefit from the learning curve of overhauling ships of a particular class several times. In the old days the major overhaul estimates were often inflated to ensure there was sufficient funding and schedule flexibility. Under the new project management approach estimates are developed using the actual repair list. This calculation method has resulted in a reduction of 15 to 20% in estimated man-hours.

The initial contract for a project is defined with the US Navy (i.e. the type commander who is in charge of a group of ships). During the overhaul process, the project has a type commander representative who serves as a direct link to the customer. To control a project, the PS and his team use the zone technology concept. A major overhaul period of a ship generally consists of the following zones:

1. repair and temporary services;
2. major alterations;
3. other alterations;
4. engine rooms.

In most cases the zones are geographically determined. It is however common practice to establish the alterations of complex systems on board the ship as a zone. The principle for determining a zone is that it should ease the PS's task to plan, control, check progress, and execute his project. The zones are determined by a PS and the Project Engineering and Planning Manager (6 months before the execution starts). A separate zone manager is assigned for each zone (4 months before the execution starts). The zone managers are required to comprehensively review the job summaries for their respective zones. After this review, internal project contracts between the PS and his zone managers are established. The zone managers supervise the different production groups in the execution phase. Table 5.4 shows an example of a part of the zone division for a relatively small overhaul period on the USS Arleigh Burke.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>Installation of plastic, waste disposal system</td>
<td>2500 man-days</td>
</tr>
<tr>
<td>Zone 2</td>
<td>Installation of EHF, SATCOM systems</td>
<td>3000 man-days</td>
</tr>
<tr>
<td>Zone 3</td>
<td>Installation bleed air system</td>
<td>-</td>
</tr>
<tr>
<td>Zone 4</td>
<td>Opening, inspection and closure of 43 tanks</td>
<td>1000 man-days</td>
</tr>
</tbody>
</table>

Table 5.4: Zones in overhaul period USS Arleigh Burke.

The entire work package of this overhaul contained 15,500 man-days. This package contained 12,100 man-days blue-collar work and 3,400 man-days white-collar work. During the project planning phase, NNS puts much effort in developing an efficient work breakdown structure. First, component units (CU's) are defined (i.e. parts of installations or systems that need maintenance and/or modification). These CU's are stored in a database. Although the initial development of the CU's has been labour-intensive, the CU database has proven to be very useful in the project planning phase of subsequent projects. The project planning uses the Ships Work List Item Number (SWLIN) as a basis for the work breakdown structure. A SWLIN may comprise several job summaries and the jobs are uniquely attached to one SWLIN. The job size should enable the project team to effectively track, monitor, progress, schedule, and execute the work. NNS has spent a lot of effort to determine, via trial and error, the right job size. The projects now use a job size of about 40 to 80 hours on average.

In the execution phase, the zone manager has the disposal of a number of first-line supervisors (foremen). These foremen are assigned after completion of the project work documents. The zone managers and the foremen exchange work between zones where it makes sense to do so. This co-operation between zones is important for the project's flexibility. For example, a cable installation that runs through two or three zones is the subject of negotiation between these zones. The result should be that one of the zones takes the responsibility for the installation of the entire cable. The philosophy within a zone is to first determine the activities and then assign the workers as necessary, as opposed to trying to find work for a fixed number of workers. In this way workers are assigned to upcoming jobs rather than left to find the work themselves. Workers without any tasks are returned to the resource shops for the assignment to other projects. The most efficient projects move workers on a daily basis.

Important for the shipyard management is a performance measurement system. For each project a diagram is made up in which the 'budgeted cost of work scheduled' (BCWS), the 'actual cost of work performed' (ACWP) and 'budgeted cost of work performed' (BCWP) are visualised. This information provides cost and schedule variance indicators, which are used to identify and resolve problems. After completion of the project there is a
90-day warranty period, in which problems related to the overhaul period are resolved. After this period the project manager and the shipyard’s business office make up the bill and an evaluation report. Table 5.5 outlines the time schedule of a project at NNS. It provides an insight into the responsibilities and actions of the various employees involved in project management.

For integral planning purposes all the project schemes are integrated into a high-level co-ordinated plan. This task is carried out after scheduling each individual project. The high-level plan provides an integral overview, but does not allow for adjustment of project schedules. The officials at NNS explicitly acknowledged that an intelligent Decision Support System would be most helpful in carrying out integral scheduling and rescheduling tasks.

<table>
<thead>
<tr>
<th>What</th>
<th>When</th>
<th>Who</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtain work package and start up funding</td>
<td>A minus 12 months</td>
<td>Business and Strategic Planning Officer (BSPO)</td>
</tr>
<tr>
<td>Review package and obtain a rough estimate by work order</td>
<td>A minus 7 months</td>
<td>Project Superintendent (PS), Project Engineer and Planning Manager (PEPM) and BSPO</td>
</tr>
<tr>
<td>Hold a work definition conference with the type commander and firm up the work package</td>
<td>A minus 6 months</td>
<td>PS, PEPM, BSPO</td>
</tr>
<tr>
<td>Decide on work breakdown structure and zone breakdown</td>
<td>A minus 6 months</td>
<td>PS, PEPM</td>
</tr>
<tr>
<td>Develop job summaries for each work order, order long lead material</td>
<td>A minus 5 months</td>
<td>PEPM and staff as needed</td>
</tr>
<tr>
<td>Bring on zone managers to conduct job summary reviews as needed, look for crew size, duration, proper shops, and technical sequence. Develop a project internal control price (ICP)</td>
<td>A minus 4 months</td>
<td>PS, zone managers, resource shops</td>
</tr>
<tr>
<td>Turn completed job summaries in working instructions</td>
<td>A minus 2 months</td>
<td>PEPM and staff</td>
</tr>
<tr>
<td>Conduct internal control price brief with ship yard commander, bare bones plus project’s reserve</td>
<td>A minus 2 months</td>
<td>PEPM and staff</td>
</tr>
<tr>
<td>Package first weeks work for execution, with instructions, material and drawings</td>
<td>A minus 1 week</td>
<td>Work packaging section with zone manager and Chief Test Engineer input</td>
</tr>
<tr>
<td>Start execution, hold plan of the days (POD’s) at least twice a week, first looking at what work should be complete to date, then at what work is to be packaged in the next three weeks.</td>
<td>A minus 0</td>
<td>PS, PEPM, Zone Managers, Work packager, CTE, Ship Force</td>
</tr>
</tbody>
</table>

Table 5.5: Time schedule projects.

The role of management at all levels, particularly the former shop superintendents, has changed dramatically in this new control structure. These managers used to supervise only workers of a single trade. Nowadays they have to manage multi-trade skill teams. This also holds for the zone manager and the foreman. In addition, the project managers are expected to shape the project personnel into a highly motivated, efficient team supporting the project cost, schedule, and quality goals.
5.4.4.3 The information structure

The four shipyards and their headquarters in Washington use an integral automated system called 'BAIM', which comprises all relevant data and schedules. The standards within NNS are kept in a 'component unit' (CU) BAIM database system. Based on these standards all planning and work execution products are developed. The CU's are used to develop 'job summaries' (a high-level description of the tasks required to accomplish a major job) and technical work documents. These documents are linked to generate a project schedule in the BAIM system.

This schedule is used to track and monitor the project progress. The project schedule is saved and accessible for the planning of subsequent projects. A later project team may call up the project and remove the schedule 'links' and any work not performed in its assignment. A new project plan may be built on this plan, for which an automated updating feature is incorporated in the BAIM system.

The BAIM system does not provide integral resource loads and automatic intelligent scheduling rules. Especially when priorities between the projects have to be made, this is felt as an important shortcoming.

5.4.5 Comparison with the design model

In this section we first consider the NNS process characteristics. Next, we compare the structure of NNS with the technological rules of our design model.

NNS is confronted with a moderate market uncertainty. NNS is quite certain about its work package in the upcoming years, in spite of the introduction of a strong customer-contractor relationship. The process uncertainty, on the other hand, can be qualified as high. The maintenance and overhaul of complex state-of-the-art warships is inherently uncertain. These maintenance objects are also responsible for a high material and capacity complexity. The overhaul and maintenance of these ships require many different spare parts and materials and various skills.

- The establishment of a process-oriented organisation
  By consolidating the original thirteen shops into five essential shops and introducing strong project management for the primary flow (the large overhaul process), NNS has established a process-oriented structure.

- The integration of non-physical and physical activities
  NNS integrated the non-physical and physical activities within a project team. This ensures a strong information exchange between the engineering, specification, planning, and scheduling, on the one hand, and the execution activity on the hand. During our visit it soon became clear that this strong project management approach highly benefited the overhaul process of an object.

- A three level planning structure
  Restructuring from a functional management style to project management, led to a reduction in mid-level managers (general foremen) and first-line supervisors (foremen) from 189 to 97 and 357 to 130, respectively. This downsizing, combined with significant cultural change in the shipyard, resulted initially in a strong resistance to the changes associated with the conversion to project management. However, NNS ultimately succeeded in establishing a structure with four organisational levels and three planning levels, and in this way eliminated unnecessary co-ordinating layers.

- A clear coherent planning hierarchy with a distinction between aggregate and detailed capacity
  The new structure comprises different planning levels, each with its own responsibility. For example within the project team, there is a PS, next come the zone managers, and finally the foremen. Each function has a clear responsibility regarding the various planning tasks. A striking property of the planning levels within NNS is the very strong position of the project team, especially when compared to responsibilities of the five shops. A project is always entitled to obtain its resources and may send them back whenever the work is
finished. It seems that the shops are confronted with a mission impossible, whenever they want to balance workload and resource availabilities. Therefore a more balanced responsibility assignment between projects and shops might benefit the usage of NNS resources. NNS uses a distinction between the high level planning whenever a project starts and the more detailed planning in the work specification phase. However NNS does not consciously make a difference between detailed and aggregate capacity.

- **The use of the portfolio management methodology**
  Every week there is a briefing on the progress of the various projects with the general director of NSS, the project superintendents, and the department heads. This meeting may be considered as a portfolio management meeting. However, the strong single project orientation and a lack of integral resource loads overviews (i.e. multi project scheduling) rules out a consultation as meant in Chapter 4.

- **The use of multi-disciplinary teams at the micro level**
  Important elements of working in teams, which was perceived positively by the workers, are the improved planning, scheduling, and execution processes. It ensures that the work space is available, all tooling and material is on hand, trade skills and technical support are available, system isolation has been set, and work documents are provided before the work is released to the worker. However due to the frequent changing of team members, the teams within NNS will never be able to incorporate responsibilities and competencies as meant in the multidisciplinary team concept of Chapter 4. This concept may increase the problem-solving capabilities of the workforce. Although NNS must accept a loss of flexibility it seems profitable to reconsider the use of the team concept.

- **The use of information technology as an enabler**
  NNS uses a large, company-wide information system. It provides good features for the storage of standards, single project scheduling, and resource load surveys. However it does not provide a multi-project scheduling feature. For a company that puts so much emphasis on project management such a system would be a powerful tool. In addition it would enable a more balanced responsibility between the projects and the shops, by providing integral overviews of resource loads.

### 5.4.6 Conclusions
Elements of the design model are clearly present within NNS. Examples are the process-oriented structure, the introduction of project management for the dominant order flow, and a hierarchical planning. However, the strong emphasis on the project teams' competencies and responsibilities may lead to an inadequate use of the available resources. The introduction of a portfolio management methodology and the use of an integral macro level scheduling tool may improve significantly the process control of NNS.

### 5.5 Smit Transformatoren BV

#### 5.5.1 Introduction
The fourth case study is related to an engineer-to-order (ETO) company, i.e. Smit Transformatoren BV. We include this case study due to the high similarity between LSMO and ETO processes. In general both processes have a high uncertainty level regarding the product characteristics and a large customer influence on the company process. The Smit case indicates whether this similarity justifies the use of the design model in an ETO environment.

Smit Transformatoren BV was established in 1913. Since its beginning it has played an active role in the development and manufacturing of large power transformers and reactors (see Photo 5.4). The product range of
Smit includes ratings up to 1000 MVA, with voltages up to 525 kV, and insulation levels of 1550 kV BIL (= Basic Insulation Level). The manufacturing plant is located in Nijmegen, in the eastern part of the Netherlands. Smit Transformatoren employs approximately 320 people, among which 200 so-called blue-collar workers (including engineering) and 120 white-collar workers. Depending on capacity demands, hiring temporary employees can expand the workforce. Although temporary, more than 100 persons work on a more or less permanent basis, with a one to three years flexible contract. The yearly turnover of Smit is 10000 MVA (total amount of volume produced) and 140 million Netherlands guilders (NLG).

5.5.2 The market developments of Smit Transformatoren

Smit's main markets are located in Europe and the United States. Customers are mainly electricity companies, which use transformers in production or distribution processes. The strength of Smit lies in the manufacturing of engineer-to-order applications and not in the standardised applications. Therefore almost every order leads to a unique product. Of course a similarity exists with respect to the constructed parts of the different transformers. The product features make Smit Transformatoren an engineer-to-order company. The size of the transformers varies from 50 kVA to 850 MVA. The price of a transformer depends on its size (this relates to the number of working hours needed in manufacturing) and the specific technology (the amount of engineering) needed. To give an idea of a transformer's price: the price for a custom made 500 MVA transformer is approximately 8 million NLG.

 NOT AVAILABLE IN THIS VERSION

Photo 5.4: Large transformer manufacturing at Smit Transformatoren BV.

In 1997, Smit Transformatoren introduced an integral improvement program. Changing customer attitudes mainly caused the need for this improvement program. As already mentioned, the market of Smit primarily consists of electricity producers and distributors. These companies used to be government owned and protected. Due to the liberalisation of this 'electricity producing and distributing market', Smit's customers are no longer focused only on quality aspects only, but also on lead time reduction, an excellent due date performance, and low prices. This changing customer attitude caused a drastic shortening of the planning horizon of electricity companies: from approximately twenty-five years to periods of three to five years. As a consequence, costs gained significant importance. The reduced horizon also resulted in a demand for reduced lead times and reliable due dates. These changes made it impossible for Smit to rely any longer on 'easy market circumstances' (the sellers market changed to a buyers market).

Besides this general market change, Smit had to recover from an unsuccessful attempt to establish a manufacturing plant in the United States, which turned out to be a failure, partly due to a lack of common opinion on strategic goals. Halfway the nineties, the company decided to reconsider its strategy and to close the USA plant.

5.5.3 The mission statement of Smit Transformatoren

At the breaking point halfway the nineties, the company made a plan of action, to ensure continuity by improving the output. The starting points of this plan are considered a mission statement of Smit Transformatoren. A result of the plan of action is an already mentioned integral improvement program called 'Operation Green Wave'. This program aims for improvements in time (due date performance and time to market intervals), financial performance (output and turnover rates), and quality aspects (reducing number of alterations and 'doing it right the first time'). To achieve these targets, three action programs were initiated: an 'anatomical survey' program, product data management, and finally a theory of constraints program [Goldratt
In the anatomical survey, the different processes within Smit were analysed. Product data management concentrates on optimising technical and commercial product data control, and improving manufacturing processes, products, automated systems, and people. The theory of constraints is used as a basis for the development of a customized production control system. Operation Green Wave started halfway 1997, and is foreseen to end at the start of the year 2000. In the description of the different processes within Smit, we use interim results of this improvement program.

5.5.4 The organisational structure of Smit Transformatoren

5.5.4.1 The production structure

In the actual manufacturing process of a transformer we can distinguish five distinct constructional activities: the tank, the winding, the active part, the core transformer, and finally the secondary installation. In the production structure of Smit, two main flows can be distinguished: ‘make to order’ and ‘engineer to order’. The small transformers are manufactured in the ‘make to order’ flow. This is a flow with standardised transformers, which do not need engineering work, and yield a sufficient workload to employ a group of employees throughout the year. Besides this, the manufacturing process of small transformers needs its own specific equipment. Therefore Smit has set up a separate section for these transformers: the NF section. In this section all manufacturing activities, except the tank construction, are incorporated. The tanks for these small transformers are purchased at an external company.

For the actual manufacturing of ‘make to order’ and ‘engineer to order’ large transformers, Smit set up three departments: the electrical department, the tank fabrication, and the assembly department. The electrical department is subdivided into the following groups: the winding section, the core manufacturing, the wood shop, and the inside tank manufacturing group. The subdivision of the tank fabrication is as follows: tank manufacturing, parts production, surface protection, and mechanical calibration. The design and subdivision of these flows characterises Smit’s production structure as process-oriented. As early as 1982, Smit chose for this process-oriented approach; this approach has been tuned to the essential structural elements of a transformer.

The difference between the ‘make to order’ and ‘engineer to order’ flow consists of the amount of engineering needed. In the ‘make to order’ flow, a customer usually orders a series of transformers. Only the first one will need extensive engineering efforts (and therefore is allocated to the ‘engineer to order’ flow). The remaining part of the series does not need extensive engineering, and can be manufactured without extensive consultations between the production and engineering departments. Figure 5.9 displays a view on the production flow for the manufacturing process of an ‘engineer-to-order’ or ‘make-to-order’ transformer.

In an ‘engineer to order’ process, engineering plays an important role. For this purpose, Smit set up a separate engineering department. Four different sections are located within this department. Two sections are primarily concerned with transformer design: design/development and construction. The first section is concerned with basic engineering: the design of the transformer’s active part. After the completion of this global design, the construction section performs basic engineering of the tank and secondary installations, as well as the complete detailed engineering. For this purpose, Smit subdivided construction engineering into tank construction, active part construction, and finally secondary installations. It is obvious that a tight interaction between the global and detailed engineering is needed. This interaction is also emphatically present during the manufacturing process.
Supervisors from the manufacturing section meet on a regular basis to discuss the manufacturing progress of a specific transformer.

The other two sections within engineering comprise the projects department (project management, secretary's office, documentation centre, price calculation, and transport) and the testing department. Project management
is involved from the quotation process until the delivery of a transformer to the customer. Almost always this includes on-site installation and start-up of the transformer. The price calculation section is specialised in making an offer based on customer specifications. Smit uses a separate transport specialist to co-ordinate the transport of a transformer from the manufacturing plant to the customer; in view of the size and weight of the transformers, the means of transportation need specific attention.

![Organisation structure](image)

Figure 5.10: Organisation structure Smit Transformatoren (270897).

A separate department has been set up for marketing and sales purposes. Through this department, Smit carries out active order procurement in the different market segments. The sales department is subdivided into marketing, sales AB-trial, sales Benelux, sales USA, sales Germany, export, and repair/maintenance/service.

Sales offices are established in the USA and Germany. For sales outside these regions a general section ‘export’ has been established. Besides this sales section, marketing and sales contain a business development section (which has to recognise trends in customer demands) and a maintenance selling service. Finally, we can distinguish the activities financial management, quality and environmental control, and personnel management.

These activities are distinct supporting activities within the production structure. Figure 5.10 shows the organisation structure of Smit.

5.5.4.2 The control structure

Within the management structure each department and subsection has its own responsibilities regarding work acceptance, process planning, execution, and due date performance. Due to the high emphasis on flexibility, the management of Smit even considers the delegation of control to have gone too far. With the introduction of the ‘Green Wave’ improvement program, the company tries to identify the different flows and then again to delegate tasks, but now based on a clear establishment of these flows. The process-oriented production structure benefited the organisation by achieving high levels of flexibility and decisiveness. On the other hand, due to this flexible and decisive structure, new agreements with the customers were not recorded properly. With the implementation of a more independent management structure with clear responsibilities and competencies at each level, Smit wants to maintain flexibility and decisive action and at the same time achieve a planning hierarchy in which, for example, design alterations, internal and external due dates, and lead times are clear for every employee.
The planning and control, from order acquisition until evaluation and service, are carried out at meso level by the management team. The macro level is only used for strategic and tactical consultations. Before a new order is accepted, the availability of the critical resources is roughly verified. The automated tools laboriously provide the management with the necessary resource load overviews. It is the intention of Smit to accept every new order. Hiring temporary employees may solve problems with resource shortages. Another possibility is to expand the number of working hours by working in two shifts for certain departments; already three departments structurally work in two shifts. In addition it is also possible to exchange work between departments in the case of a resource shortage within a specific department. A limiting factor is usually the availability of specific production facilities (for example the drying docks for transformers). During the execution of the work, approximately ten resources have the potential to become critical. Which one ultimately becomes critical depends primarily on the actual order mix. For example, in case of an order mix with many large transformers, the floor area of the various departments is the critical factor. For production planning and control purposes, Smit is developing a customised theory of constraints (TOC) application [Goldratt (1984)].

Smit has established a set of performance indicators to measure the relevant process parameters. Important indicators are due date reliability, time-to-market intervals, costs, and quality. For example the latter one is measured in the number of changes in engineering documents during the execution phase and in the number of 'first time right' realisations. Objectives for these indicators are a decrease from 300 changes in the beginning of 1998 to approximately 30 changes by the end of 1999 and an increase in the percentage of 'first time right' realisations from 87% to 95% in the same timeframe.

5.5.4.3 The information structure
At the company level a relatively simple spreadsheet program is used to gain insight in the workload for the different resources. Based on this schedule new orders are accepted. The different sections within Smit (i.e. engineering and the various sections within production) make up their own workload schedule. An automated system registers the individual work order progress.

5.5.5 Comparison with the design model
In this section, we first briefly consider the characteristics of Smit Transformatoren. Next, we compare the structure of Smit Transformatoren with the technological rules of our design model.

The market uncertainty of Smit is high. Smit is a commercial company that has to compete with other companies on the market for large transformers. The process uncertainty varies between medium and high. Especially transformers with new specifications cause the uncertainty within Smit’s processes. These orders require extensive engineering efforts and sometimes changes in the execution phase. Smit tries to reduce this uncertainty by introducing a certain level of standardisation in its transformer design. However, specific customer wishes will always occur. A transformer type that has already been produced in the past causes in general less uncertainty. The manufacturing process for a series of transformers gets in the end a ‘make-to-order-character’. The building process for a transformer is characterised by an average capacity and material complexity.

- **The establishment of a process-oriented organisation**
  The turnaround of Smit’s market into a real sellers market forced Smit to introduce a highly flexible process-oriented structure. We experienced in our case study the awareness of Smit’s management that this is the only way to ensure the continuity.

- **The integration of non-physical and physical activities**
  In the engineer-to-order flow the design of a transformer plays an important role. For this purpose Smit established a separate engineering department. However, the nature of the manufacturing process demands a close interaction between the employees who build the transformer and the engineers. The informal culture
The Follow-up Case Studies

at Smit encourages this close interaction between engineering and production. The work specification, resource planning, and scheduling is done within the various resource departments. In this way, Smit has integrated the non-physical and physical activities.

- **The different planning levels in a coherent hierarchy**
  Each level has its own planning responsibilities and competencies. Smit introduced this planning hierarchy to achieve a highly flexible structure. The management even feels that this delegation of tasks gets out of hand, since the company process flows becomes somewhat invisible. By performing a survey of the company process (i.e. the anatomical survey) the primary flows were identified. At the moment, Smit is visualising these flows in the process structure and establishes a coherent three level planning hierarchy. The meso level only uses detailed capacity overviews for resource scheduling. The various departments and sections perform the detailed scheduling. The match between the aggregate and detailed capacity overviews is made at the meso management level.

- **A three level organisational structure**
  The aim for flexibility also led to a flat organisation with short communication lines. Within Smit Transformatoren there exist three organisational levels: the management level, the production group managers, and finally the shops.

- **The use of portfolio management methodology**
  The meso level operational management is a form of portfolio management. In spite of the arduous support of existing automated tools, the management of Smit seems to succeed in balancing the workload and resource availability. A qualitatively better support of the automated systems would improve the result of this consultation process.

- **The use of multi-disciplinary teams at the micro level**
  Smit does not explicitly use the multi-disciplinary team concept in its business process concept. However the case study pointed a high responsibility and competence level of the various production groups. For example the wood shop determines its resource availability, accepts new work, and makes agreements on the due dates. This is due to the aim for a high flexibility level. It seems beneficial to give the team concept more direct attention. This provides the company with a further improvement of the workforce’s problem solving capabilities. The breeding ground for this concept is in any case present at Smit.

- **The use of information technology as an enabler**
  Smit Transformatoren exploits a number of automated supporting tools. These tools are general home-made systems that only record the resource loads and have no intelligent scheduling capabilities. In view of the achieved results with the improvement it seems necessary to obtain more appropriate automated support. Smit Transformatoren is already taking its bearing to determine which systems are suitable for its organisational structure. In our view the most important criterion in this selection process is the possibility to perform intelligent multi-order scheduling with decision support features at the various organisational levels. The introduction of a coherent structure of automated systems, that incorporates such a feature, would benefit and speed up the improvement program.

### 5.5.6 Conclusions

Smit used an improvement program called ‘Green Wave’ to improve production control. Many elements of this approach are similar to the features of the design model. For example the search for order flows, the division in parallel flows, and the establishment of a clear planning hierarchy are present in both approaches. Also the characteristics and the approach of Smit Transformatoren confirm the resemblance between the LSMO and ETO environments. Therefore, a further testing of the design model in ETO companies may be promising. In
the coming period, the biggest challenge for Smit Transformatoren lies in the introduction of appropriate supporting automated tools. In view of Smit’s current control approach, it seems it would highly benefit from a system such as the DSS.

5.6 A cross case analysis

Table 5.6 presents for each case the characteristics and the presence of the technological rules from the design model. The reader should be cautious in interpreting the values from Table 5.6. They are relative values that are only to be used to compare the different cases.

<table>
<thead>
<tr>
<th>Analysis Criteria:</th>
<th>Market Uncertainty</th>
<th>Process Uncertainty</th>
<th>Material Complexity</th>
<th>Capacity Complexity</th>
<th>Process-oriented structure</th>
<th>Integration of non-physical &amp; physical act.</th>
<th>A three level planning structure</th>
<th>Coherent planning hierarchy</th>
<th>Use of portfolio management</th>
<th>Use of multi-disciplinary teams</th>
<th>Use of IT as an enabler</th>
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<td>The Cases:</td>
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Table 5.6: The cross-case analysis.

We included for the RNND Dockyard both the initial and the design situation. This table shows that all companies have established (or in the case of the RNND will establish) a process-oriented structure. Also, our visits to these companies showed that a process-oriented structure is a necessity to achieve high customer service levels. Especially Smit Transformatoren has incorporated many of the essential elements from the design model. An important explaining factor is the high market and process uncertainty of this company. In addition, Smit Transformatoren has always been a commercial company and was probably confronted with changing markets in an earlier stage.

Another important conclusion drawn from Table 5.6 is that the portfolio management methodology is practically not used in any of these companies. However, every company admitted that it would like to use this methodology to some extent. Especially the companies with a high uncertainty level were very interested in the methodology and the related DSS. It seems that the absence of proper information systems prevents a structural use of a macro level planning. In every company macro level planning is done with self-made spreadsheet files.
We strongly believe that the use of portfolio management and the DSS would benefit the macro level planning capabilities of these companies tremendously.

Another possibility for improvement is an extension of the multidisciplinary team concept. All companies admit that the incorporation of control tasks in the workforce increases the company flexibility and promptness. As every company has established a coherent three level planning hierarchy (a necessity for a sound incorporation of control tasks within the teams) the extension of the team concept would ultimately improve the company’s performance.

### 5.7 The applicability of the design model

The survey in the previous section shows that every case has to some extent implemented elements from the design model. In none of the cases we have discovered a full implementation of all technological rules. While MCW’s design process is similar to ours, their operational and management structure resembles to a large extent the production structure of our model. Other companies have implemented technological rules based on actual control problems or the use of other management approaches (e.g. the implementation of a strong project management approach in NNS). We have detected in none of the cases that it was not beneficial to use one of the technological rules. Most companies even admitted that a full implementation of the rules would probably benefit the company performance.

Based on these observations we cautiously conclude that our design model indeed benefits non-flow LSMO’s and that an extension to the ETO-companies might be possible. However, we must also conclude that due to the small range of this multiple case study it is not possible to claim a sufficient level of theoretical saturation. In our research we have only achieved a limited degree of saturation by showing the applicability of our model in a primary case and four follow-up cases. The limited range of this case study was due to the size of the primary case and the availability of follow-up cases. Further research is recommended by extending the follow-up case study to other LSMO’s and ETO-companies.

We conclude from the multiple case that we have found no evidence that our design model is not applicable to non-flow LSMO’s in the research domain. In addition, we have found clues that the model might also be applicable to ETO-companies. For a sufficient level of saturation, however, it is necessary to extend the multiple case study.
Chapter 6

6. Discussion

6.1 Introduction

In the last phase of the problem-solving cycle we reflect on the research results (see Figure 6.1). The essential research issue discussed in this thesis, concerned ways to improve the controllability of non-flow LSMO's. In this chapter we review the research approach, research activities, and research results, and provide recommendations for further investigations. Therefore, we first briefly consider the research starting points, including the problem definition and the research objectives. Next, we discuss the research approach and activities. From there we move to the multiple-case study. First, we consider the primary case of the Royal Netherlands Dockyard (RNND). The achieved results and the expected improvements are reviewed. Subsequently, we consider the results of the follow-up case studies. Finally, we analyse the applicability of the design model for LSMO's within the research domain. In addition, we summarise the improvements to be expected when applying the model to an LSMO. This chapter concludes with recommendations on further research.
6.2 The problem and the research objectives

The crucial characteristic of a non-flow LSMO is the uncertainty with respect to the timing, the size, as well as the actual work contents of each customer order. In the worst case the actual work contents does not become fully known until the work execution phase. In combination with tight customer demands this uncertainty characteristic inevitably leads to a controllability problem. A survey of the literature revealed no available design model that is able to deal with the specific LSMO controllability issue. So the central problem in our research is the absence of a design model that provides non-flow LSMO’s with tools to achieve a sufficient controllability. A sufficiently controllable maintenance system should allow for a flexible and prompt process, yielding products or services satisfying time, costs and quality constraints. Following this problem definition, we defined the objectives of the research project as to develop a design model for a class of non-flow LSMO’s that is able to sufficiently improve the controllability.

6.3 The research design

We selected the design science approach for developing design knowledge. This knowledge should provide heuristic technological rules for improving the controllability of a specific class of LSMO’s. The knowledge is developed by means of a multiple case study.

In a problem-solving cycle we first defined the problem and subsequently created a design process based on an eclectic selection of available organisation theories. This design process was next used in a primary case study, resulting in a model that might improve the controllability within this case. To test and predict whether the application of these rules would really improve the primary case’s controllability, we performed several real-life tests. Subsequently, we generalised the primary case model by extracting its essential characteristics. In this way we developed a design model for the non-flow LSMO’s of the research domain. This model consists of a set of heuristic technological rules (i.e. rules with a qualitative format that provide a baseline for specific cases). The next issue in the research design concerns the general applicability. To test the applicability of the design model we carried out four follow-up case studies. This set of cases should provide the first steps in achieving theoretical saturation of the design model. The last step in the research domain is the reflection on the results of the multiple case study.

6.4 The results of the multiple case study

In this section we elaborate on the conclusions of the multiple case study. First we discuss the results and achievements within the primary case: the Royal Netherlands Navy Dockyard (RNND). We include a summary of the design model characteristics. Next, we move to the test of the design model in four follow-up cases. Based on the results of this test, we consider the general applicability of the design model, which is discussed in the next section.

6.4.1 The primary case: the RNND

We designed a new organisational structure for the RNND with the use of the Integral Organisational Change approach. We successively investigated the RNND environment and the company itself, determined the RNND’s goals, and finally designed a new organisational structure. We concluded the primary case with a real-life test of essential elements from the new organisational structure. These results provided the basis for a prediction of the expected improvements after the implementation of the new model. In addition, we generalised the result of the primary case into a design model for a class of LSMO’s.
The organisational structure is based on a top-down design of the production structure, a bottom up design of the control structure, and finally the design of the information structure. Figure 6.2 depicts the general structure of an LSMO. The characteristics (i.e. the heuristic technological rules) of the design model can be formulated as:

1. The establishment of a process-oriented organisation
2. The integration of non-physical and physical activities;
3. A three level organisational structure;
4. A coherent planning level hierarchy, based on aggregate and detailed capacity profiles;
5. The use of the portfolio management methodology;
6. The use of multi-disciplinary teams at the micro level;
7. The use of information technology as an enabler.

We claim to achieve the following improvements by implementing these technological rules within the RNND:

1. An improved flexibility and promptness;
2. An improved performance and efficiency;
3. An improved employee satisfaction;
4. An improved controllability.

It is not possible to uniquely relate one technological rule to one specific improvement. It is merely the integral implementation of the technological rules that is responsible for these improvements. For example, the flexibility and promptness improvement is a result of all technological rules.

![Figure 6.2: A general organisational structure for LSMO’s.](image)

### 6.4.2 The follow-up cases

In four cases we tested the general applicability of the design model. The test showed the presence of several characteristics of the design model in the different companies. In addition, a discussion with the management of the various companies indicated that the implementation of absent technological rules might well benefit the company in question. Based on these results we cautiously conclude that the design model indeed benefits non-
flow LSMO’s and that an extension to ETO-companies might be possible. At the same time, we note that due to the small range of cases studied it is not possible to claim a sufficient level of theoretical saturation. In this study we have only achieved a limited degree of saturation by showing the applicability of our model in four follow-up cases.

6.5 The applicability of the design model

As mentioned in the strategic choices of Chapter 1, we aim for theoretical saturation with respect to the statements on the effects when applying the design model. In view of the small range of follow-up cases, we have, however, achieved only a limited degree of saturation. It seems worthwhile to further extend the application of the design model to LSMO’s outside the military maintenance organisations. However, the results of the follow-up case studies supported the heuristic technological rules of the design model. On the one hand many characteristics (rules or part of rules) were already present in each particular case, while on the other hand we had strong clues that implementation of absent rules would benefit the company. We therefore conclude that the result of this study in general is applicable for non-flow LSMO’s within the research domain. When applying the design model, the technological rules have to be customised with the use of the process design from Chapter 2. This provides an integral re-engineering approach that diminishes the danger of omitting specific company characteristics. The application of the design model in other cases will eventually lead to the desired level of theoretical saturation.

6.6 Recommendations for further research

In reflection, several issues deserve further research. First, we mention the theoretical saturation of the design model. In this research project we obtained evidence that the technological rules from the design model indeed improve the controllability of LSMO’s. Examples include the improvement of the efficiency and customer satisfaction of the multidisciplinary team ‘small vessels’ within the RNND. Also the presence of various technological rules in the follow-up case studies supported the claim for a better controllability. In this respect we mention the results of the establishment of clear process-oriented flows within WBA and NNS, the achievements of the multidisciplinary teams within MCW, and the use of a simple form of portfolio management at Smit Transformatoren. However, to obtain theoretical saturation it is necessary to expand the follow-up case studies. For instance, a possible extension concerns large scale maintenance operations in large industrial enterprises like steel manufacturing companies. Ultimately, this may lead to the desired level of theoretical saturation.

Second, some technological rules need further testing to really show their improvement capabilities. In this respect we especially recommend a full test of the portfolio management methodology in combination with the prototype DSS. During our research project it was not possible to test the DSS on the entire RNND workload. A full test may prove the systems capabilities and enable the benefits of real portfolio management.

Also the multidisciplinary team concept in organisations with a high uncertainty and an unstable workload needs further research. Due to flexibility reasons exchange between the various teams or the creation of temporary teams is a necessity. At the RNND the first steps in creating such teams have been taken. In line with this initiative, further research on the possibilities to still benefit from the team concept and at the same time to ensure flexible resources is advisable.

The last recommendation is to further integrate quantitative and qualitative research. This thesis describes only the qualitative part (i.e. a design model for LSMO’s) of the total research project. De Boer (1998) describes the
quantitative part (i.e. the development of a prototype DSS). During the research project the synergy between these approaches clearly provided better results. The DSS enables the portfolio management methodology, while the DSS itself indeed incorporates the features of a multi-order planning system. We strongly believe that also future research might benefit from this synergy.
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11. Samenvatting

Dit proefschrift beschrijft een onderzoek naar een organisatiemodel voor grotere onderhoudsbedrijven (tenminste 150 medewerkers) met een hoge mate van onzekerheid in de samenstelling en omvang van het werkpakket. De primaire taak van deze bedrijven is het onderhouden, repareren en modificeren van technische systemen. De genoemde onzekerheid speelt daarbij een dominante rol in de beheersbaarheid van de bedrijfsgeschiedenis. Deze onzekerheid manifesteert zich in de samenstelling en omvang van het werkpakket, maar ook in het moment van optreden, de aard en de werkinhoud van een individuele opdracht. Dit kan zelfs in de uitvoeringsfase nog tot verrassingen leiden.

Net als andere productiebedrijven, ervaren ook onderhoudsbedrijven een steeds grotere druk om flexibel en slagtwaardig, een kwalitatief goed product of dienst te leveren. Helaas zijn de vaak traditionele, functionele georiënteerde bedrijfsstructuren niet in staat adequaat op deze stringente marktveranderingen te reageren. Dit resulteert onvermijdelijk in de noodzaak de huidige organisatiestructuren te heroverwegen. Helaas biedt de bestaande literatuur over reorganisatievernieuwing deze bedrijven te weinig houvast. Binnen deze bedrijven bestaat de behoefte aan een ontwerpmethode die met name rekening houdt met de onzekerheidsfactor en de daarmee gepaard gaande beheersingsproblematiek. Dit ontwerpmethode moet deze bedrijven concepten, hulpmiddelen en technieken aanbieden, welke hen in staat stellen binnen de randvoorwaarden tijd, kosten en kwaliteit, flexibel en slagtwaardig te produceren.

Voor de ontwikkeling van het ontwerpmethode heb ik eerst een ontwerpproces gedefinieerd. Dit ontwerpproces is gebaseerd op bestaande managementtheorieën. In een omvangrijke praktijkstudie is met behulp van dit ontwerpmethode een nieuw organisatieontwerp ontworpen. Vervolgens zijn de resultaten van dit specifieke organisatieontwerp gecombineerd met een generiek ontwerpmethode. Dit model bestaat uit een verzameling van technologische regels die bij toepassing moeten leiden tot een verbeterde beheersbaarheid. Om te controleren of deze regels inderdaad de beheersbaarheid van genoemde bedrijven verbeteren, hebben we het generische model getoetst in een aantal kleinere praktijkstudies. Uiteindelijk moeten deze praktijkstudies leiden tot een theoretisch verificatieniveau, waarbij er vanuit gegaan mag worden dat het model inderdaad de beheersbaarheid van bedrijven uit het onderzoeksdomein vergroot.

Daar functionele georiënteerde structuren niet geschikt zijn voor de bedrijven uit ons onderzoeksdomein, hebben wij gekozen voor een procesgerichte structuurbenadering. Deze benadering stelt bedrijven in staat om een grote variëteit aan producten en diensten snel en flexibel te leveren, waarbij sneller gereageerd kan worden op technologische veranderingen of veranderingen in de markt. In dit onderzoek is het ontwerpproces voornamelijk gebaseerd op de 'Nederlandse sociotechniek'. Deze zogenaamde 'integrale organisatievernieuwing' bestaat uit vier ontwerpstappen. De eerste stap omvat een diagnose en onderzoek van de bedrijfsomgeving. Hier worden de eisen vanuit de markt en mogelijk kansen voor het bedrijf onderzocht. Aansluitend volgt een interne diagnose van het bedrijf. De volgende stap baseert zich op deze diagnose door te definiëren waar de uitdagingen en kansen voor het bedrijf liggen: ofwel de missie van het bedrijf. Het ontwerp van de organisatie vindt plaats in de derde stap. Allereerst worden van hoog naar laag niveau de activiteiten gedefinieerd in het primaire proces die nodig zijn om de vereiste producten en services voort te brengen (de productiestructuur). Vervolgens vindt in
omgekeerde volgorde de opbouw van de besturingsstructuur plaats, door de coördinerende regelkringen te ontwerpen. Ten slotte komt de informatiestructuur aan bod waarin de informatiestromen en daarmee verbonden geautomatiseerde systemen in kaart worden gebracht. De laatste stap omvat de implementatie van het organisatiemodel.

De initiële omvangrijke praktijkstudie is uitgevoerd bij de Rijkswerf te Den Helder. Dit is het onderhoudsbedrijf voor de romp, werktuigkundige systemen, energiesystemen en elektrische bewakingssystemen van marineschepen. De bedrijfsvoeringsproblemen bij de Rijkswerf werden veroorzaakt door veranderende klanteneisen. Door een veranderende defensieorganisatie kwam de nadruk steeds meer te liggen op flexibiliteit en tijdigheid. Door de sterk functionele organisatiestructuur had de werf steeds meer moeite om aan deze zwaardere eisen te voldoen. Aanvankelijk dacht men door de introductie van nieuwe geautomatiseerde systemen deze problemen op te kunnen lossen. Echter de uitkomsten van een onderzoek naar de aard van de problematiek gaven aan dat de sterk functionele scheiding, met name tussen de voorbereidende en uitvoerende activiteiten, en een splitsing van het productieproces in negen sterk gescheiden sequentiële stappen, de diepere oorzaak vormden. Vervolgens heeft een projectteam met behulp van het ontwerpmodel een nieuw organisatiemodel voor de werf ontwikkeld. Relevante delen van dit model zijn vervolgens getest binnen de werf. Deze testen omvatten onder andere de toepassing van multidisciplinaire teams, het gebruik van project management inclusief zonetotechniek, de toepassing van portfoliomanagement en het gebruik van een prototype beslissingsondersteunend systeem voor het macroniveau operationele planning. De uitkomsten van deze testen waren duidelijk positief dat de werf uiteindelijk heeft besloten het nieuwe model integraal in te voeren. Voor de ontwikkeling van het ontwerpmodel voor onderhoudsbedrijven is het ‘werfmodel’ veralgemeneerd. Dit resulteerde in zeven technologische regels waarvan de toepassing een verbeterde beheerbaarheid moet opleveren. In de volgende alinea’s bespreek ik kort de inhoud van deze regels.

Allereerst is het voor de onderhoudsbedrijven uit het onderzoeks domein essentieel dat ze gebruik maken van een procesgerichte organisatie. De coördinatie- en organisatie is in een functioneel gerichte organisatie te hoog om snel en flexibel te reageren op veranderende omstandigheden. En dit laatste is nu eenmaal een gegeven in dit soort bedrijven.

In de tweede plaats is een integratie van de voorbereidende en uitvoerende activiteiten belangrijk. Daar iedere onder in dit soort productieprocessen vrijwel uniek is ligt er een sterk nadruk op de voorbereidende activiteiten. Door de uitvoerende en voorbereidende processen te integreren, kan enerzijds de kennis van de uitvoering worden gebruikt in de voorbereiding en kan anderzijds de uitvoering anticiperen op de komende werkzaamheden. Ook bij eventuele uitvoeringsproblemen is een geïntegreerde voorbereiding en uitvoering bevorderlijk voor de bedrijfsvoering.

Een beheersingsstructuur die bestaat uit drie niveaus is het onderwerp van de derde regel. Door alle beheerstaken op het laagst mogelijke niveau te plaatsen en alleen taken op een hoger niveau te plaatsen als de consequenties en reikwijdte van eventuele beslissingen niet kunnen worden overzien op het lagere niveau, is een beheersstructuren van maximaal drie niveaus ontstaan.

De vierde regel schrijft voor dat een duidelijke planningshiërarchie dient te worden gehanteerd, meer specifiek voor de capaciteitsplanning. Daarbij dient een onderscheid te worden gemaakt tussen de initiële capaciteitsplanning op een hoog aggregatieniveau, en de detailplanning op een lager niveau. Tussen deze twee vormen van capaciteitsplanning vinden we de werkvoorbereiding. De aldus aangebrachte planningshiërarchie dient te voorzien in duidelijke aanmerken waarbinnen ieder organisatieniveau voldoende speling heeft om zelf te kunnen beslissen over de reactie op mogelijke verstorenden, mits binnen bepaalde grenzen. Op deze wijze wordt verzekerd dat niet elke kleine verstoring op een laag niveau onmiddellijk doorwerkt op de planning op datzelfde of een hogerliggend niveau. De planningshiërarchie onderscheidt twee vormen van capaciteit.
Allereerst kennen we de aggregaatcapaciteit waarin de beschikbare capaciteit wordt weergegeven op basis van de verschillende vaardigheden, rekening houdend met eventueel aanwezige multidisciplinariteit, in totale aantallen uren. Met behulp hiervan kan snel, maar grof, worden ingeschat of mogelijkerwijs extra capaciteit dient te worden verworven (uitbesteden, inhuur, overwerk). De tweede verschijningsvorm van capaciteit ontstaat nadat het werk daadwerkelijk is toegewezen aan de verschillende medewerkers, en leidt tot het gedetailleerde capaciteitsoverzicht. Het is van belang dat beide verschijningvormen naast elkaar, maar onderscheiden kunnen worden gehanteerd, zodanig dat een toegewezen aggregaatcapaciteit na een gedetailleerde werkvoorbereiding omgezet kan worden in een gedetailleerde capaciteitstoezijwing. Op deze wijze ontstaat een beheerste en consistente capaciteitsplanning.

De vierde regel omvat het gebruik van de portefoliomanagement methodiek voor het macroniveau operationele planning. Op dit niveau komen de vraagers en aanbieders bij elkaar om te beslissen over de mogelijke portfolio's. Het is belangrijk om in een multi-order situatie een eenduidige afweging te maken tussen de verschillende soms tegengestelde belangen. Uiteindelijk moet dit leiden tot een voor de gehele organisatie duidelijke prioriteitsstelling tussen projecten, orders en capaciteitsgroepen.

Het onderwerp van de zesde regel is de toepassing van multidisciplinaire teams op het laagste organisatieniveau. Door binnen een team zoveel mogelijk voorbereidende, plannings- en uitvoerende taken te integreren, wordt het probleemoplossend vermogen van een organisatie aanmerkelijk vergroot. Voor de flexibiliteit en slaggrootheid van een onderhoudsbedrijf is dit van wezenlijk belang.

De laatste regel omvat de noodzaak om gebruik te maken van de mogelijkheden die moderne geautomatiseerde systemen bieden. Reeds bij het ontwerp van de organisatiestructuur moet men zich vergewissen van deze mogelijkheden. De elementen van een informatiestruktuur bestaan in de kern uit de systeemsoftware, vervolgens uit toestandsafhankelijke software, daarna de toestandsafhankelijke software en uiteindelijk de beslissingsondersteunende systemen. Het onderzoek heeft uitgewezen dat met name passende systemen uit de laatste categorie de verwezenlijking van de portefoliomanagement methodiek bevorderen.

Deze zeven technologische regels zijn vervolgens getest in vier praktijksituaties. Achtereenvolgens zijn het goederenwagon-onderhoud van de Nederlands Spoorwegen, het onderhoudsbedrijf voor materieel van de Koninklijke Landmacht, een scheepsonderhoudsbedrijf van de Amerikaanse marine en ten slotte een fabricagebedrijf voor transformatoren bezocht. Het laatste bedrijf is een zogenaamd 'engineer-to-order' bedrijf, oftewel een bedrijf dat produceert op klant specificatie. Deze praktijkstudie is toegevoegd vanwege de grote overeenkomsten tussen het onderzoeksdoel en dit soort bedrijven.

Het resultaat van deze praktijkstudies gaf aan dat het merendeel van de genoemde regels in meer of mindere mate reeds aanwezig was binnen deze bedrijven. In een aantal gevallen heb ik voorzichtig geconcludeerd dat toepassing van een bepaalde regel het betreffende bedrijf voordelen zou opleveren in de bedrijfsvoering. Daarnaast heb ik geconstateerd dat in sommige bedrijven één of meerdere regels niet zo expliciet aanwezig dan wel toegestaan dienden te worden, als gevolg van bijvoorbeeld een technisch minder gecompliceerd onderhoudsobject. De laatste praktijkstudie bevestigde het vermoeden dat genoemde regels ook binnen engineer-to-order omgevingen toepasbaar zijn. Echter, gezien de omvang van de praktijkstudie is het voor een aflopende toetsing vereiste niveau van 'theoretisch verzoekiging' nog niet bereikt. Daarvoor is een verdere toetsing van het model naar andere onderhouds- en engineerto-order bedrijven noodzakelijk.

Ten slotte wil ik nadrukkelijk aanbevelen om ook in de toekomst kwantitatief en kwalitatief onderzoek toe te integreren. Het onderzoek naar een nieuwe organisatiestructuur onder gelijkstijde ontwikkeling van planningsmethodieken voor het macroniveau en een prototype van een beslissingsondersteunend systeem, had een duidelijke meerwaarde. Dit geldt zowel voor het uiteindelijk ontwerpmodel als voor het prototype beslissingsondersteunende systeem.
Bij het in beschouwing nemen van de onderzoeksresultaten constateer ik in de eerste plaats dat een verdere toetsing van het model in verschillende bedrijven noodzakelijk is. In de tweede plaats zouden enkele technologische regels uitgebreider getest moeten worden. Portfoliomanagement bijvoorbeeld is met behulp van een prototype beslissingsondersteunend systeem op beperkte schaal getest binnen de werf. Alhoewel de resultaten zeer hoopgevend waren, toont een bedrijfsbrede invoering pas echt de bruikbaarheid van deze benadering aan. Ook de invoering van multidisciplinaire teams waarbij als gevolg van vereiste capaciteitsflexibiliteit uitwisseling van werknemers tussen de teams moet plaatsvinden, verdient nader onderzoek. Hoe dit bijvoorbeeld op langere termijn de samenhang van een team beïnvloedt is nog niet geheel duidelijk.

Ten slotte wil ik nadrukkelijk aanbevelen om ook in de toekomst kwantitatief en kwalitatief onderzoek te integreren. Het onderzoek naar een nieuwe organisatiestructuur onder gelijktijdige ontwikkeling van planningsmethodieken voor het macroniveau en een prototype van een beslissingsondersteunend systeem, had een duidelijke meerwaarde. Dit geldt zowel voor het uiteindelijk ontwerpmodel als voor het prototype beslissingsondersteunende systeem.
12. Curriculum Vitae

Arie Jan de Waard was born in Leeuwarden, The Netherlands, in 1961. After finishing his secondary education at the 'Willem de Zwijger Scholengemeenschap' in Papendrecht, he went to the Technical University Delft. In 1982 he switched to the Royal Netherlands Naval College in Den Helder and became a midshipman. In 1985 he graduated as a Mechanical Engineering Officer. In the next year he was placed as a trainee on board HNLMS Tromp. In 1987 he returned to the Naval College for a continuation of the Officers training program. Under this program he was allowed to study at the University of Twente, Faculty of Mechanical Engineering for one year, leading to an MSc degree in Mechanical Engineering. Next, he was employed as Deputy Mechanical Engineering Officer at successively HNLMS Jacob van Heemskerck and HNLMS Tromp. By the end of 1992 he was appointed an ashore job at the Royal Netherlands Navy Dockyard. For one and a half year he was head of the staff section evaluation.

In April 1994, he accepted a job as project leader of a re-engineering project at the Royal Netherlands Navy Dockyard. In the years 1994 - 1997, the project team, consisting of approximately 15 people, developed a new organisational structure for the dockyard. As a project leader he worked under the direct supervision of the Dockyard’s Board of Management. The development of the new organisational model and its automated systems was done in co-operation with the University of Twente. In addition to his job as a project leader, he worked on a PhD project with the University of Twente, Faculty of Mechanical Engineering. Within the framework of the co-operation between the dockyard and the university, he extended the dockyard results into a design model and tested it in various companies. In this research project he worked under the supervision of prof.dr. W.H.M. Zijm (Production and Operations Management). During the last two research years, prof.dr.ir. J.E. van Aken (Technical University of Eindhoven, Technology Management) joined the research project as a second supervisor, in addition to prof.dr. W.H.M. Zijm.