A roadmap towards a resilient internal supply chain of welding equipment & consumables

Final report

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Paulien Eggink
13020701
Final Report

Author H.N.P. (Paulien) Eggink
Student number 1302701
Email h.n.p.eggink@gmail.com

Institute University of Technology Delft
Program Master Transport, Infrastructure & Logistics
Specialisation Supply Chain Engineering
Faculty Civil Engineering and Geosciences
Technology, Policy and Management
Mechanical, Maritime and Materials Engineering
Section of graduation Transport & Planning of Civil Engineering and Geosciences

Graduation Committee

Chairman Prof. dr. R.A. Zuidwijk (CiTG), Professor Freight Transport
Section Transport & Planning; Faculty of Civil Engineering and Geosciences
Delft University of Technology

1st supervisor Dr. B. Behdani (CiTG), postdoc researcher
Section Transport & Planning; Faculty of Civil Engineering and Geosciences
Delft University of Technology

2nd supervisor Dr. J.H.R. van Duin (TPM), assistant professor
Section Transport & Logistics; Faculty of Technology, Policy and Management
Delft University of Technology

External supervisor Ir. H.W.(Erik) Kramer, Unit Head Equipment
Pipeline Production Department, Allseas Engineering bv

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This thesis is the result of my internship at Allseas Engineering bv and my pièce de résistance for my MSc, titled Transport, Infrastructure & Logistics at the Delft University of Technology. The objective of this research project was to develop insights in the disruption handling of the Pipeline Production Department of Allseas. The result of this research project is a roadmap towards a resilient internal supply chain of welding equipment and consumables.

It all started with a catchy Allseas slogan on promotional material and now a few months later I am done! I am confident that this project has come to a satisfactory ending. At the start of this project I knew that it would be a big challenge for me to write a thesis. Therefore I would like to thank my committee for guiding me through this process. Professor Zuidwijk for accepting me as a student, although the topic was more appropriate from an Erasmus point of view. Mister Behdani for the quick responses, the in-depth discussions on literature and coaching me throughout the whole process. Mister van Duin for the sharp questions and the more outside view on the topic. And Mister Kramer, Erik, thank you for providing me with a topic for this thesis and the daily supervision.

Next to my committee I have the deepest respect and gratitude towards my family and friends. My parents for always being there for me and even on vacation are willing to provide me with valuable feedback. Kim, Hannah, and Pieter for your on-going moral support, understanding and help during this process.

Paulien Eggink
Delft, July 16th 2013
Allseas is one of the major offshore pipeline installation and subsea construction companies in the world. The process of pipeline installation is executed by operating specialised vessels, which are designed in-house. Allseas executes the pipeline installation with the S-lay method. The pieces of pipe (the joints) are assembled to form one pipeline in a horizontal working plane, the “firing line”, on board of the vessel. First the two joints are welded together, followed by the inspection step (Non-Destructive testing) and before leaving the vessel the pipe is coated (Field Joint Coating).

The system analysed in this research is the equipment-unit of Pipeline Production Department (PPD). PPD is responsible for the preparation of all offshore welding, NDT and coating services. PPD encountered problems with timely delivery of their project equipment and consumables and seeks for measures to solve this. This thesis will focus on the internal supply chain of the welding unit within PPD. The other supply chains are out of scope due to the complexity of the whole system.

Problem Definition
Due to strict norms and regulations in the offshore industry almost all procedures need to be qualified onshore. Only if procedures get approval from the client, the process can continue. This imposes difficulties for the internal supply chain of the welding unit. The wish of Allseas is to control and optimise the logistics of project equipment and consumables for the welding unit. This means reducing the vulnerability of the internal supply chain for a disruption.

The ability of a system to withstand and accommodate a disruption is called resilience. In this thesis the following definition of resilience is used: resilience is the ability of a system to return to its original form after unforeseen changes. This ability of the system can be defined in a twofold matter, the time to recover to the original form and the impact this unforeseen change temporarily has on the system.

A system can develop resilience in a threefold manner, as seen in Figure 1, by increasing redundancy, building flexibility into the system, and the right corporate culture. The work of Sheffi will be the theoretical framework for this thesis. By improving the flexibility of a chain the time_to_respond to a disruption will become shorter. A more resilient culture and a higher level of redundancy will reduce the impact of a disruption.

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**ABSTRACT**

Allseas is one of the major offshore pipeline installation and subsea construction companies in the world. The process of pipeline installation is executed by operating specialised vessels, which are designed in-house. Allseas executes the pipeline installation with the S-lay method. The pieces of pipe (the joints) are assembled to form one pipeline in a horizontal working plane, the “firing line”, on board of the vessel. First the two joints are welded together, followed by the inspection step (Non-Destructive testing) and before leaving the vessel the pipe is coated (Field Joint Coating).

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![Figure 1: Breakdown on how to reduce supply chain vulnerability](image-url)
Research Objective
Based on the problem definition the following research objective can be stated:

*Increase the resilience of the internal equipment and consumables supply chain of Allseas’ welding department to cope with the disruptions stemming from the seasonal planning.*

Based on the research objective the main research question for this thesis is the following:

*How to increase the resilience of the internal equipment and consumables supply chain of Allseas’ welding department to cope with the disruptions stemming from the seasonal planning?*

This research question is assessed and the results of this research are shown in three parts: part I: qualitative analysis, part II: quantitative analysis, and part III: roadmap.

Part I: Qualitative Analysis
The goal of part I was to determine the root cause of the problem with handling disruptions. This in order to gain insights in the system and to search for the drivers behind the problems in the chain. This qualitative analysis starts with a disruption analysis followed by the bottlenecks and finished with a search for lessons learned from other industries.

The disruption analysis is conducted based on a framework of disruption assessment by Jüttner, Peck, & Christopher. This framework makes a distinction between on the one hand risk sources and on the other hand risk drivers and their mitigating strategies. This framework is applied on Allseas for example when dealing with a vessel swap. The risk sources are not the main cause of problems in the disruption handling of PPD. The reason why the previous vessel swap was executed in such a chaotic way was due to a lack in general preparation at the equipment side and not communicating in a proper way.

The supply chain risk drivers were the basis of the bottleneck analysis. By assessing the drivers as the bottlenecks. Clear problems were pinpointed and the effect of these bottlenecks on resilience is shown as well.

- Communication is a big problem within PPD. There is not a structured way to communicate and this influences the execution of projects. The lack of communication influences the flexibility of the chain because the current way of communicating consumes the much needed preparation time.
- The innovative culture of Allseas helped them to be one of the major companies in their industry; however it is now a threat to their supply chain. Innovations cannot be planned or scheduled and this implements high uncertainty to the chain.
- The current way of equipment handling does not have an explicit strategy, therefore it is not clear why some equipment is purchased and other equipment is rented (the make or buy decision). These uncertainties in the equipment pool influence the redundancy of the chain. In the chaotic ad-hoc way of working everyone choses the quick fix instead of working on a more fundamental solution.

The measures that are going to be tested only have influence on the flexibility of the system and not on the redundancy or the culture of this system. This is due to the fact that improvements on redundancy cannot be tested in this system. The lack of transparency in the equipment pool makes it impossible to see whether or not improvements are made. Culture is as well not tested due to the ambiguous nature of this topic and is therefore difficult to quantify. Culture will, however, be part of the roadmap towards a resilient chain. Flexibility will be the core of the measures that will be tested in part II. Especially the time between different tasks is important. The influence of these tasks on each other and on the time to make the deadline of mobilisation of a project is important.
Part II: Quantitative Analysis
In part I the system was analysed and from the synthesis it can be concluded that the relations between different processes in a project are of major importance. The interdependencies between different projects influence the total project time. To assess the influence of the interdependencies the total project time the impact of the sequence of events is evaluated. This sequence of events is called the critical path of a project.

One alternative set up will be tested in this analysis; this scenario is based on the conclusions of part I. The goal of the scenario analysis is to quantify the improvements in the internal supply chain of PPD. The changes in the process should be shown in a different critical path and a reduction in total process time.

To improve the flexibility the two main lessons are taken into account in the improved schedule.

- The first lesson is to have a “Kingpin”, a central point to be the controller of the whole process.
- The second lesson is that preparation is key for flexibility. This is done by: a split in the information flow and the equipment flow and creating an explicit step of organising equipment.

By decoupling planning of the equipment from the mobilisation process more time_to_respond is created. With these changes the chain will be more flexible in order to improve the resilience of the internal supply chain of welding equipment and consumables. From the analysis it can be concluded that the new supply chain set-up is more flexible and in the end will increase the resilience. The two disruptions did not have an effect on the internal supply chain in the new internal supply chain set-up. The effect of moving the step of planning the equipment forward in the chain created time_to_respond to a disruption. And with this creation build in the system one of the major aspects of a resilient chain is gained.

Part III: Roadmap
The framework of Sheffi proposed three types of solutions to increase the resilience of a supply chain. This can be done by increasing the flexibility and redundancy, and changing the culture. Per type of solution the following should be implemented to increase the resilience of the internal equipment and consumables supply chain.

Flexibility; the procedures and the equipment needs to be pre-qualified onshore before going offshore. This is the reason that preparation is key. The new internal supply chain set-up splits the internal supply chain in an information and a physical flow of goods. With parallel processes the internal supply chain has time_to_respond to disruptions and contributes to a more resilient supply chain.

Redundancy; the equipment database needs to be fully up to date before decisions concerning equipment can be made. When all the equipment is updated an assessment can be made on the criticalness of certain equipment. And criteria can be set up to make the make or buy decisions.

Culture; the culture issue has not been a major part of this thesis. However, using the OCAI method as an initial analysis it is apparent that a culture change is a necessary. This cultural change is a precondition to implement the measures.
Allseas is een offshore aannemer van pijpinstallatie projecten. Het pijpleggen wordt uitgevoerd door speciale schepen die door Allseas zelf zijn ontwikkeld. Het proces van pijpleggen verloopt als volgt: de stukken pijp worden aan boord gebracht, vervolgens worden twee stukken aan elkaar gelast door een lasrobot, deze las wordt getest door niet-destructief onderzoek (NDT) en daarna wordt de las bedekt met een beschermende laag (Field Joint Coating [FJC]).

In dit onderzoek staat de Pipeline Production Department (PPD) van Allseas centraal. Binnen deze afdeling wordt de focus van dit onderzoek de equipment-unit. PPD is de afdeling die eindverantwoordelijk is voor het lassen, NDT en FJC. PPD heeft op dit moment problemen met het tijdig leveren van de benodigde apparatuur voor deze activiteiten en is op zoek naar oplossingen voor dit probleem. Centraal in dit rapport staat de interne keten van lasapparatuur, de andere twee ketens worden buiten beschouwing gelaten.

Probleem stelling:
De offshore industrie wordt gekenmerkt door strikte wet en regelgeving. Het gevolg van deze regelgeving is dat elke procedure gekwalificeerd moet worden. Als de klant de resultaten van de kwalificatie voldoende vindt kan een procedure offshore uitgevoerd worden. Dit proces van kwalificeren is erg tijdrovend en brengt problemen met zich mee voor de interne goederen keten van de lasafdeling. Allseas wil meer grip hebben op deze interne keten en wil dat de kwetsbaarheid verminderd wordt. Vooral de kwetsbaarheid van de keten op verstoring van buiten af is een belangrijk onderdeel van deze kwetsbaarheid.

Het vermogen van een systeem om een verstoring te weerstaan heet veerkracht. In dit rapport wordt de volgende definitie van een veerkrachtig systeem gebruikt: Veerkracht is het vermogen van een systeem om terug te keren in zijn oorspronkelijke vorm na een onvoorziene verandering. Dit vermogen kan op twee manieren gedefinieerd worden. Enerzijds is het de tijd die nodig is om te herstellen en anderzijds de impact die de onvoorziene omstandigheid tijdelijk op het systeem heeft.

Een systeem kan op drie manieren veerkracht ontwikkelen, zie Figuur 1. Dit kan door het verhogen van de redundantie, verbeteren van de flexibiliteit en het zorgen voor de juiste bedrijfscultuur. Deze drie manieren om veerkrachtigheid te ontwikkelen komen voort uit het werk van Sheffi en zal de basis zijn van het theoretisch kader van dit onderzoek. Door een hogere mate van redundantie in het systeem wordt de impact van een verstoring minder groot. Een flexibeler systeem zorgt ervoor dat er sneller gereageerd kan worden op een verstoring, dit geldt ook voor een bedrijfscultuur waarin veerkracht voorop staat.

SAMENVATTING
Allseas is een offshore aannemer van pijpinstallatie projecten. Het pijpleggen wordt uitgevoerd door speciale schepen die door Allseas zelf zijn ontwikkeld. Het proces van pijpleggen verloopt als volgt: de stukken pijp worden aan boord gebracht, vervolgens worden twee stukken aan elkaar gelast door een lasrobot, deze las wordt getest door niet-destructief onderzoek (NDT) en daarna wordt de las bedekt met een beschermende laag (Field Joint Coating [FJC]).

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Figuur 1: Het reduceren van de kwetsbaarheid van een supply chain
Onderzoeksopzet
Naar aanleiding van de bovenstaande probleemstelling is het volgende onderzoeksdoel geformuleerd:

Het verhogen van de veerkracht van de interne supply chain van apparatuur voor de lasafdeling van Allseas om de verstoringen vanuit de planning van de schepen beter te kunnen opvangen

Op bases van dit onderzoeksdoel is de hoofdvraag voor dit onderzoek geformuleerd:

_Hoe kan de veerkracht van de interne supply chain van apparatuur voor de lasafdeling van Allseas verbeterd worden om de verstoringen vanuit de planning van de schepen te kunnen opvangen?_

Deze onderzoeksvraag wordt geëvalueerd en de resultaten van dit onderzoek worden in drie delen: deel I: kwalitatieve analyse, deel II: kwantitatieve analyse, en deel III: stappenplan.

Deel I: Kwalitatieve analyse
Het doel van deel I is om de oorzaak van het probleem met het omgaan van verstoringen te bepalen. Dit om inzicht in het systeem te krijgen en te zoeken naar de drijvende factoren achter de problemen in de keten. Deze kwalitatieve analyse begint met een analyse naar de verstoringen. Vervolgens wordt met een knelpuntenanalyse uitgevoerd en wordt afgesloten met een zoektocht naar “lessons learned” vanuit andere sectoren.

De analyse van de verstoringen is uitgevoerd op basis van een theoretisch framework van Jüttner, Peck, en Christopher. Dit framework maakt een onderscheid tussen enerzijds risicobronnen en anderzijds risico factoren en hun mitigatie strategieën. Het model is toegepast op Allseas met verschillende case studies zoals “hoe om te gaan met een verandering van schip”. De risicobronnen zijn niet de belangrijkste oorzaak van de problemen in de omgang met verstoring binnen PPD. De reden waarom de vorige verandering van schip op een zo chaotische manier werd uitgevoerd was te wijten aan een gebrek in de algemene voorbereiding en slechte communicatie.

De supply chain risicofactoren zijn de basis van de knelpuntenanalyse. Door het beoordelen van deze factoren als de knelpunten wordt het effect van deze knelpunten op de veerkracht getoond.

- Communicatie is een groot probleem bij de PPD. Er is geen gestructureerde manier om te communiceren en dit heeft invloed op de uitvoering van projecten. Het gebrek aan communicatie beïnvloedt de flexibiliteit van de keten omdat de huidige manier van communiceren de voorbereidingstijd beïnvloedt.
- De innovatieve cultuur van Allseas heeft geholpen om een van de grootste bedrijven in deze industrie te worden, echter is dit ook een bedreiging voor de supply chain. Innovaties kunnen niet worden gepland en dit zorgt voor grote onzekerheid in de keten.
- De huidige manier van het beheren van de apparatuur heeft geen expliciete strategie, daarom is het niet duidelijk waarom sommige apparatuur is aangeschaft en andere apparatuur wordt gehuurd (de make or buy beslissing). Deze onzekerheden in de database beïnvloeden de redundantie van de keten. In de chaotische ad-hoc manier van werken kiest iedereen voor de snelle oplossing in plaats van het werken aan een meer fundamentele oplossing.

De maatregelen die zullen worden getest hebben alleen invloed op de flexibiliteit van het systeem en niet op de redundantie of de cultuur van dit systeem. Dit komt door het feit dat verbeteringen in redundantie niet in dit systeem kan worden getest. Het gebrek aan transparantie in de apparatuur database maken het onmogelijk om te zien of verbeteringen worden aangebracht. Cultuur is ook niet te testen vanwege het dubbelzinnige karakter van dit onderwerp en daarom moeilijk te kwantificeren. Cultuur zal echter deel uitmaken van de roadmap voor een veerkrachtige keten. Flexibiliteit zal de kern van de maatregelen zijn die in deel II zal worden getest.
Deel II: Kwantitatieve Analyse
Vanuit de kwalitatieve analyse in deel I kan worden geconcludeerd dat de verbanden tussen diverse processen in een project van groot belang. De onderlinge afhankelijkheden tussen verschillende projecten beïnvloeden de totale projecttijd. Om de invloed van de onderlinge afhankelijkheden te beoordelen wordt de impact van verschillende gebeurtenissen op de totale projecttijd geëvalueerd. Deze opeenvolging van gebeurtenissen heet het kritieke pad van een project.

Een alternatieve interne supply chain zal worden getest in deze analyse; dit scenario is gebaseerd op de conclusies van deel I. Het doel van de scenarioanalyse is om de verbeteringen in de interne supply chain van PPD te kwantificeren. De veranderingen in het proces moet een andere kritieke pad geven en een verlaging van de totale procestijd.

Om de flexibiliteit te verbeteren de twee belangrijkste lessen uit deel I komen in aanmerking voor een verbetering van de planning.
• De eerste les is om een ‘Kingpin’, een centraal punt op de controller van het hele proces te hebben.
• De tweede les is dat de voorbereiding is de sleutel voor flexibiliteit. Dit gebeurt door: een scheiding van de informatiestroom en de goederenstroom en het creëren expliciet stap organiseren apparatuur.

Met de planning van de apparatuur losgekoppeld van het mobilisatie proces meer wordt er meer tijd gecreëerd om te reageren op een verandering. Met deze veranderingen wordt de keten flexibeler en verbeterd daarmee de veerkracht van de interne keten van lasapparatuur en verbruiksgoederen. Uit de analyse kan worden geconcludeerd dat de nieuwe supply chain set-up flexibeler is en uiteindelijk ervoor voor een hogere veerkracht zal zorgen. De twee verstoringsscenarios hadden wel effect op de interne supply chain en niet op de nieuwe interne supply chain set-up. Het effect van het verplaatsen de stap van de planning van de apparatuur voorwaarts in de keten creëert veel tijd om op een verstoring te reageren.

Deel III: Roadmap
Het framework van Sheffi stelt drie soorten oplossingen voor om de veerkracht van een supply chain te verhogen. Dit kan worden gedaan door het vergroten van de flexibiliteit en redundantie, en het veranderen van de cultuur. Per type oplossing zal het volgende moet worden uitgevoerd om de veerkracht van de interne uitrusting en verbruiksgoederen supply chain te verhogen.

Flexibiliteit, de procedures en de apparatuur moeten pre-gekwalificeerd worden on-shore voordat ze offshore gaan. Dit is de reden dat de voorbereiding essentieel is voor een goed proces. De nieuwe interne supply chain set-up splitst de interne supply chain in een informatie-en een fysieke stroom van goederen. Met parallelle processen de interne supply chain heeft meer tijd om op verstoringen te reageren en draagt daarmee bij aan een meer veerkrachtige supply chain.

Redundantie, de apparatuur database moet volledig up to date zijn voordat beslissingen betreffende redundante gemaakt kunnen worden. Wanneer de database is bijgewerkt een evaluatie kan worden gemaakt over bepaalde apparatuur. Hierop gebaseerd kunnen criteria worden opgesteld voor de make or buy beslissing.

Cultuur, de cultuur is niet een groot deel van dit onderzoek geweest. De OCAI methode is gebruikt om een eerste analyse van de cultuur te maken. Hieruit blijkt dat een cultuur verandering is noodzakelijk is. Deze cultuur verandering is een voorwaarde om de maatregelen uit te voeren en moet meegenomen worden vanaf het eerste moment om de veranderingen door te voeren.
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1 INTRODUCTION

"No guts, No glory"
Edward Heerema

1.1 BACKGROUND INFORMATION

The Swiss-based, Châtel-Saint-Denis, Allseas Group S.A. was founded in 1985 by Edward Heerema. Allseas is one of the major offshore pipeline installation and subsea construction companies in the world (Allseas, 2013). Project preparation and coordination is done in the main office of Allseas engineering bv located in Delft, the Netherlands. The coordination of projects which are not installed in the North Sea is done locally by smaller project offices on site.

The process of pipeline installation is executed by operating specialised vessels (as seen in Figure 1-2), which are designed in-house. Allseas' approach is to already support their clients in the conceptual design stage and offer the full package in project management, engineering, procurement, installation, and commissioning. In this section a short overview of the process of pipeline installation will be given based on the introduction to pipe laying of Allseas (Allseas, 2012).

The S lay method of pipeline installation
The S-lay method of pipe laying is, as far as installation is concerned, fast and applicable over a wide range of water depths. The pieces of pipe (the joints) are assembled to form one pipeline in a horizontal working plane, the “firing line”, on board of the vessel. First the two joints are welded together, followed by the inspection step (Non-Destructive testing) and before leaving the vessel the pipe is coated (Field Joint Coating). Due to the horizontal working plane the pipeline needs to be supported by a steel structure while exiting the vessel. This steel structure with rollers is called the stinger and it prevents the pipeline from buckling (failure due to bending of the pipeline).
Equipment & Consumables

Based on the configuration of the firing line the three major steps of production are discussed in the following paragraphs.

Welding is done by Phoenix, an automatic welding system, developed by Allseas in 1993. The need for the welding robot is due to the inability to rotate a joint on the firing line which is needed in order for the joints to be welded. Phoenix moves around the pipe to get a smooth weld of the joints.

Non Destructive Testing (NDT) is done by a specialised subcontractor on board of the vessel, Shaw. Each joint has to be assessed when the welding is completed; this is done by means of X-ray or ultrasonic testing (UT). These two methods are applied to ensure that the quality of the weld without cutting the weld. With NDT the quality of the weld is determined by measuring the level of defects. The quality level is defined beforehand by the client and assessment is done by the subcontractor and the client.

To prevent corrosion of the welds a coating needs to be applied. This is done in the Field Joint Coating (FJC) station. First, the weld is prepared for the application of the coating by either grit blasting or power wire brushing. This preparation step will make sure that the pipe surface is clean and bare. Second the anti-corrosion coating is applied on the clean surface and if needed a second coating is applied for isolation or impact prevention.

1.2 CURRENT SUPPLY CHAIN

To gain more insights in the system for the initial demarcation, the internal supply chain of Allseas is analysed. This is done by using two methods, the Supply Chain Operations Reference Model (SCOR) and a method adapted from Handfield & Nichols (2002) to map a supply chain.

The SCOR framework makes it possible for organisations to quickly determine and compare the performance of a supply chain and related operations within their organisation against other organisations (Supply Chain Council Inc., 2010). This is done by mapping the five core processes: plan, source, make, deliver and return. By defining these five processes insights are gained in the business processes and how these link with the corresponding suppliers and customers. In Figure 1-4 an overview of the SCOR model is provided. The SCOR Model is not fully representative for this case study. This is due to the fact that his is a project supply chain and not a process supply chain. Later in this section the SCOR framework will be applied on the Allseas case study to support the demarcation of the system.

The method of Handfield and Nichols uses ANSI Methodology to make process flow charts. These charts are required to understand what actually happens in the supply chain (Handfield & Nichols, 2002). These charts visualize step by step “who does what” in the supply chain. The used symbols are shown in the visualisation of the supply chain.
The first level of the SCOR Model is a general overview of the core process within the company. For this thesis only four processes, (plan, source, make and deliver) as seen in Figure 1-5, are taken into account. The return-flow is negligible due to the fact that the engineers only order at certified suppliers that guarantee a certain quality level. Furthermore the return flow of the end product i.e. the installed pipeline seldom happens due to the fact that during the installation every step is closely monitored. The process of planning does not encounter a companywide planning tool from sourcing to delivering; these planning steps are divided in planning of sourcing (P2), planning of making (P3) and planning of the delivery (P4).

The make-process within the internal supply chain of Allseas is engineer-to-order. This is based on specifications set by the client in the tender document. Based on these specifications the configurations for the vessel lay out are determined. For every project the set-up of the firing line within the vessel needs to be adapted to be able to install the required pipeline. The adaption of the vessel is called mobilisation:

*The act of preparing a vessel or other equipment for its specific task on a project entails that all personnel, project consumables, installation aids etc. are loaded onto the vessel and then the vessel is ready to sail to the offshore installation site. When all the systems are in place, the vessel is correctly configured for the project, and ready for operation the vessel is considered mobilised (Allseas, 2003)*

**Figure 1-5: SCOR Level 1 & 2 Processes for Allseas Engineering bv**

The level 1 process can be branched into separate components needed for the process of pipeline installation. This primary process of pipeline installation consists of five basic logistical Chains: joints, vessel consumables, welding equipment and consumables, NDT equipment and equipment and consumables for FJC.

The Pipeline Production Department (PPD) is responsible for the preparation of all offshore welding, non-destructive testing (NDT) and coating services. The highlighted process, as seen at the right side of Figure 1-5, is one of three processes of PPD. This department encountered problems with the supply of their project equipment and consumables and seeks for measures to solve this. This thesis will focus on the internal supply chain of the welding department. The other supply chains are out of scope due to the complexity of the whole system.
In Annex A the supply chain of welding is shown into more detail. The project chain is controlled by different information flows. One of these flows is the output of the qualification procedure for the process. Due to the strict norms and regulations in the offshore industry almost all procedures need to be qualified onshore and only if this procedure gets approval from the client, the process can continue.

The decisions concerning the equipment within the chain are currently made by the individual welding engineers. The new equipment unit is implemented in order to structure this process. The transport of all the goods is controlled by two departments of Allseas Engineering bv: Logistics and Material Control. The logistical engineers control the choice of mode and the freight forwarder used and the material controllers governs what needs to be transported and the destination of the transport.

The main aim of the internal supply chain of Allseas’ PDD is to ensure a continuous production. A more reliable chain is a way to prevent expensive down time due to idle hours or days offshore, e.g. an idle day for the Audacia costs Allseas around half a million.

1.3 PROBLEM DEFINITION

In this section the problem definition is stated, first the background to the problem is described and based on this information a more academic problem definition is stated in the second part.

1.3.1 BACKGROUND TO THE PROBLEM

A mobilisation phase, as explained in section 1.2, is required to install a pipeline. During this phase a starting amount of pipe, specific pipe production equipment, welding consumables, structure(s) and other project materials are needed.

In the mobilisation phase the project specifications are of utmost importance; a different kind of pipe diameter requires a different set of production equipment, a different kind of welding procedure or a different kind of pipe coating could require a different kind of production equipment.

For each project a project planning is made in the tentative vessel utilisation schedule (seasonal planning). This seasonal planning is bound to changes over time; these changes could be minor but can be large as well. For example a vessel change can be planned; weather conditions could affect the planning or the delay of vital equipment. Due to the commitment of Allseas’ employees most of the disruptions can be defined as a close call. With an increasing complexity of the projects and the logistical chain these close calls are a threat to the stability of Allseas’ operations.

A new unit within Allseas is to be set up within PPD, a unit in which all project equipment will be merged into one central database. Secondary to a project planning, there is a logistical planning of project equipment and consumables to supplement it. Now it could take a considerable amount of time to see the consequences of changes to the project planning on the logistics of project equipment and consumables planning.

How, in the broadest sense of the word, can the logistics of project equipment and consumables be controlled and optimised in order to reduce risks, keep costs of the logistics under control, and ensure a flexible planning to speed up implementation of changes in planning?
1.3.2 Problem definition of this research

This research will be conducted within the Pipeline Production Department of Allseas Engineering bv. The department is responsible for the preparation of all offshore welding, non-destructive testing (NDT) and coating services. To prepare a ship for a pipe lay project a mobilisation phase is required to configure the ship for this project. The project planning that is made, is bound to changes over time as a result of disruptions due to weather conditions, changing project order and last minute projects. For instance: strict regulations around Australia cause geographical and institutional restrictions.

A disruption can be seen as a change in the seasonal schedule due to external influences such as weather conditions, institutional restrictions, geographical restrictions, and liquidated damages.

Since December 2012 a new unit within PPD called ‘equipment’ is supervising the mobilisation of PPD equipment. This new unit already started with solving some of the problems with the mobilisation of the equipment and started to resolve some of the major issues, therefore some processes are in a transition phase.

The main drivers behind changes in the project planning are Liquidated Damages (LD) (financial penalties from the clients) and institutional & geographical restrictions. The logistical planning of the project equipment of the PPD department is not able to follow these disruptions stemming from the seasonal schedule. This is reflected in an ad-hoc improvisational manner of reacting to these disruptions acting on the internal supply chain.

The production offshore should be stable and guaranteed and to support this production a reliable supply chain is needed. The aim of Allseas is to be able to control and optimise the internal supply chain of project consumables and equipment in order to adapt the logistical planning to uncertainties stemming from disruptions. The ability of a system to withstand and accommodate a disruption is called resilience.

Resilience is defined by the authors Klibi, Martel & Guitoni (2010) as follows: “Resilience can be seen as a strategic posture of deployed resources (facilities, systems capacity and inventories), suppliers and product-markets, as a physical insurance against supply chain risk exposure, providing the means to avoid disruptions as much as possible, as well as the means to bounce back quickly when hit.”

Joseph Fiksel & Bhavik Bakshi from the centre for Resilience (2011) use the following definition “the capacity of a system to survive, adapt, and grow in the face of unforeseen changes, even catastrophic incidents” in this thesis the following definition will be used for the term resilience:

Resilience is the ability of a system to return to its original form after unforeseen changes.

Figure 1-6 visualises the definition of resilience. This ability of the system can be defined in a twofold matter, the time to recover to the original form and the impact this unforeseen change temporarily has on the system.

![Figure 1-6: Visualisation of resilience](image-url)
A system can develop resilience in a threefold manner, as seen in Figure 1-7, by increasing redundancy, building flexibility into your system, and the right corporate culture (Sheffi, 2005). With a sufficient level of redundancy the system is instantly robust; however a robust supply chain is not sufficient to react to all disruptions.

*Redundancy is the duplication of critical equipment in order to continue operations when failure arises.*

![Diagram](image)

Figure 1-7: Breakdown on how to reduce supply chain vulnerability.

The authors Prater, Biehl & Smith (2001) break down the definition of flexibility into two capabilities: the velocity with and the degree to which a system can adjust its supply chain volume, speed, and destinations.

Dan Gilmore editor-in-chief of Supply chain Digest (2010) defines two types of flexibility; micro and macro flexibility. The definition of micro flexibility is the ability of the supply chain to detect and react fast to sudden issues and opportunities on the short term. Macro flexibility on the other hand is the speed on which a company can adapt their supply chain to the changes. Agarwal, Shankar & Tiwari (2006) characterise a shorter definition to flexibility “the ability to counter uncertainty in the decision parameters”.

Ron Sanchez (1995) divides flexibility in a twofold manner; resource flexibility and coordination flexibility. Coordination flexibility is not the main subject in this thesis; the resource flexibility is currently the major problem. For this thesis not a system definition but more a disaggregate definition of the characteristic is stated:

*Flexibility is the ability of a system to be in different states and switch fast from the one system state to the other state.*

Figure 1-7 shows the break-down based on the work of Yossi Sheffi, director of the MIT Centre for Transportation and Logistics, of the key aspect of this thesis: resilience. The definition of the three terms, resilience, redundancy, and flexibility, is given previous in this section. The work of Sheffi will be the theoretical framework for this thesis. By improving the flexibility of a chain the time_to_respond to a disruption will become shorter, this goes as well for a more resilient culture, and a higher level of redundancy will reduce the impact of a disruption.
1.4 Scope of the Research

The system analysed in this research is the equipment-unit of PPD rather than Allseas as a whole. The equipment-unit of PPD is in charge of handling the disruptions and they have a limited level of influence on the full system of a pipeline installation. In Annex A the current supply chain is mapped and from this initial mapping only one out of six (sub) supply chains is taken into account in this thesis. This demarcation of the system is done in order to evaluate the multiple options for improvement in the ability to handle disruptions in the supply chains of welding equipment and consumables.

Figure 1-8 shows a possible aggregated system-diagram of the system in this thesis. This system-diagram is defined based on work on Enserink et al. (2010), which proposes a system analysis approach to analyse large and complex systems and put structure to complex problems. A system is a part of the reality that is being studied and with a system-diagram the boundaries and structure of this reality are shown.

The external factors on the left side of the diagram are the aspects which cause the disruptions in the seasonal vessel planning. These factors cannot be influenced by the PPD but are the main drivers behind the chaotic ad-hoc changes in the logistical planning.

The control factors, that enter the system from the topside, are the factors that are the means of the department to influence the internal supply chain of welding equipment and consumables.

Finally, on the right side of the diagram the criteria to measure the output are listed. To measure the ability of the system to handle disruption, two preliminary indicators are defined; switching time, and costs. The system should have the lowest possible switching speed (in days) to go from the one logistical planning to the other planning and this with the lowest cost as possible.

![Figure 1-8: A possible system-diagram](image-url)
1.5 RESEARCH OBJECTIVE

Based on the previous sections the following research objective can be stated:

*Increase the resilience of the internal equipment and consumables supply chain of Allseas’ welding department to cope with the disruptions stemming from the seasonal planning.*

1.6 RESEARCH QUESTION

To realise the objective of this project a research set up has to be made, in the following paragraphs this research set up is operationalised into a main research question and sub questions.

1.6.1 MAIN RESEARCH QUESTION

Based on the research objective the main research question for this thesis is the following:

*How to increase the resilience of the internal equipment and consumables supply chain of Allseas’ welding department to cope with the disruptions stemming from the seasonal planning?*

1.6.2 RESEARCH SUB QUESTIONS

To answer the main research question a set of more descriptive sub questions is formulated:

1. How is the current equipment and consumables supply chain of welding organised and who are the main actors?
2. How to create a resilient supply chain?
3. What is a disruption and what are the causes of disruptions?
4. What are the main bottlenecks in the handling of disruptions in the current equipment and consumables supply chain of welding?
5. How to mitigate the effect of disruptions on the supply chain of welding?
6. How to evaluate mitigating strategies for a more resilient supply chain?
7. How to implement the mitigating strategies to increase the resilience of the current equipment and consumables Supply chain of welding?

1.7 RESEARCH METHODOLOGY

The purpose of designing a research project is to determine everything you wish to achieve through the research and how to realise this (Verschuren & Doorewaard, 2010). In this thesis, different measures for the operation of the supply chain are going to be evaluated. At the end of this research, recommendations will be made to develop a resilient supply chain of welding equipment and consumables. A combination of three both qualitative as quantitative research methodologies are going to be used in this research, as seen in Table 1-1: desk research, field research and project management tools like Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT).

*Figure 1-9: Visualisation of the research structure (Verschuren & Doorewaard, 2010)*
To gain more insights in the current supply chain and the corresponding factors, desk and field research were used to analyse sub question one to three. For the fourth research question only desk research is needed because these insights are going to be retrieved from corresponding industries.

Quantitative project management tools are going to be used to gain more insights in the evaluation of the measures (Hillier & Lieberman, 2001). PERT and CPM are helpful to assist in planning and displaying the coordination of all activities.

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ1: Evaluation of current Supply chain &amp; Actors</td>
<td>Desk Research &amp; Field Research</td>
</tr>
<tr>
<td></td>
<td>• Interviews</td>
</tr>
<tr>
<td></td>
<td>• Process mapping (SADT, SCOR, and ANSI)</td>
</tr>
<tr>
<td>RQ2: Resilient Supply Chain</td>
<td>Desk Research</td>
</tr>
<tr>
<td></td>
<td>• Literature review</td>
</tr>
<tr>
<td>RQ3: Disruptions</td>
<td>Desk Research &amp; Field Research</td>
</tr>
<tr>
<td></td>
<td>• Literature review</td>
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<tr>
<td></td>
<td>• Interviews</td>
</tr>
<tr>
<td>RQ4: Bottlenecks</td>
<td>Desk Research &amp; Field Research</td>
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<td></td>
<td>• Literature review</td>
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<td></td>
<td>• Interviews</td>
</tr>
<tr>
<td>RQ5: Lessons Learned</td>
<td>Desk Research</td>
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<td></td>
<td>• Literature review</td>
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<td></td>
<td>• Interviews</td>
</tr>
<tr>
<td>RQ6: Evaluation measures</td>
<td>Quantitative project management tools</td>
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<td></td>
<td>• Critical Path Method (CPM)</td>
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<td></td>
<td>• Program Evaluation and Review Technique (PERT)</td>
</tr>
<tr>
<td>RQ7: Implementation</td>
<td>Desk Research &amp; Field Research</td>
</tr>
<tr>
<td></td>
<td>• Literature review</td>
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<td></td>
<td>• Interviews</td>
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Table 1-1: Research Instruments

In Figure 1-10 the relationships between the different research questions and the path to the recommendations is shown.

Figure 1-10: Interrelations of the research questions
In part I qualitative analyses will be conducted to determine the root cause of the problem with the handling disruptions. This will be done based on a supply chain risk assessment framework. In this part RQ 3, 5 and 5 will be answered. Questions 1 and 2 are already elaborated on in the introduction of this thesis.

In part II quantitative analysis will be conducted to pin point the weaker parts of the system. As conclusion of part II measures to increase the resilience of the current equipment and consumables supply chain of welding will be proposed. This will be done by first looking into more detail in the proposed quantitative project management tools and second by applying these tools on the current internal supply chain of welding equipment and consumables. In this part RQ 6 will be answered.

In the final part of this research conclusions will be drawn and recommendations will be made in order to provide Allseas Engineering bv with a roadmap towards a resilient internal equipment and consumables supply chain. In this part RQ 7 will be answered and the conclusion and answer to the main research question will be given.
In this part of the thesis qualitative analyses are going to be conducted to determine the root cause of the problem with handling disruptions. This will be done by first looking at the concept of disruptions through the introduction of a disruption assessment framework. The second step in the qualitative analysis is the analysis of the bottlenecks in the system of disruption handling. And third, a structured search for best practices is conducted in order to compose mitigating strategies in regard to the bottlenecks of disruption handling. The three chapters are going to be synthesised in chapter five to serve as a starting point for part II of this thesis the quantitative analysis.
2 DISRUPTIONS

“If you have a fire, you don’t want to -- at that point -- start buying fire trucks and training people”

Yossi Sheffi (1948 - ) Director of the MIT centre for Transportation and Logistics

In the introduction a disruption was defined as follows: a disruption can be seen as a change in the seasonal schedule due to external influences such as weather conditions, institutional restrictions, geographical restrictions and liquidated damages. These disruptions are the root of the problem and therefore they need to be looked at in detail. Previous disruptions will be used to analyse this problem. First a framework of disruption assessment is discussed and second this framework is applied to the Allseas case study. This will be followed by the conclusion on disruptions. With these conclusions an answer will be given to research question 3; what is a disruption and what are the causes of disruptions?

2.1 SUPPLY CHAIN RISK ASSESSMENT

A disruption affecting an entity anywhere in a supply chain can have a direct effect on a corporation’s ability to continue operations (Jüttner, Peck, & Christopher, 2003). Organisations often overlook the critical exposures along their supply chain. Especially the trend of more flexible manufacturing and Just-in-Time supply chains disguise huge impact of possible disruptions. Jüttner, Peck, & Christopher (2003) provided a framework and foundation for systematically exploring the concept of risk management in supply chains.

This framework consists of four basic constructs, as can be seen in Figure 2-1:

1. Risk Sources, supply chain-related, organisation, or environmental variables that can impact the outcome of the chain and are uncertain and cannot be predicted;
2. Adverse Supply Chain Risk Consequences, the focused supply chain outcomes in another form than the wanted outcome;
3. Supply Chain Risk Drivers, they magnify the impact of the disruptions;
4. Supply Chain Risk Mitigating Strategies, can reduce the impact of the disruptions.

Based on the aforementioned framework a co-ordinated approach can be implemented to reduce supply chain vulnerability as a whole. This framework will be applied on the Allseas case in order to mitigate the effects of the disruptions on the chain. These mitigating strategies will be tested in part II of this thesis and will be the basis for the roadmap towards a more resilient internal supply chain of welding equipment and consumables. Every aspect outside of PPD is seen as an external cause due to the fact that PPD cannot directly influence these aspects.
2.2 IDENTIFYING THE RISKS IN THE ALLSEAS CHAIN

Based on the framework described in 2.1 the four basic constructs will be analysed in this section. The data on which these analyses are based stem from interviews with personnel of PPD.

2.2.1 RISK SOURCES

The risk sources are the supply chain-related, organisation, or environmental variables that can impact the outcome of the chain and are uncertain and unpredictable (Das & Teng, 1998). The network related uncertainties are the risk sources of the various links in the chain and the environmental and organisational uncertainties are the risk sources to the links in the chain (Christopher & Peck, 2004).

In the initial problem description multiple disruptions were described by Allseas as by the Author of this report, however a distinction can be made. A part of the initial disruptions are part of the risk sources.

- Weather conditions; for every project two estimations of the project duration are made, with and without the expected weather conditions. These estimations are made based on weather data from NAVAL, a meteorological institute specialised in forecasting for the naval industry. With weather data from the past NAVAL compiles workability estimations for specific locations and time periods. These estimations about the workability in a certain time frame are as well used during the tender phase. However, during a project these predictions do not hold. The actual weather is always very unpredictable especially in the harsh offshore environment in which Allseas operates.
- Management Decisions; based on these decisions a vessel swap can arise or other changes in the seasonal planning can be made.

2.2.2 ADVERSE SUPPLY CHAIN RISK CONSEQUENCES

The adverse supply chain risk consequences are the impact that the disruptions have on the chain. The following two consequences are listed for Allseas:

- Liquidated Damages (LD); the LD are financial penalties from the client if a project is not delivered on the due date set in the contract. These penalties can go up to 10 % of the total contract value. To avoid LD the contract negotiations sometimes will start over when it becomes clear that a project is not able to be delivered at the set time. These negotiations are not good for the image of Allseas. However, due to the mind set of all the employees almost all the disruptions result in a near miss. These near misses are not registered; they belong to the normal way of working. The extra costs made to prohibit a LD or extra delays are not registered as well.
- Delays; the other unfortunate outcome of a full disruption.
The supply chain risk drivers multiply the impact of the risk sources. Due to these drivers the impact of a disruption can become bigger than the initial impact. This is due to the fact that these drivers affect the two dimensions of a resilient chain, they extend the time to handle a disruption and increase the impact on the chain. Five risk drivers are identified in this case study based on interviews with personnel of PPD. There are two external risk drivers to Allseas and three internal drivers:

External Supply Chain Risk Drivers

- Institutional restrictions, Australia have very strict rules and regulations regarding employment of offshore crew and the environment. You are obliged to have a certain percentage of crew from Australia. This implies that the vessel needs a full clean up as well, before entering the coastal area of Australia. This is done in order to protect the habitat of both flora and fauna.

- Geographical restrictions, the North Sea is not operational throughout the year; the winter on this part of the globe is too harsh to operate in. This complies for other regions as well so if one project is delayed this could have a gigantic impact on other projects. Especially when some of the seasonal beginnings/ endings are about to come.

The External Supply Chain Risk Drivers negatively induce the flexibility of the system. This is due to the fact that these external factors influence the time to react to a disruption. If a vessel has to wait for the correct staff or to have a full clean up this causes enormous delays in the schedule or is unable to operate due to seasonal changes.

Internal Supply Chain Risk Drivers

- The communication structure between the different departments and even within departments is not on a satisfying level. The lack of information sharing causes the individual engineers to deal with events that could have been prevented.

- The innovative and entrepreneurial set up of Allseas; Innovations is the R&D department of Allseas and from time to time the new equipment is not delivered on time.

- Equipment pool; the equipment for the different projects is not well organised. This is the main reason why PPD the new equipment unit was set up.

The lack of transparency in the equipment pool is a big threat for the redundancy of the system. With uncertainty about the number of equipment and the exact location of the equipment huge delays can be imposed on the internal chain.

The Internal Supply Chain Risk Drivers have a negative effect on all three the aspects of a resilient system.
2.2.4 SUPPLY CHAIN RISK MITIGATING STRATEGIES

The effects of the supply chain risk drivers can be mitigated by implementing mitigating strategies. At this moment these strategies are not made explicit within PPD. When a disruption occurs everyone puts in all the energy to make it work. The current “policy” is really hands-on and everyone is occupied with firefighting.

In the past a vessel swap occurred, from the Lorelay to the Audacia, this was the starting point of this study. This swap was handled in a chaotic way and it ended in major delays. From informal interviews with the stakeholders it can be concluded that the chaos was due to the set-up at that particular moment in time. If the equipment is ready for production at the first date, the project team wants it to be there. Then there should be no problem with handling disruptions. This is not always the case however, and this is because the preparation of production equipment is not executed by a structured protocol.

To mitigate the effects of the supply chain risk drivers, strategies should be implemented to adverse the negative effects. These strategies should target the aspects of a resilient supply chain: flexibility, redundancy and culture. This will be the roadmap towards a resilient supply chain. Based on the analysis of the disruptions it is clear that a distinction can be made between risk sources and risk drivers. The risk sources are not the main problem within Allseas, the supply chain risk drivers are the cause of the problems.
2.3 Conclusion on Disruptions

At the start of this thesis the assumption was made that all disruptions caused the same impact on the internal supply chain of Allseas. Based on the framework of Jüttner, Peck, & Christopher the disruptions were assessed on the following can be concluded.

The two risk sources, weather conditions and management decisions, do not have to be the biggest cause of the Adverse Supply Chain Risk Consequences. The Risk Drivers aggravate the effect of the sources and cause the unwanted effect on the chain. In Figure 2-2 the whole assessment of the disruptions on the internal supply chain of PPD is presented. The risk sources are not the main problem but the risk drivers cause the biggest problems in the chain.

In conclusion it is clear the reason why with the previous vessel swap, from the Lorelay to the Audacia, was executed in such a chaotic way was due to a lack in general preparation at the equipment side and not communicating in a proper way. Risk sources can be eliminated for the biggest part by good communication.

In the next chapters the supply chain risk drivers and the supply chain risk mitigating strategies will be analysed. The risk drivers will be elaborated on in chapter three, bottlenecks, and the first step towards the roadmap will be taken in chapter four; lessons learned. In these chapters emphasis will lay on the effect that these risk drivers and mitigating strategies have on the three aspect of a resilient supply chain. With these new insights the Supply Chain Risk Mitigating Strategies can be tested in part II of this thesis.

The quantification of the current situation is nearly impossible, due to the fact that no near miss or extra effort is registered. This is seen as the culture of Allseas and all employees really do their best to make sure that no LD or delay occurs.
3 BOTTLENECK ANALYSIS

"An hour saved at a non-bottleneck is a mirage"
Dr. Eliyahu M. Goldratt (1947-2011), author of The Goal

The oxford dictionary defines a bottleneck as follows; a situation that causes delay in a process or system (Oxford Dictionaries, 2013). In the previous chapter a framework was introduced, this framework assesses disruptions from the root till the impact. In this chapter a more detailed analysis of the Supply Chain Risk Drivers will be provided. This will be done by looking at the Supply Chain Risk Drivers as bottlenecks. By looking at the bottlenecks the business “as usual”-state is described as well. The emphasis in this chapter will lie on the effect this state has on disruption handling. The topics addressed as bottlenecks are a nuisance to the day to day operation and a big problem when handling a disruption.

In the previous chapter five Supply Chain Risk Drivers were identified based on interviews with employees of Allseas. This chapter starts with communication because institutional and geographical are external restrictions. All the stakeholders know the effect of the external drivers and management is anticipating on these restrictions; however PPD cannot do anything to influence this. Therefore, only the internal drivers will be analysed in this chapter; communication, innovation, and equipment pool.

3.1 COMMUNICATION

The communication within Allseas PPD is analysed based on two aspects: the processes of the department and the actors involved.

3.1.1 PROCESSES

The analysis of the total process, Annex C: Process Oriented Modelling, is conducted using the IDEF0 method. This method is a structured analysis of the processes and it uses rectangles and arrows to map the process, Figure 3-1. This process analysis builds on the visualisation of the current supply chain of Allseas, Annex A: Current Supply Chain, as mentioned in the introduction (National Institute of Standards and Technology, 1993).

From the process analysis the following conclusions can be drawn:

The installation of pipelines is a worldwide process which entails large transport distances in the chain. This creates challenges in the transportation of the equipment from and to the vessels. Next to the fact that distances are long the responsibilities lie at different departments. This creates difficulties. This is due to the fact that communication between the different actors and departments does not run smoothly and there is no central steering.
The input of a process is defined by the output of its predecessor. With these interdependencies in this global chain it is important that the communication runs smoothly. This communication within PPD (intra PPD) and within Allseas (inter PPD) affects the whole company.

The preparation of a new project is not fully standardised, it depends on the experience of the welding engineer which steps are taken. For each different project step multiple engineers are involved, as seen in Figure 3-2. These steps are related to each other and in these steps the communication is again a big problem. Currently a new process only starts if the predecessor is finished; this creates a very vulnerable project chain.

Another problem in the streamlining of the different processes within Allseas is the fact that different software suites are used for the planning of projects.

![Figure 3-2: Project overview of a welding project](image)

Figure 3-3 shows the typical disruption profile. When the different stakeholders do no cooperate with each other the disruptive event is suddenly there. And then the firefighting starts to ensure that the long term impact is minimal. When a disruptive event occurs redundancy is needed to respond to this event and recovery can be supported by different flexibility measures. Due to the fact that redundancy is complex within Allseas, the preparation phase is very important. If a structured project start up would exist all stakeholders are aware of the project scope. If the processes are better streamlined all stakeholders are warned for a disruptive event and preventive measures can be taken.
Figure 3.3: Disruption profile (Sheffi, 2007)
3.1.2 ACTORS

In the previous sections the impact of the organisational set-up arose multiple times. In this section the formal structure of the organisation is looked at, Annex D: Formal Actor diagram.

The organisational set-up was mentioned multiple times due to the fact that there is not a real clear structure. Allseas is a hierarchical organised company with a lot of responsibility placed with the professionals working in the organisation. The control within the organisation is output based on the quality of a project and not on the tasks the engineers performed to finish the project. Per project multiple engineers have ownership over the project and their specific roles are defined, however these roles are not strictly followed.

The engineers are the focal point of the company and within this structure, capturing tacit knowledge could be a problem (Mintzberg, 1983). Tacit knowledge is the implicit knowledge gained by experience and hard to codify (Bots & de Bruijn, 2002). The more experienced an engineer is the less procedures he will follow. Due to their tacit knowledge the individual engineers act like they are on their own islands.

The main actors for each project are seen in Figure 3-2, please note that the interaction between the project, welding, and equipment engineer is important for a successful project. Especially the communication between the different stakeholders is a significant factor. This is due to the fact that for example the scope of work might change and this is not reported through the official channel. The original culture within Allseas reflects on the communication structure. The culture within the organisation strains the communication structure.

The communication within PPD and from PPD to the rest of the company is problem. The different processes and the multiple stakeholders involved create a complex communication structure. And on this communication structure the culture of Allseas has a big influence. Solutions can be found by structuring this communication structure.
3.2 INNOVATIONS

“Not Guts, No Glory” that is the main vision of Allseas. Allseas is now one of the major companies in its field because of the entrepreneurial and innovative mind-set of all the employees. However, this mind-set and all the innovations cause problems to the internal supply chain. In this section an assessment of the culture is conducted because the culture of Allseas is the driver behind the R&D. This culture heavily influences the equipment pool because of the non-decisions on buying, renting or developing equipment.

3.2.1 CULTURE

Allseas is a hierarchical organised company with a lot of power with the professionals working in the organisation. The control within the organisation is output based on the quality of a project and not on the tasks the engineers performed to finish the project. The organisation Allseas lies in between a typical adhocracy and a professional bureaucracy (Mintzberg, 1983). From the formal analysis, Annex D, can be concluded that a complex organisation like Allseas needs a lot of supervision in process to streamline all the different aspects.

The culture within the organisation is a very important aspect of the whole system. This is the reason that a short survey is distributed among the staff of PPD, Annex E: OCAI Questionnaire. This survey is the Organizational Culture Assessment Instrument; this framework consists of four Competing Values that correspond with four types of organisational culture (Krikke, 2010). Every organisation has its own mix of these four types of organizational culture. A mix of juniors, seniors, and unit heads made the questionnaire in order to see the culture within every layer of PPD. The result of the OCAI shows the culture and the demand for change within an organisation.

The overall result of all the questionnaires is the same for all respondents; Allseas’ PPD is a combination between an adhocracy and market driven organisation. This means that it is a dynamic, entrepreneurial place to work with a result-oriented control. The leaders are innovators and risk takers but are as well competitors. The adhocracy stems from the early days of Allseas and this entrepreneurial culture still exists. The more market driven focus comes from the fact that Allseas is expanding and there is more and more competition in pipeline installation.

The demand for change is more towards a hierarchy and clan oriented organisation. The wish for more hierarchy results from the desire of more standardised procedures. And the clan organisation desire shows that more human interaction is wanted. These results provide insights in the organisation and the demand for change is of value for the final recommendations of this thesis project.

3.3 EQUIPMENT POOL

With an object-oriented modelling method a definition framework of the system is made. This is a vocabulary that can be used to describe the system and the problems experienced in the system, an overview of all the analysis conducted can be found in Annex B: Object Oriented Modelling.

The first step in the creation of the definition framework is the description of the main objects in the system. This is done using the Unified Modelling Language (UML); this language serves the purpose of defining the relevant relationships and objects in a system (Jacobsson, Erickson, & Jacobsen, 1994).
With the UML the following objects are identified.

- Client; with a budget, a desired delivery date, and functional specifications of the project.
- Project; a project needs equipment consumables and a vessel to be executed.
- Equipment; manual welding equipment and automatic welding equipment.
- Vessel; a single or a double joint mainline.
- Consumables.

These objects are combined in an overview of the project structure, Figure 3-2. In this overview the corresponding engineers are linked to their parts in the project chain. This break down makes clear that multiple engineers are accountable for the same parts in the project chain. This is an important aspect that needs to be examined in more detail.

The last step is to zoom in on the characteristics of both the equipment as of the vessels. With an overview of these characteristics a better view of the possibilities and complexity can be provided. The main conclusions of the characteristics of the welding equipment and vessels are the following:

- Welding equipment; the equipment pool of welding is expanding due to Allseas’ strategy of wanting to own and control everything in their production chain. In the current set up some of the equipment is rented but the trend is of developing more equipment. The development of the equipment is done by Allseas’ R&D department, Innovations. Most of the equipment, next to the Phoenix welding robot, is only purchased if the budget of the client is sufficient. A clear investing strategy is up to now not present. The make or buy decision is made based on the experience of the corresponding welding engineer, criteria for this decision do not exist.

  The strategy of Allseas to own and control all the equipment in their production chain is best illustrated by some examples. NDT is currently performed by a subcontractor, Shaw. In the past year several NDT engineers were hired in order to be able to develop Allseas NDT. The same goes for a specific type of equipment for the line-up of joints. Based on field experience Innovations developed a new type of clamp that is better fit for Allseas’ operations. Currently those line-up clamps are rented because these clamps are very expensive. The department Innovations is, as the equipment pool, expanding over time. Due to this strategy there is a constant need for new R&D engineers to help to fulfil this strategy.

  Another feature of the equipment pool of welding is the fact that not all the equipment is in the Oracle ERP system of Allseas. This causes difficulties for both the welding as the equipment engineers to ascertain the correct equipment for every project. Due to the uncertainty in availability, location, and amount.

- Vessels; Not one of the vessels has the same set of characteristics as another vessel. The ability to withstand high waves, deep, and shallow water creates a unique profile per vessel. In the tendering phase and the negotiation of the contract every vessel has her commercial value. Merging both the features create vessels that are not interchangeable.

With the definitions known other problems in the equipment pool arise. Not all the equipment is in the Oracle ERP system of Allseas. As a result a lot of equipment is lost or not known if they really exist. This problem is being tackled by Material Control, because a transition is put in place to make sure that the database is up to date.
3.4 CONCLUSION OF THE BOTTLENECK ANALYSIS

In this bottleneck analysis the Supply Chain Risk Drivers were taken as the bottlenecks in the system. And the following can be concluded:

Communication is a problem at PPD. There is not a structured way to communicate and this influences the execution of projects. Due to the lack of communication the processes are not executed in an efficient manner and are focused on the short term. This has to do with the organisational set up of Allseas; the engineers are encouraged to perform their work independently and this in combination with the dominant culture of adhocracy creates an organisation that does not follow procedures. The communication problems are inter and intra the PPD department.

The innovative culture of Allseas helped them to be one of the major companies in their industry however; it is now a threat to their supply chain. Innovations cannot be scheduled and this implements high uncertainty on the chain.

The current way of equipment handling does not have an explicit strategy, therefore it is not clear why some equipment is purchased and other equipment is rented. If more equipment will be added to the equipment pool then it is really important that the Oracle ERP system is up to date and the transition phase is over. Allseas does not have a lot of official procedures and on top of that none of them are followed. It, therefore, depends on the experience of the corresponding engineer which steps are taken.
4 LESSONS LEARNED

“Only a fool learns from his own mistakes. The wise man learns from the mistakes of others”
Otto von Bismarck (1815-1898) Prussian German statesman and aristocrat

4.1 INTRODUCTION

In this section the preliminary literature review is extended to search for similarities in other industries or papers addressing maintenance and or logistics. A subset of the method of benchmarking is used in order to learn lessons from other industries. Originally a benchmark serves the purpose to make a comparison between business processes and performance metrics of different companies. Using the following scheme generalisable lessons can be deduced from the industry (van Dam, Adhitya, Srinivasan, & Lukso, 2009):

1. Definition of the objectives for the study;
2. Identification of what is to be benchmarked;
3. Evaluation if object of study are comparable;
4. Determination and specification of performance measures;
5. Description of scenarios (well-structured experiments) and their simulation;
6. Conclusions.

The objective of this chapter is two folded; the first objective is to show the characteristics of other industries to seek similarities in order to generalise the outcome of this thesis. The second objective is to explore best practices based on handling of disruptions in corresponding industries to find out whether these lessons can be translated into the business process of Allseas. It shows the state of the art of the current logistical processes.

What is to be benchmarked, this needs be defined in a clear and detailed manner in order that others are able to reproduce the results (van Dam, Adhitya, Srinivasan, & Lukso, 2009). First the characteristics of every industry are shown in comparison with the pipeline installation industry. And second the way disruptions are handled are analysed.

Based on the work of Sheffi (2007) the focus should lay on industries that are disrupted frequently. These industries are the high-technology and fashion industries because they are subject to particularly uncertain demand. In view of this theory these subjects should be the focal point of this benchmark as well. However, due to the particular nature of the offshore industry and the construction industry these proposed industries are not chosen. The focus will therefore be on industries that are business to business and are known for handling disruptions.

In this chapter the following industries will be discussed, step 3 till 6: the dredging industry, the military, humanitarian relief, and the construction industry. But first the pipeline industry and the network of Allseas will be described. The assessment of the different industries will be followed by the conclusion in which the answer will be given to sub research question 5; How to mitigate the effect of disruptions on the supply chain of welding?
4.2 OFFSHORE CONSTRUCTION INDUSTRY

Allseas can be characterised as a company in the offshore construction industry (Allseas, 2012). Especially the fact that Allseas operates offshore imposes challenges for the handling of disruptions. The process of pipeline installation is described in section 1.1 and in this section the organisational set up of Allseas is described as well. To install a pipeline a pipe carrier vessel transports joints towards an Allseas vessel. On-board the joints go into storage and from the storage they go into the firing line. In this horizontal working space the joints are first welded, then inspected, and then coated.

The disruptions that Allseas encounters are analysed in chapter two of this thesis. The transportation of all the equipment and consumables is organised in a hub and spoke network (Kreutzberger, Kongins, & Witteveen, 2010). This means that the all goods are shipped in a consolidated flow from the main hub, the BOYS yard in Rotterdam.

To finalise the industry in which Allseas operates the general characteristics of Allseas are listed:

- Work is done based on projects;
- A project is awarded to the best economic proposal in a tender;
- Up to 10 competitors;
- Harsh environmental conditions;
- Strict institutions;
- High time pressure during operations.

4.3 DREDGING INDUSTRY

The dredging industry is, as a pipeline installation, part of the maritime industry (Nederland Maritiem Land, 2013). Most of the activities are performed offshore and the consequence is that the players in the dredging industry face similar problems as Allseas encounters. The main drivers are the operational costs offshore; these costs are significantly higher than the onshore costs. With this comparison the dredging industry is a good benchmark for Allseas.

Table 4-1: Characteristics of the offshore construction industry in comparison to the dredging industry

<table>
<thead>
<tr>
<th>Similar</th>
<th>Different</th>
</tr>
</thead>
<tbody>
<tr>
<td>A global, very competitive, and capital intensive industry (Veenstra, Zuidwijk, &amp; Geerling, 2006).</td>
<td>Main activity is moving sand (Veenstra, Zuidwijk, &amp; Geerling, 2006).</td>
</tr>
<tr>
<td>Dredging operators balance between continuous operation and pro-active maintenance (Veenstra, Zuidwijk, &amp; Geerling, 2006).</td>
<td></td>
</tr>
<tr>
<td>Significant transhipment time of service parts (Yang, Dekker, Gabor, &amp; Axsaeter, 2013).</td>
<td></td>
</tr>
<tr>
<td>The vessel can be seen as a moving factory, not a production facility like the pipelaying vessels, the vessel is the production (Dekker, Pince, Zuidwijk, &amp; Naiman Jalil, 2011).</td>
<td></td>
</tr>
<tr>
<td>Transportation network is a hub and spoke network (Kreutzberger, Kongins, &amp; Witteveen, 2010).</td>
<td></td>
</tr>
<tr>
<td>A project is awarded to the best economic proposal in a tender (European Dredging Association, 2009).</td>
<td></td>
</tr>
</tbody>
</table>
The operators in the dredging industry encounter similar disruptions as Allseas does. The offshore nature of the operational grounds imposes major problems. However, the method of handling disruptions in the offshore industry is not clearly stated in the literature found. So no lessons learned could be deduced from the dredging industry. The reason is that the focal point of the literature is about the demanding aspects of operating offshore. The only fact that is stated is that it is challenging to provide the vessels with their consumables (Veenstra, Zuidwijk, & Geerling, 2006). Using Table 4-1 it can be concluded that the dredging industry is similar to the industry in this thesis. The major difference is that the main activity of the dredging industry is moving sand, instead of pipeline installation. Both industries face similar difficulties with the supply of parts to their operational grounds. Therefore the dredging industry is a good reference point to generalise the final results of this case study, the first objective of this benchmark. Unfortunately it is not a good point of reference for comparison in handling disruptions offshore, the second objective of this benchmark.

4.4 Army

Army logistics are the crucial link in both the World Wars for effective warfare and from that moment on concepts from the army were translated into business logistics (DHL, 2005).

Table 4-2: Characteristics of the offshore construction industry in comparison to the military

<table>
<thead>
<tr>
<th>Similar</th>
<th>Different</th>
</tr>
</thead>
<tbody>
<tr>
<td>• In crisis an ad hoc organisation however, in instance a hierarchical set-up (Pagonis, 1996).</td>
<td>• Transport over non existing infrastructures (Pagonis, 1996).</td>
</tr>
<tr>
<td>• Only specialised and skilled personnel (Funk, 1985).</td>
<td>• Focus on life and death (Pagonis, 1996).</td>
</tr>
<tr>
<td></td>
<td>• Great deal of responsibilities on very young people (Pagonis, 1996).</td>
</tr>
<tr>
<td></td>
<td>• Patriotism is the main driver of the process (Pagonis, 1996).</td>
</tr>
<tr>
<td></td>
<td>• Core capability is to handle disruptions (Funk, 1985).</td>
</tr>
<tr>
<td></td>
<td>• Transportation network is a trunk, collection and distribution network (Kreutzberger, Kongins, &amp; Witteveen, 2010).</td>
</tr>
</tbody>
</table>

Handling disruptions is the essence of army logistics. Every war can be seen as a disruption and the logisticians need to react fast to make sure that the war can continue. From the army two practical lessons can be learned that improve the flexibility and contribute to a culture of resilience.

A measure to increase the flexibility is to let the handling of disruptions be coordinated by a “Kingpin” according to Lt. General William “Gus” Pagonis (1996). With a “Kingpin” in charge, fast decision making is encouraged and this contributes to a faster time_to_respond to a disruption. The founding father of this “Kingpin” is a four star General H. Norman Schwarzkopf. His central idea for Operation Desert Storm was to give a one-stop logistical command responsibility. With his strategy the logisticians of the U.S. army were able to successfully fulfil the demands of this paramount mission. This mission has been compared to moving the entire population of Alaska, with all their belongings, to the other side of the world and this with a very short notice. This “Kingpin”, in combination with direct chain communication, provided the Army with sufficient logistical battle force.

The measure to contribute to a culture of resilience is the way the army trains their personnel. From the start of their training military learn how to be prepared for disruptions (Pagonis, 1996).
The comparison stated in Table 4-2 shows that there is not a significant overlap between the army and Allseas. However lessons can be learned from their disruption handling. It shows that central coordination with direct communication helps to have a resilient chain. And that a resilient culture can be imposed on the personnel if it is taken into account in the basic training.

4.5 HUMANITARIAN RELIEF

Harsh environmental conditions are inherent to the offshore industry. Next to the challenge of the environmental conditions the fact of moving destinations imposes a challenge as well. The humanitarian relief organisations are facing the same challenges. In this section a comparison is made between the humanitarian relief industry and Allseas.

<table>
<thead>
<tr>
<th>Similar</th>
<th>Different</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Agile &amp; Lean Supply chain (Cozzolino, 2012).</td>
<td>• 80 % of the total costs are logistics (Gatignon, van Wassenhove, &amp; Charles, The Yogyakarta earthquake: Humanitarian relief through IFRC’s, 2010).</td>
</tr>
<tr>
<td></td>
<td>• A time delay may result in a loss of life (Kovács &amp; Spens, 2007).</td>
</tr>
<tr>
<td></td>
<td>• Operations need to be carried out in an environment with destabilised infrastructures. (Kovács &amp; Spens, 2007).</td>
</tr>
<tr>
<td></td>
<td>• The demand of goods is unpredictable. (Kovács &amp; Spens, 2007).</td>
</tr>
<tr>
<td></td>
<td>• Transportation network is a trunk, collection and distribution network (Kreutzberger, Kongins, &amp; Witteveen, 2010).</td>
</tr>
</tbody>
</table>

For the humanitarian relief organisation the same statement about handling disruptions fits as the army. The core of the organisations in this sector is to handle disruptions. From the humanitarian logistics industry multiple lessons practical lessons can be learned that improve the flexibility of a chain. These measures are the following:

Preparation is the key to success according to Kovács & Spens (2007) and Cozzolino (2012). A proper preparation makes sure that the organisation can respond adequately to a disruption. This in order to decrease the initial impact of a disruption, as mentioned in the disruption profile of Sheffi in Figure 3-3.

Kovács & Spens (2007) describe three phases of disaster relief operations: preparation, immediate response, and reconstruction. In the preparation phase it is important that one prepares for particular risks. However preparation and training are often neglected. Cozzolino (2012) describes that the preparation phase is crucial. This is because it is the one phase in which the physical network design, information and communications technology systems, and the bases for collaboration are developed.
The second measure is to decentralise the supply chain, as seen in Figure 4-1, to shorten the time to respond to a disruption.

![Original Centralized Supply Chain](image1)

![New Decentralized Supply Chain](image2)

*Figure 4-1: From the IFRC’s original centralized supply chain to their new decentralized one (Gatignon, van Wassenhove, & Charles, 2010)*

A decentralised supply chain helps to respond fast to a disruption due to the following aspects (Gatignon, van Wassenhove, & Charles, 2010):

- Agility, Adaptability, and Alignment; adopting a decentralized system based on pre-positioning and pooling.
- Bucks, Bytes and Boxes; implementing this system was made possible thanks to the standardisation of items and processes (bucks and boxes) and traceability of goods through adapted information systems (bytes)
- Identity (i.e. a clear definition of roles), information processes, and incentive systems.
- Alignment was promoted through the three I’s

It becomes apparent from Table 4-3 that only one similarity exists between Allseas and the humanitarian relief organisations. Important lessons can be learned on this one similarity in forms of their ability to handle harsh conditions and uncertainties. However a footnote must be made, the main focus of their logistics department is completely different. For the humanitarian relief organisations the end goal is to get their goods on site, the following process is almost insignificant. For Allseas it is the opposite, the end process is the most important and the way the spare parts arrive is not important. From the core process of humanitarian relief, responding to disasters, the following lessons can be learned. Preparation is the key to success.
Allseas is a contractor; therefore the construction industry could be a good benchmark. Construction companies have the same interactions with their clients and a wide network of suppliers.

Table 4-4: Characteristics of the offshore construction industry in comparison to the construction industry

<table>
<thead>
<tr>
<th>Similar</th>
<th>Different</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Resource-driven nature (Lu &amp; Li, 2003).</td>
<td>• Main activity is to build a construction.</td>
</tr>
<tr>
<td>• Project driven industry (Vrijhoef, 2011).</td>
<td>• Onshore.</td>
</tr>
<tr>
<td>• Location-bound design (Vrijhoef, 2011).</td>
<td>• Transportation network is a trunk feeder configuration (Kreutzberger, Kongins, &amp; Witteveen, 2010).</td>
</tr>
<tr>
<td>• One-off production (Vrijhoef, 2011).</td>
<td></td>
</tr>
<tr>
<td>• Changing production coalitions per project (Vrijhoef, 2011).</td>
<td></td>
</tr>
<tr>
<td>• Outdoor and environmental circumstances (Vrijhoef, 2011).</td>
<td></td>
</tr>
</tbody>
</table>

The two best practices to handle disruptions came forward in an interview with mister Vrijhoef on his dissertation. In his dissertation Vrijhoef (2011) addresses the emergence of integrated and repetitive strategies in a fragmented and project-driven industry, the construction industry. The two best practices can be applied on improving the redundancy of the chain and to create a culture of resilience.

The first best practice helps to improve the redundancy of the system. Vrijhoef addresses this issue as buffering. By adding buffers in your chain your system has the ability to take the first blow. This phase is between the disruption and the full impact of in the disruption profile of Sheffi in Figure 3-3.

The second best practice contributes to a culture of resilience and this aspect is addressed by Vrijhoef as shielding. With shielding the chain is protected by the management for disruptions to get a grip on it. A more safe way of thinking is applied in order to pro-active handle disruptions.

With these two control mechanisms an integrated chain can be developed on which disruptions have a less significant effect. The construction industry has a close association with Allseas as seen in Table 4-4. There are two main and important differences; the activities take place onshore and different kinds of structures need to be constructed. In spite of these differences, lessons can be learned on chain integration and reduction of spillage.
The operations in the dredging industry resemble most of the operations which are carried out by Allseas. The challenging environment of offshore production, capital inventiveness of the industry, and the need for continuous operations are all similar characteristics between the dredging industry and the industry of pipeline installation. The dredging industry is therefore an interesting industry for best practices and to generalise the outcomes of this thesis. Unfortunately, it is not a transparent industry. Information about best practices is not shared with academics.

To streamline a supply chain that is influenced by disruptions a central director (“Kingpin”) is needed. Next to the “Kingpin”, emphasis should lay on structuring the information flows. These two important lessons can be deduced from the military. The possible implications for Allseas are a different corporate structure and implementing a “Kingpin”. In this structure a new communication structure should be implemented. With a different structure the information flows will be improved. The production engineer is the most suitable candidate to perform the role as “Kingpin”.

The humanitarian relief organisation shows that preparation is key. All the literature on disaster relief shows the importance of an elaborated preparation phase with an analysis of potential risks. For Allseas this means that more emphasis should be given to the preparation of a project. If all the risks of a project are identified beforehand adequate actions can be taken in case of a disruption.

As seen in the previous section, the construction industry coincides with Allseas. The resource driven nature of the project driven industry is very similar to the projects of Allseas. The main difference is in the fact that activities of the construction industry are performed onshore. However, due to the enormous pressure of cost minimisation on the construction industry, this industry has become more and more efficient. The ability of minimisation of spillage and their advanced supply chain integration provide guidance for Allseas. Allseas should look into the redundancy of the equipment pool. The protection of the internal chain by means of shielding can be a valuable lesson for the management of Allseas. With more shielding applied the engineers can focus even more on their individual tasks instead of handling the internal disruptions.

In PART II measures will be tested to improve the resilience of the internal supply chain of the welding department of Allseas. Figure 4-2 shows the initial framework of Sheffi with the corresponding industries. These industries have important lessons to implement based on the three concepts of a resilient supply chain. These lessons will be the input for the mitigating strategies that will be tested in PART II and in the end will be the base of the roadmap towards a more resilient supply chain of PPD welding’ department.
5 SYNTHESIS OF PART I

The goal of part I was to determine the root cause of the problem with handling disruptions. This in order to gain insights in the system and to search for the drivers behind the problems in the chain. In this chapter a synthesis is given of the three different analyses conducted in part I. At the end of this chapter the input for the quantitative analysis will be provided.

5.1 CONCLUSIONS OF THE QUALITATIVE ANALYSES

The first step in the qualitative analysis was looking at the concept of disruptions and a disruption assessment framework was introduced. The second step was to look at the bottlenecks in the system of disruption handling. The last step was a structured search for best practices in corresponding industries.

5.1.1 CONCLUSIONS FROM DISRUPTION ANALYSIS

This disruption analysis was conducted based on a framework of disruption assessment by Jüttner, Peck, & Christopher as seen in Figure 2-1. This framework makes a distinction between on the one hand risk sources and on the other hand risk drivers and their mitigating strategies. This framework was applied on the Allseas case and the following is concluded.

The risk sources are not the main cause of problems in the disruption handling of PPD. The problems arise due to the effect the risk drivers have on the sources. In a well prepared and more structured organisation a disruption does not have to be a big problem. Five risk drivers were identified, two external and three internal, and these risk drivers form the base of the bottleneck analysis. The internal risk drivers can be influenced by mitigating strategies and are the lack of communication, innovations, and the equipment pool.

The previous big disruption was assessed as well. The reason why with the previous vessel swap was executed in such a chaotic way was due to a lack in general preparation at the equipment side and not communicating in a proper way. The general way of working was assessed as well in the bottlenecks analysis.

5.1.2 CONCLUSIONS FROM BOTTLENECK ANALYSIS

The supply chain risk drivers were the basis of the bottleneck analysis. By assessing the drivers as the bottlenecks clear problems were pinpointed and the effect of these bottlenecks on resilience is shown as well.

Communication is a big problem at PPD. There is not a structured way to communicate and this influences the execution of projects. Due to the lack of communication the processes are not executed in an efficient manner and are focused on the short term. The lack of communication influences the flexibility of the chain because the current way of communicating cuts the preparation time short. This preparation time, towards a disruption as seen in Figure 3-3, is essential to forecast a disruption.

The innovative culture of Allseas helps them to be one of the major companies in their industry however; it is now a threat to their supply chain. Innovations cannot be scheduled and this implements high uncertainty on the chain. This influences as well the flexibility of the chain due to the impact these uncertainties have on the preparation phase.
The current way of equipment handling does not have an explicit strategy, therefore it is not clear why some equipment is purchased and other equipment is rented. There are no criteria for the make or buy decision. Allseas does not have a lot of official procedures and still none of them are followed, it depends on the experience of the corresponding engineer which steps are taken. These uncertainties in the equipment pool influence the redundancy of the chain.

The current way of handling disruptions resembles the system dynamics archetype shifting the burden (Senge, 1990) With this archetype the phenomenon of a quick fix is shown. This means that a short term solution is used to correct a problem. It is resembles the trap of being tempted to take an aspirin to relieve a headache caused by a brain tumour. The quick fix is used to heal the symptoms and not to go to a fundamental solution.

This archetype is especially applicable on the flexibility side of the resilient supply chain. In the chaotic ad-hoc way of working everyone choses the quick fix instead of working on a more fundamental solution.

5.1.3 CONCLUSIONS FROM LESSONS LEARNED

A literature review for best practices is conducted; the objective of this analysis was two-folded. The first objective was to show the characteristics of other industries to seek similarities in order to generalise the outcome of this thesis. The second objective was to explore best practices based on handling of disruptions in corresponding industries to find out whether these lessons can be translated into the business process of Allseas.

From the literature review the following conclusions on generisability of relevant industries were found.

- The dredging industry resembles Allseas’ industry of pipeline installation. This industry faces the same problems in offshore production and the result of this thesis can be generalised to be implemented in this sector as well.
- The army and the humanitarian relief organisations do not resemble Allseas. However, they are very important for best practices. Both industries are founded to handle disruptions.
- The construction industry is of use as well; although this industry is do not face the difficulties of being offshore. Originally Allseas is a contractor and from the construction industry valuable lessons can be learnt on handling disruptions and reducing spillage. The construction industry is a leader in the minimisation of spillage and uses advanced chain Integration.

Best practices were found in the army, humanitarian relief, and construction industry. These are summarised in an updated version of the framework of Sheffi, as seen in the below stated Figure. These corresponding lessons can be of valuable input for the roadmap towards a resilient internal supply chain of welding consumables and equipment. These findings will be the base of PART II quantitative analysis. The goal of this part is to show what effect the measures have on the process of welding.
The objective of part II of this thesis is to test whether or not the proposed measures will improve the resilience of the system. The quantification of the current situation is nearly impossible, due to the fact that no near miss or extra effort is registered. This is seen as the culture of Allseas and all employees really do their best to make sure that no LD or delay occurs.

The measures that are going to be tested only have influence on the flexibility of the system and not on the redundancy or the culture of this system. This is due to the fact that improvements on redundancy cannot be tested in this system. The lack of transparency in the equipment pool makes it impossible to see whether or not improvements are made. Culture is as well not tested due to the ambiguous nature of this topic and therefore difficult to quantify. Culture will, however, be part of the roadmap towards a resilient chain.

Flexibility will be the core of the measures that will be tested in part II. In the process analysis the interrelations between different tasks emerged and this is crucial for the quantitative analysis. It is important to test the measures in a linked system to see the impact on the whole system and not on a single task itself. The bottlenecks have an impact on the preparation and execution time of a project and therefore time will be the unit for the quantitative analysis. Especially the time between different tasks and the influence of these tasks on each other and on the time to make the deadline of mobilisation of a project are important. These aspects should be the focal point of part II.
PART II: QUANTITATIVE ANALYSIS

In part II quantitative analyses will be conducted to pin point the weaker parts of the system. As conclusion of Part II measures to increase the resilience of the current equipment and consumables Supply chain of welding will be proposed. This will be done by first looking into more detail in the proposed quantitative project management tools and second by applying these tools on the current internal Supply chain of welding equipment and consumables. With these analyses an answer to research question 6 will be given in chapter eight conclusions of part II.
6 MODEL SPECIFICATION

“You can’t manage, what you don’t measure”
Peter Ferdinand Drucker (1909 – 2005) Inventor of the concept of management by objectives

In the introduction a system overview was provided for this study. In part I this system was analysed and from the synthesis can be concluded that the relations between different processes in a project are of major importance. Supply chain management is, in its core being, about managing interdependencies in a system (Greef & Ghoshal, 2004).

These interdependencies influence the total project time and as before mentioned big delays can lead to high fines for Allseas. To assess the influence of the interdependencies on the total project time the impact of the sequence of events should be evaluated. This sequence of events is called the critical path of a project and in this chapter tools will be introduced to analyse this path. The chapter starts with a more detailed description of the project management tools. Next, the model will be described with the entities and the basic constructs. This chapter ends with the scenario analysis set-up.

6.1 PROJECT MANAGEMENT TOOLS

A project is a short endeavour occupied to make a unique product, service or result (Virtual University of Pakistan, 2009). An investment project is a project where resources are used to create assets that will produce benefits over a period of time. It is a unique process, consisting of a set of coordinated and controlled activities with a start and finish date, undertaken to achieve an objective conforming to specific requirements, including the constraints of specification, time, cost and resources. For the bigger projects risk estimation is very important in order to fit the three-fold criterion of success; meeting cost, schedule, and performance targets (Williams, 1995). An efficient tool to address the risks involved is the risk matrix of Prouty (Kallman & Maric, 2004).

PERT is an activity based network model designed for planning, coordination, and controlling complex projects with many interrelated tasks (Hillier & Lieberman, 2001). It is a wide used tool to gain more insights in the paired relationships within a project. The effect of these paired relations is a major problem for the internal supply chain of PPD. PERT is a statistical method that helps the analyst with measuring and forecasting of the progress in large projects. With PERT a path will be shown to execute your project. The critical path is that order of events and whose completion will require the greatest expected time.

PERT is developed on behalf of the Special Projects Office of the U.S. Navy in the early 1960s for the POLARIS nuclear submarine missile programme and the basic requirements for this tool are as follows (Roseboom, Clark, Fazar, & Malcolm, 1959):

- All tasks must be visualised in unambiguous manner to create a network structure.
- Every event or activity should be in a sequence in the network based on a logical set of rules and premises.

Advantages of using PERT as a project management tool.

- The network based structures provides insights in the interdependencies and problem areas that are not obvious.
- PERT determines the probability of achieving a deadline.
- The ability of evaluating the effect of changes in a project.
- The effect of divergence in the expected project time can be predicted.
- A PERT can be presented in a well-organised diagram that provides insights in the customer as the analyst.
6.2 MODEL DESCRIPTION AND ENTITIES

The base of a PERT model is the network or the directed graph from a mathematical point of view (Roseboom, Clark, Fazar, & Malcolm, 1959). A project network consists of all the activities, precedence relationships and time information of a project (Hillier & Lieberman, 2001). With this information known a PERT can be computed and this will be done with the following steps:

1. Gathering information;
2. Break down the project in individual activities;
3. Identify the immediate predecessors of the activities;
4. Estimate the duration of each activity: the three step approach; optimal, most likely and pessimistic time estimation;
5. Visualise the network;
6. Mark the critical path;
7. Mark lack in the planning;
8. Approximate the probability of meeting the initial project deadline.

The following terminology concerning the application of PERT is adapted from the handbook of project management of Jack R. Meredith and Samuel J. Mantel, Jr. (2012).

- Activity, a task or a set of tasks that are needed for a project, and use resources, and take time to be executed;
- Event, an end state that is reached by completing one or more activities;
- Network, the visualisation of all the activities which defines the precedence relationships;
- Path, series of connected activities between two or any of the events;
- Critical, events, activities or paths which will delay the completion of the whole project.

Figure 6-1 shows the two main constructs in a PERT diagram, a distinction can be made between critical and non-critical constructs.

In PERT more constructs can be used to assign tasks in a project. These are external factors, summaries of activities, and highlighted tasks. In this analysis emphasis will lay on a more aggregated approach and therefore only the two basic constructs of milestones and activities are going to be used.
The set up for the scenario analysis will have a time span of 2 years, 2011-2013. In this way current projects and project in the future will be used as input to see their resources. The three year timespan is the planning horizon on which Allseas anticipates.

The analysis of the critical path of the resources will be done by using Microsoft Project. This software package is designed to help a project manager with his tasks of running a project. These tasks are scheduling, assigning resources to tasks, budget and time management, supervising the progress, and analysing workloads.

Different schemes are now made within Allseas to schedule the equipment and the projects that need to be executed. A problem that arises from these schedules is that there is no linkage available between the different schemes. And the different planners use different estimates for the same activities.

In the scenario analysis first the whole system will be shown. This will be done in order to give a more detailed overview of the interdependencies between the different projects and resources. Second the base scenario and the alternative scenario will be tested. This will be on a more detailed level than the whole system. To show the impact of the changes different projects will be taken into account in order to show as well the interdependencies between projects and not only on the equipment.

The comparison of the different scenarios will be done on a less aggregate level than the system overview. Therefore, a translation of the real data is made. The very detailed schedules are translated into a six step schedule; this is done based on two reasons. The first reason is that the details do not matter on this level of the chain. The second reason is that the details in the planning give too much away about the way Allseas works.

One alternative set up will be tested in this analysis; this scenario is based on the conclusions of PART I. The goal of the scenario analysis is to quantify the improvements in the internal supply chain of PPD. The changes in the process should be shown in a different critical path and a reduction in total process time. Other changes are hard to quantify due to the fact that the focus within Allseas is not on business processes but on the production process. Hardly any data is available and therefore the focus will be on the links and the time of the projects.

This testing will be done based on two disruption scenarios; the first scenario is a delay in the supply of equipment to make the mobilisation deadline. The second scenario is to advance the mobilisation deadline. In the next chapter there will be elaborated on the scenario analysis and results will be shown. In order to know which set-up is best a risk analysis conforming the Prouty approach is conducted.
In this chapter a scenario analysis will be conducted. With this analysis insights will be gained in the effectiveness of the measures proposed in the previous chapter. This will be done by first showing the whole system to gain more insights in the interdependencies. The second step is to show the base scenario, in this step the current way of working will be translated in an aggregated model. With this aggregated model a PERT analysis can be conducted. The third step is to take the results of part I into account by composing an improved process to work a project. Different scenarios will be compared and the results will be the input for part III; a roadmap towards a resilient internal supply chain of welding equipment and consumables.

In order to perform a quantitative analysis basic data should be available. As been mentioned before the culture and attitude of Allseas employees are not geared toward registration of the data needed for such an analysis. The primary focus is on getting “the job done”. Therefore it was necessary to make assumptions, rather than have exact figures. This also implies that a quantitative calculation on different scenarios is limited in its effect. Trying to overcome this shortcoming the Prouty matrix is used in order to give some insight of the risks involved in the different scenarios.

7.1 SYSTEM OVERVIEW

In order to conduct the scenario analysis, a better understanding of the total system must be gained. For this reason a system overview is provided in this section. If this planning is put in a PERT diagram with the appropriate equipment links between the projects the following visualisation is seen, Figure 7-1. This Figures shows that you cannot get an overview of the system on a detailed level. It becomes apparent from Figure 7-1 that this system is too complex to analyse. This is the reason that the analysis will be conducted on a higher aggregation level.

![Figure 7-1: Project overview with interrelations between equipment](image)

In Figure 7-2 the vessel planning for 2011-2013 is provided for the three main vessels of Allseas. The projects in these schedules are made anonymous due to the commercial activities of Allseas. The three schedules of the vessels are shown without the relation between the projects of different vessels. These relationships are based on the shared equipment. From these Figures can be seen that all the projects of a vessel are linked to each other. Delay in a project has major impact on the successor. As explained in the introduction every project has its final delivery date. If it is known, beforehand, that if a delivery date is not going to be made, new negotiations with the client start in order to prevent LD.
Figure 7-2: Aggregated tentative vessel utilisation schedule for 2011-2013
### 7.2 Current Internal Supply Chain Set-Up

A system overview was presented in section 7.1. From this overview could be concluded that a more aggregated analysis should be conducted. In Annex G the translation of the detailed scenario into a more aggregated project is performed. Table 7-1 provides a summary of the different project steps, the output of a step, the stakeholders, and the duration of a project step. This Table is translated in an aggregated PERT diagram as seen in Figure 7-3.

Table 7-1: Projects steps of the current internal supply chain set-up

<table>
<thead>
<tr>
<th>Step</th>
<th>Output</th>
<th>Stakeholders</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tender for a project</td>
<td>Project requirements by client</td>
<td>Project engineer, Proposals engineer</td>
<td>?</td>
</tr>
<tr>
<td>2. Kick-off the project</td>
<td>Scope</td>
<td>Project Engineer, Proposals Engineer, Welding Engineer, Assistant Project Manager, Project Manager</td>
<td>1 day</td>
</tr>
<tr>
<td>3. Qualify Project Procedures</td>
<td>Welding Procedure Specification</td>
<td>Training School Welder, Welding Engineer, Client, Quality Controller, Equipment Engineer</td>
<td>190 days</td>
</tr>
<tr>
<td>4. Mobilise project equipment and consumables</td>
<td>Project ready equipment</td>
<td>Equipment engineer, Equipment pool coordinator, Welding engineer, Warehouse manager Vessel, Warehouse manager BOYS</td>
<td>18 days</td>
</tr>
<tr>
<td>5. Installation of pipeline</td>
<td>Installed pipeline</td>
<td>Welder, Welding Engineer, Superintendent, Project Engineer</td>
<td>9 days</td>
</tr>
<tr>
<td>6. Demobilisation of project equipment</td>
<td>Used equipment</td>
<td>Logistics Engineer, Material Controller, Equipment Engineer, Welding Engineer, Warehouse manager Vessel, Warehouse manager BOYS</td>
<td>14 days</td>
</tr>
</tbody>
</table>

![Figure 7-3: Current internal supply chain set-up for project 2 S-W](image)

With the current internal supply chain set-up defined the proposed improvements of part I can be implemented in the next section.
7.3 NEW INTERNAL SUPPLY CHAIN SET-UP

The new scenario must fulfil the criteria of a resilient supply chain. Based on the analysis in part I improvements are made in the current process. The focus of these new project steps is to increase the flexibility of the chain.

As concluded in the synthesis, redundancy issues can only be fixed if the equipment pool is up to date and the cultural issues will part of the roadmap. To improve the flexibility the two out of three measures from the lessons learned are taken into account in the improved schedule. The third lesson that is not taken into account in this PERT analysis is the lesson learned from the humanitarian relief organisation. This lesson has implications on the transportation network and will be part of the roadmap.

The first lesson is to have a “Kingpin”, a central point to be the controller of the whole process. This will be the production engineer. With a more frequently updated scope and more control of the scope everyone within PPD should be continuously up to date of the correct scope of work. This main lesson cannot be tested in this analysis. This is due to the fact that this control is done by a person and this does not show up in the PERT diagram. In the next paragraphs will be elaborated on the improvements in the information flow.

The second lessons are that preparation is key for flexibility. In the current way of working the equipment engineer is not a participant of the project kick-off. In the whole process there is not a milestone at which point the equipment department should be informed about the project specifications. This will be changed in the new scenario; the following adjustments are made:

- A split in the information flow and the equipment flow. Only the qualification procedure will be the information flow that will serve as final control of the mobilisation. With this measure not all the processes are planned sequential anymore. In this way two parallel chains will be formed.

- Creating an explicit step of organising equipment. Currently this is pushed towards the mobilisation deadline. With this step made explicit the equipment engineer can start on time with ordering and collecting the correct equipment. This is now always done last minute and puts a lot of pressure on meeting the deadline for mobilisation.

In Table 7-2 and Figure 7-4 this new and improved scenario is shown.
### Table 7-2: Projects steps of the new internal supply chain set-up

<table>
<thead>
<tr>
<th>Step</th>
<th>Output</th>
<th>Stakeholders</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tender for a project</td>
<td>Project requirements by client</td>
<td>Project engineer, Proposals engineer</td>
</tr>
<tr>
<td>2.</td>
<td>Kick-off the project</td>
<td>Scope</td>
<td>Project Engineer, Proposals Engineer, Welding Engineer, Assistant Project Manager, Project Manager, Equipment Engineer, Production Engineer</td>
</tr>
<tr>
<td>3.</td>
<td>Organise the equipment</td>
<td>Equipment</td>
<td>Equipment Engineer, Welding Engineer</td>
</tr>
<tr>
<td>4.</td>
<td>Qualify Project Procedures</td>
<td>Welding Procedure Specification</td>
<td>Training School Welder, Welding Engineer, Client, Quality Controller, Equipment Engineer</td>
</tr>
<tr>
<td>5.</td>
<td>Mobilise project equipment and consumables</td>
<td>Project ready equipment</td>
<td>Equipment engineer, Equipment pool coordinator, Welding engineer, Warehouse manager Vessel, Warehouse manager BOYS</td>
</tr>
<tr>
<td>6.</td>
<td>Installation of pipeline</td>
<td>Installed pipeline</td>
<td>Welder, Welding Engineer, Superintendent, Project Engineer</td>
</tr>
<tr>
<td>7.</td>
<td>Demobilisation of project equipment</td>
<td>Used equipment</td>
<td>Logistics Engineer, Material Controller, Equipment Engineer, Welding Engineer, Warehouse manager Vessel, Warehouse manager BOYS</td>
</tr>
</tbody>
</table>

![Figure 7-4: New internal supply chain set-up for project 2 S - W](image-url)

In the next section the results of the scenario analysis are shown. The scenarios that are going to be tested are, as aforementioned, a delay in equipment deliveries and a different mobilisation deadline.
7.4 RESULTS OF THE SCENARIO ANALYSIS

In this section the effect of the two disruption scenarios are shown. First the effect of the disruptions will be shown on the base scenario and second on the improved scenario. The first disruption is a delay in the supply of equipment. Instead of the normal four days this step will take 12 days. The second disruption is an early start of pipeline installation. A predecessor of project 2 S-W is going to finish his project a week before schedule. This means that the new start date for this project will be December 24th. These scenarios are based on interviews with the corresponding engineers at PPD.

7.4.1 NON-DISRUPTED SCENARIO

Figure 7-5: Results of the non-disrupted scenario

In Figure 7-5 the two internal supply chain set-ups are shown. These set-ups will encounter a disruption and in the next two sections the effect of those disruptions is shown.

7.4.2 DISRUPTION SCENARIO 1: DELAY IN SUPPLY OF EQUIPMENT

Figure 7-6: Results of disruption scenario 1: delay in supply of equipment

The current internal supply chain set-up shows that a delay in the supply of equipment of eight days directly gives you a delay of eight days in the start of your project. When equipment is part of the final step of the internal chain it becomes very time critical. And these time delays can be very expensive due to the operational costs of the vessel and the LD by the client. As seen in the above shown figure, the disruption does not influence the internal supply chain of the new internal supply chain set-up.
7.4.3 DISRUPTION SCENARIO 2: CHANGED MOBILISATION DEADLINE

The current internal supply chain set-up shows that if the mobilisation needs to take place a week before the initial planning, no time left for organising the equipment. The shipping of all goods towards the vessel takes on average 14 days. So in order to be on time everything should be shipped immediately. Due to the commitment of the personnel of Allseas, this type of disruption has been handled before. However, it is always a very close call and if something goes wrong with the supply of the equipment the deadline will be missed.

As seen in the above shown figure, the disruption again does not influence the internal supply chain of the new internal supply chain set-up.
7.5  SENSITIVITY ANALYSIS

In the previous section a scenario analysis is conducted to see the impact of the new internal supply chain set up. To check the robustness of these solutions a sensitivity analysis is conducted. This will be done on the impact of the qualitative changes on the resilience parameters. And this will be done on the disruptions itself.

7.5.1  SENSITIVITY ANALYSIS OF THE MEASURES

In this section the robustness of the new internal supply chain set up will be looked up on. The two measures, the “Kingpin” and the explicitly made equipment step, will be tested. On the “Kingpin” the effect of the cultural change will be shown. On the equipment step the effect of innovations will be tested.

“Kingpin”

From the cultural assessment came forward that there is a need for change. This need for change can helps the implementation of the Kingpin however, in this sensitivity analysis is assessed what the influence of an ineffective cultural change is.

Table 7-3: Sensitivity analysis on the effect of cultural change

<table>
<thead>
<tr>
<th>Succeeded cultural change</th>
<th>Impact on effectiveness of the “Kingpin”</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>If the culture within PPD is changed towards a full resilient mind set the “Kingpin” is able to control the total process. This resilient mind set entails that adhocracy is not permitted anymore and a more hierarchical way of working is implemented. With this way of working the engineers consult each other on changes in the scope of work. The production engineer is the central controller and is in this way able to streamline the process.</td>
</tr>
<tr>
<td>80%</td>
<td>If the cultural change did not succeed to the full 100% the “Kingpin” is less effective. In this scenario the resilient mind set is transferred to almost all the engineers however, some are resistant. These engineers will continue working like usual and will frustrate from time to time the job of the “Kingpin”. With some of the engineers not participating in the new way of working the “Kingpin” is still effective it only is more difficult to execute the tasks of the “Kingpin” for the production engineer.</td>
</tr>
<tr>
<td>50%</td>
<td>With only a 50% culture change the “Kingpin” will encounter severe problems with streamlining the process. The resilient mind set is only transferred to the new engineers and the rest continues with their old ways of working.</td>
</tr>
</tbody>
</table>
Equipment step
Innovation is hard to schedule and this can really impact the internal supply chain. In this sensitivity analysis the impact of innovations on the effectiveness of the new internal supply chain set up is shown.

Table 7-4: Sensitivity analysis on the effect of innovations

<table>
<thead>
<tr>
<th>Innovations in a project</th>
<th>Impact on effectiveness of the new equipment step</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>With no need for new designed equipment the new equipment step is very stable. If the equipment engineer knows from the beginning of the project which equipment is needed the equipment can be ordered or overhauled and these process times are known.</td>
</tr>
<tr>
<td>20%</td>
<td>If 20% of the equipment needs to be designed and made at the beginning of a project this could lead to delays in a project. This can only be effective if the communication between PPD and innovations runs smoothly.</td>
</tr>
<tr>
<td>50%</td>
<td>With 50% of the equipment that needs to be designed and made at the beginning of a project the equipment step becomes uncontrollable. Innovation</td>
</tr>
</tbody>
</table>

7.5.2 SENSITIVITY ANALYSIS OF THE DISRUPTIONS

Two types of disruptions are tested in the scenario analysis. A delay in the delivery of equipment and the change of mobilisation date. In this section the bandwidth of these disruptions is assessed.

Delay in the delivery of equipment
The scenario analysis is based on the most likely delay in the delivery of equipment. In this sensitivity analysis the impact of bigger delays is assessed.

Table 7-5: Sensitivity analysis on the effect of a bigger delay in the supply of equipment

<table>
<thead>
<tr>
<th>Delay in weeks</th>
<th>Impact on the internal supply chain</th>
<th>New set-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double</td>
<td>All type of delays have a paramount impact on the current internal supply chain set-up. Due to the parallel sequence of steps a delay in this step instantly results in missing the mobilisation deadline. With missing this deadline idle days of the vessel will occur or even LD.</td>
<td>In the new set-up even a quadrupling of the lead time of the equipment step does not influence the system. This is due to the fact that the split of the information and the physical flow creates a lot of time to arrange all the equipment needed.</td>
</tr>
<tr>
<td>Triple</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadruple</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Change of mobilisation date
A change in mobilisation date is a disruption that occurs in almost every project. The scenario analysis was based on the most likely change in mobilisation deadline. In this sensitivity analysis the impact of an even bigger change is assessed.

Table 7-6: Sensitivity analysis on the effect of moving the mobilisation deadline

<table>
<thead>
<tr>
<th>Moving forward of the deadline</th>
<th>Impact on the internal supply chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>One week</td>
<td>Every change in the mobilisation deadline forward in the timeline creates troubles with equipment. As with the delay in the supply of equipment, bigger changes lead to an even longer time a vessel has to wait.</td>
</tr>
<tr>
<td>Two weeks</td>
<td>As seen in the scenario analysis the change of a week in the mobilisation deadline does not affect the internal supply chain.</td>
</tr>
<tr>
<td>Three weeks</td>
<td>If the deadline of mobilisation is moved forward two or even three weeks the new set-up will encounter difficulties as well. This is not on the equipment side of the chain but on the qualification process. More research should be conducted on this aspect. From the daily processes it is seen that from time to time some of these qualification processes can be shortened in time.</td>
</tr>
</tbody>
</table>

7.5.3 CONCLUSIONS OF THE SENSITIVITY ANALYSIS

From the sensitivity analysis on the measures the following can be concluded:

- In the “Kingpin” case it is important that the new mind set is transferred. All engineers should change because otherwise the “Kingpin” encounters a lot of problems with streamlining the process.
- In the equipment case a high level of innovations in a project results in an uncontrollable delays. Attention should be given to the level of innovations in a project especially if it is a tight schedule. If there is a high level of innovations in a project communication between Innovations and PPD is very important.

From the sensitivity analysis on the disruptions the following can be concluded:

- The new internal supply chain set-up is not affected by even bigger delays in the delivery of equipment.
- The equipment step in the new internal supply chain set-up is not affected by a change in the mobilisation deadline. However, problems arise in the qualification process and more research should be conducted to gain more insights in the effect of a shorter time for qualification. In practice it is seen that from time to time some procedures can be written in a shorter time frame.
In this section a scenario analysis was conducted. In this analysis the current internal supply chain set-up was compared with the new internal supply chain set-up. This new set-up was composed based on the findings of part I of this thesis. From this scenario analysis the following can be concluded:

In the current set-up all steps in the process are part of the critical path. Every task is executed sequential and this results in a chain in which every task is dependent on the predecessor. And the scenario analysis showed that both the disruptions have a negative effect on the chain. In one of the cases this resulted in missing the deadline of mobilisation with eight days.

Beforehand it cannot be said that missing a deadline immediately results in LD. However, a delay will result in an idle vessel. With the operation costs of a vessel around the half a million euro’s a delay of eight days will result in a loss for Allseas of four million euro’s.

In the improved case the internal supply chain is adapted in order to reduce the criticalness of the whole chain. The analysis shows that the new scenario has a positive effect on the critical path. The improved scenario has two new things.

- The first improvement is the fact that the step of involvement of the equipment engineer is moved forward in the chain. In this way the equipment department can anticipate on the external disruptions and one of the risk drivers will be eliminated.
- The second improvement is the fact that the “Kingpin” needs to be implemented. A more central steering in the chain is needed to make the chain less critical.

In the new internal supply chain set-up all deadlines are made and no time delays occurred.

These improvements will make the internal supply chain more flexible. With the step of the organisation of equipment decoupled from the mobilisation process more time_to_respond is created. With these changes the chain will be more flexible in order to improve the resilience of the internal supply chain of welding equipment and consumables.

However, this analysis was performed with a more aggregated project planning. The sensitivity analysis showed that the new internal supply chain set-up is capable of handling multiple types of disruptions. Emphasis should be given to the implementation of the measures because they can be influenced by innovations and the willingness to change. More research should be conducted on the effect of this set-up on the whole system.
8 CONCLUSIONS OF PART II

In part II a scenario analysis was conducted. The goal of this analysis was to show whether or not the measures of part I were effective in making the supply chain more resilient.

The new internal supply chain set-up must fulfill the criteria of a resilient supply chain, as defined based on Sheffi (2007) in the introduction. Based on the analysis in part I improvements are made in the current process. The focus of these new project steps is to increase the flexibility of the chain. As concluded in the synthesis of part I redundancy and culture were not part of this solution. To improve the flexibility the two main lessons conclusions of part I were taken into account.

The first lesson is to have a “Kingpin”, a central point to be the controller of the whole process. This will be the production engineer. With a more frequently updated scope and more control of the scope everyone within PPD should be always up to date of the correct scope of work. This main lesson cannot be tested in this analysis. This is due to the fact that this control is done by a person and this does not show up in the PERT diagram.

The second lesson is that preparation is key for flexibility. In the current way of working the equipment engineer is not a participant of the project kick-off. In the whole process there is not a milestone at which point the equipment department should be informed about the project specifications.

As a result a new internal supply chain set-up was composed. In this set-up a split was made between the information flow and the equipment flow. With this split not all processes were sequential anymore and a parallel flow occurs. This releases the chain of its criticalness. In the current internal supply chain set-up every process is critical. With the new set-up this is not the case.

From the analysis can be concluded that the new internal supply set-up is more flexible and in the end will increase the resilience. The two disruptions did not have an effect on the internal supply chain in the new internal supply chain set-up. The effect of moving the step of organising the equipment forward in the chain created time_to_respond to a disruption. And with this time_to_respond build in the system one of the major aspects of a resilient chain is gained.

However, this analysis was performed with a more aggregated project planning. More research should be conducted on the effect of this set-up on the whole system. The results on a single chain are promising and with a “Kingpin” in control more communication between different projects will occur.

In Part III the overall conclusions and recommendations will be given, these together will form the roadmap towards a more resilient chain.
In the final part of this thesis conclusions will be drawn and recommendations will be made in order to provide Allseas Engineering Bv with a roadmap towards a resilient internal equipment and consumables Supply chain. This roadmap is as well the answer to research question seven.
“Reasoning draws a conclusion, but does not make the conclusion certain, unless the mind discovers it by the path of experience”

Roger Bacon (1214-1294) English philosopher and Franciscan

9.1 CONCLUSION

The objective of this thesis was to control and optimise the logistics of welding equipment and consumables. This is necessary in order to reduce risks, keep costs of logistics under control, and ensure a flexible planning to speed up implementation of changes in planning. In the introduction this ability of the system was defined as the resilience of the internal equipment and consumables supply chain.

The following research question was deduced from this problem statement:

*How to increase the resilience of the internal equipment and consumables supply chain of Allseas’ welding department to cope with the disruptions stemming from the seasonal planning?*

Based on this question two types of analyses were conducted. In part I qualitative analyses were conducted to determine the root cause of the problem. In part II a more quantitative analysis was conducted to see if the effectiveness of the measures. These analyses were conducted based on the resilience framework of Sheffi.

This framework proposed three types of solutions to increase the resilience of a supply chain. This can be done by increasing the flexibility and redundancy, and changing the culture. Per type of solution the following should be implemented to increase the resilience of the internal equipment and consumables supply chain.

Flexibility; from the analyses in part I & II can be concluded that flexibility in this system cannot be imposed by substitutes. Due to the nature of the operation hardly any substitutes can be used. Both the procedures as the equipment need to be pre-qualified onshore before going offshore. This is the reason that preparation is key. The PERT analysis showed that the new internal supply chain set-up removes the criticalness from the chain. The new internal supply chain set-up splits the internal supply chain in an information and a physical flow of goods. With parallel processes the internal supply chain has time_to_respond to disruptions and contributes to a more resilient supply chain.

Redundancy; the equipment database needs to be fully up to date before decisions concerning equipment can be made. When all the equipment is updated an assessment can be made on the criticalness of certain equipment.

Culture; it is of major importance to change the culture within Allseas. Instead of healing the symptoms, the firefighting behaviour, fixes for a more fundamental solution should be taken. These steps will be elaborated on in the recommendations.
9.2 GENERALISABILITY OF THE CONCLUSIONS FOR OTHER INDUSTRIES

In chapter four, lessons learned, other industries were assessed in order to gain insights in disruption handling. Another goal of this chapter was to see whether or not the results of this research could be applied on these industries.

The conclusions of this thesis are especially applicable on companies that have a similar set-up as Allseas has. Therefore, the dredging industry could benefit from the insights gained in this thesis. Dredgers face the same difficulties with their daily execution as Allseas does. The high operating costs offshore create awareness for a less vulnerable supply chain.

The framework of Sheffi is a good tool to assess a company on disruption handling. And the lessons from other industries could be of help for other companies as well. Flexibility, redundancy, and culture are three aspects on which every company can create a more resilient chain.

The welding department was the focal point in this thesis. However, the results of this thesis can be applied on all departments of Allseas. For demarcation purposes only welding was part of the scope of this research. The key to success is better communication between the different departments.
10 Recommendations

*When the wind of change blows, some will build walls, others windmills*

*German proverb*

The end goal of this thesis was to search for steps to take in order to improve the capabilities of PPD to handle disruptions. This capability of handling disruptions was defined as resilience and the recommendations for Allseas and further research are given per main aspect of resilience.

Flexibility; this aspect influences the time_to_respond to a disruption. As seen in other industries preparation is the key for success. From the quantitative analysis it can be concluded that a new internal supply chain set-up is effective in creating more time_to_respond to a disruption. It is therefore recommended to move the step of organising the equipment to the beginning of the chain. With this step directly after the project kick off a distinction can be made between an information flow and a physical flow. With these two flows a better supply chain management can be applied. With a more flexible internal chain PPD is fit to handle disruptions. A “Kingpin”, central controller, can oversee the whole chain. Within PPD the production engineer is fit for this job. The tasks of the production engineer are already in streamlining the process. With more emphasis on controlling the information flows the flexibility will improve. If the information will be allocated through one person no miscommunication about scope of work should exist anymore.

The third lesson to improve the flexibility stems from the humanitarian relief organisations. This lesson is applicable on the transportation network of Allseas. This is a topic on which more research should be conducted. If the other two measures are implemented the flexibility of the internal chain is going to be improved.

Redundancy; during this research big improvements are made by the organisation to get a more transparent equipment pool. The transparency of the equipment pool is still not sufficient and therefore no conclusions were drawn about the redundancy.

The equipment database should be organised better. It is essential to know of all the equipment what the status, location, and the lifetime is. If these aspects are known an analysis on the equipment should be conducted. With insights in the criticalness of certain equipment decisions can be made about redundancy in the system. A risk assessment should be conducted to give priority to the most critical equipment. And with the output of this assessment criteria for the make or buy decision can be set-up.

Culture; without incentives no change will be made. From the OCAI assessment it can be concluded that there is a need to change. However a more practical incentive should be given to the personnel of PPD. The engineers should see the need of change. The need is proven in this thesis. More research should be conducted in order to see how to let the engineers see this need. And which incentives are effective and how the real change can be implemented.

A workshop session must be scheduled for all personnel in PPD. In this session all engineers should be given an update on how to handle disruptions. In this session more detailed recommendations should be transferred to the engineers. This follows from lessons learned from the army; induce you personnel from the start with a resilient mind set.

The other lesson learned stems from the construction industry and concerns shielding. It is recommendable to try to prevent disruptions to happen. The management decisions were out of scope for this research, however shielding can be applied to influence one of the risk sources.
The conclusions together with the recommendations form the roadmap towards a resilient internal supply chain. If this roadmap is implemented in the daily execution of the work off the engineers the internal supply chain of Allseas’ welding department will be more resilient. With this resilience they are able to handle the disruptions stemming from the seasonal planning.

In the future more emphasis should be given to the business metrics in order to quantify the “business as usual” state. With more data available on processes disruptions can be monitored. With this data more improvements to the internal chain can be made.
REFERENCES


Figure A.1: Current internal supply chain of welding equipment and consumables.
Figure A.2: UML diagram of a welding project
Table A 1: Oracle Equipment Pool Breakdown

<table>
<thead>
<tr>
<th>ORACLE Equipment Pool Level 3</th>
<th>ORACLE Equipment Pool Level 4</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQ-900 Welding</td>
<td>EQ-905/17 MANUAL WELDING</td>
<td>6</td>
</tr>
<tr>
<td>EQ-941 INT LINEUP CLAMPS</td>
<td>EQ-941/01 Internal Line Up Clamp 24-26</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>EQ-941/02 Internal Line Up Clamp 30-36</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>EQ-941/03 Internal Line Up Clamp 14-18</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>EQ-941/04 Internal Line Up Clamp 34-36</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>EQ-941/05 Internal Line Up Clamp 30-34</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>EQ-941/06 Internal Line Up Clamp 48-52</td>
<td>2</td>
</tr>
<tr>
<td>EQ-942 BEAR CAGES</td>
<td>EQ-942/01 BEAR CAGE</td>
<td>4</td>
</tr>
<tr>
<td>EQ-943 BEVEL MACHINES</td>
<td>EQ-943/01 Pipe Facing Machine 6-12</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>EQ-943/02 Pipe Facing Machine 8-16</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>EQ-943/03 Pipe Facing Machine 16-26</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>EQ-943/04 Pipe Facing Machine 16-32</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>EQ-943/05 Pipe Facing Machine 32-48</td>
<td>11</td>
</tr>
</tbody>
</table>

Table A 2: Vessel Characteristics

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Pipelay Equipment</th>
<th>Specialties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitaire</td>
<td>Double-joint working stations: 2 x 4 (each with 3 x welding and 1 x NDT)</td>
<td>Is able to withstand higher waves than the Lorelay.</td>
</tr>
<tr>
<td></td>
<td>Main firing line welding stations: 8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pipeline diameter: 60” max</td>
<td></td>
</tr>
<tr>
<td>Audacia</td>
<td>Single-joint working stations</td>
<td>Is able to work in congested area has a high transit speed, high lay speed and large carrying capacity</td>
</tr>
<tr>
<td></td>
<td>Working stations: 7 x welding, 1 x NDT, 3 x coating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pipeline diameter: 60” max</td>
<td></td>
</tr>
<tr>
<td>Lorelay</td>
<td>Single-joint working stations</td>
<td>Has a high cruising speed and is very economical for the installation of small to medium pipes</td>
</tr>
<tr>
<td></td>
<td>Working stations: 6 x welding, 1 x NDT, 3 x coating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pipeline diameter: 41” max</td>
<td></td>
</tr>
<tr>
<td>Tog Mor</td>
<td>Single-joint working stations</td>
<td>Is able to install a pipeline in shallow water (4m), this ship is towed or uses anchors to move</td>
</tr>
<tr>
<td></td>
<td>Working stations: 3 x welding, 1 x NDT, 1 x coating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pipeline diameter: 60” max</td>
<td></td>
</tr>
</tbody>
</table>
ANNEX C: PROCESS ORIENTED MODELLING

Figure A.3: SADT A0 Pipeline installation PPD Welding

Figure A.4: SADT A3 Qualify the project procedure
Figure A 5: SADT A4 Mobilise project equipment and consumables

Figure A 6: SADT A5 Demobilise project equipment
Figure A.7: Formal Diagram
ANNEX E: OCAI QUESTIONNAIRE

The Organizational Culture Assessment Instrument (OCAI) (Krikke, 2010)
The American professor Robert Quinn and his colleague Kim Cameron developed the model of the Competing Values Framework. This framework consists of four Competing Values that correspond with four types of organizational culture. Every organization has its own mix of these four types of organizational culture. This mix is found by the completion of a short questionnaire. This questionnaire is a valid method to indicate handles for change.

You, as the test-taker, are asked to divide 100 point over four alternatives that correspond to one of the four culture types. The test needs to be repeated and this the scores should represent the desired cultural situation for Allseas.

1. Dominant Characteristics

<table>
<thead>
<tr>
<th>Current</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>The organization is a very personal place. It is a lot like an extended family. People seem to share a lot of themselves.</td>
<td></td>
</tr>
<tr>
<td>The organization is a very dynamic entrepreneurial place. People are willing to stick out their necks and take risks.</td>
<td></td>
</tr>
<tr>
<td>The organization is very results-oriented. A major concern is getting the job done. People are very competitive and achievement-oriented.</td>
<td></td>
</tr>
<tr>
<td>The organization is a very controlled and structured place. Formal procedures generally govern what people do.</td>
<td></td>
</tr>
</tbody>
</table>

2. Organisational Leadership

<table>
<thead>
<tr>
<th>Current</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>The leadership in the organization is generally considered to exemplify mentoring, facilitating, or nurturing.</td>
<td></td>
</tr>
<tr>
<td>The leadership in the organization is generally considered to exemplify entrepreneurship, innovation, or risk taking.</td>
<td></td>
</tr>
<tr>
<td>The leadership in the organization is generally considered to exemplify a no-nonsense, aggressive, results-oriented focus.</td>
<td></td>
</tr>
<tr>
<td>The leadership in the organization is generally considered to exemplify coordinating, organizing, or smooth-running efficiency.</td>
<td></td>
</tr>
</tbody>
</table>

3. Management of Employees

<table>
<thead>
<tr>
<th>Current</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>The management style in the organization is characterized by teamwork, consensus, and participation.</td>
<td></td>
</tr>
<tr>
<td>The management style in the organization is characterized by individual risk taking, innovation, freedom, and uniqueness.</td>
<td></td>
</tr>
<tr>
<td>The management style in the organization is characterized by hard-driving competitiveness, high demands, and achievement.</td>
<td></td>
</tr>
<tr>
<td>The management style in the organization is characterized by security of employment, conformity, predictability, and stability in relationships.</td>
<td></td>
</tr>
</tbody>
</table>
### 4. Organization Glue

<table>
<thead>
<tr>
<th>Current</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>The glue that holds the organization together is loyalty and mutual trust. Commitment to this organization runs high.</td>
<td></td>
</tr>
<tr>
<td>The glue that holds the organization together is commitment to innovation and development. There is an emphasis on being on the cutting edge.</td>
<td></td>
</tr>
<tr>
<td>The glue that holds the organization together is an emphasis on achievement and goal accomplishment.</td>
<td></td>
</tr>
<tr>
<td>The glue that holds the organization together is formal rules and policies. Maintaining a smooth-running organization is important.</td>
<td></td>
</tr>
</tbody>
</table>

### 5. Strategic Emphases

<table>
<thead>
<tr>
<th>Current</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>The organisation emphasizes human development. High trust, openness, and participation persist.</td>
<td></td>
</tr>
<tr>
<td>The organisation emphasizes acquiring new resources and creating new challenges. Trying new things and prospecting for opportunities are valued.</td>
<td></td>
</tr>
<tr>
<td>The organisation emphasizes competitive actions and achievement. Hitting stretch targets and winning in the marketplace are dominant.</td>
<td></td>
</tr>
<tr>
<td>The organisation emphasizes permanence and stability. Efficiency, control, and smooth operations are important.</td>
<td></td>
</tr>
</tbody>
</table>

### 6. Criteria for Success

<table>
<thead>
<tr>
<th>Current</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>The organisation defines success on the basis of the development of human resources, teamwork, employee commitment, and concern for people.</td>
<td></td>
</tr>
<tr>
<td>The organisation defines success on the basis of having the most unique or newest products. It is a product leader and innovator.</td>
<td></td>
</tr>
<tr>
<td>The organisation defines success on the basis of winning in the marketplace and outpacing the competition. Competitive market leadership is key.</td>
<td></td>
</tr>
<tr>
<td>The organisation defines success on the basis of efficiency. Dependable delivery, smooth scheduling, and low-cost production are critical.</td>
<td></td>
</tr>
</tbody>
</table>
The four culture types

1. The Clan Culture
A very pleasant place to work, where people share a lot of personal information, much like an extended family. The leaders or heads of the organization are seen as mentors and perhaps even parent figures. The organization is held together by loyalty or tradition. Commitment is high. The organization emphasizes the long-term benefit of human resources development and attaches great importance to cohesion and morale. Success is defined in terms of sensitivity to customers and concern for people. The organization places a premium on teamwork, participation, and consensus.

Leader Type: facilitator, mentor, team builder.
Value Drivers: commitment, communication, development.
Theory for Effectiveness: human development and participation produce effectiveness.
Quality Strategies: empowerment, team building, employee involvement, Human Resource development, open communication.

2. The Adhocracy Culture
A dynamic, entrepreneurial, and creative place to work. People stick out their necks and take risks. The leaders are considered innovators and risk takers. The glue that holds the organization together is commitment to experimentation and innovation. The emphasis is on being on the leading edge. The organization’s long term emphasis is on growth and acquiring new resources. Success means gaining unique and new products or services. Being a product or service leader is important. The organization encourages individual initiative and freedom.

Leader Type: innovator, entrepreneur, visionary.
Value Drivers: innovative outputs, transformation, and agility.
Theory for Effectiveness: innovativeness, vision and new resources produce effectiveness.
Quality Strategies: surprise and delight, creating new standards, anticipating needs, continuous improvement, finding creative solutions.
3. The Market Culture
A result-oriented organization whose major concern is getting the job done. People are competitive and goal-oriented. The leaders are hard drivers, producers, and competitors. They are tough and demanding. The glue that holds the organization together is an emphasis on winning. Reputation and success are common concerns. The long-term focus is on competitive actions and achievement of measurable goals and targets. Success is defined in terms of market share and penetration. Competitive pricing and market leadership are important. The organizational style is hard-driving competitiveness.

Leader Type: hard driver, competitor, producer
Value Drivers: market share, goal achievement, profitability
Theory for Effectiveness: aggressive competition and customer focus produce effectiveness.
Quality Strategies: measuring customer preferences, improving productivity, creating external partnerships, enhancing competitiveness, involving customers and suppliers.

4. The Hierarchy Culture
A very formalized and structured place to work. Procedures govern what people do. The leaders pride themselves on being good coordinators and organizers who are efficiency minded. Maintaining a smooth-running organization is most critical. Formal rules and policies hold the organization together. The long-term concern is stability and performance with efficient, smooth operations. Success is defined in terms of dependable delivery, smooth scheduling and low cost. The management of employees is concerned with secure employment and predictability.

Leader Type: coordinator, monitor, organizer.
Value Drivers: efficiency, punctuality, consistency and uniformity.
Theory for Effectiveness: control and efficiency with appropriate processes produce effectiveness.
Quality Strategies: error detection, measurement, process control, systematic problem solving, quality tools
Results of Allseas PPD department.

<table>
<thead>
<tr>
<th>Caspar</th>
<th>Erik</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Caspar Diagram" /></td>
<td><img src="image2" alt="Erik Diagram" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tom</th>
<th>Warner</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Tom Diagram" /></td>
<td><img src="image4" alt="Warner Diagram" /></td>
</tr>
</tbody>
</table>
Andre

![Radar Chart]

- **Internal Focus and Integration**
- **Flexibility and Discretion**
- **Stability and Control**
- **External Focus and Differentiation**

Legend:
- **Now**: Green
- **Future**: Red
In Table A 3 the research planning and the expected deliverables are shown. In the table of the deliverables the research planning is linked to the research questions.

**Table A 3: Research Planning**
ANNEX G: TRANSLATION OF GANNT CHART INTO AGGREGATED PROJECT STEPS

In this Annex a translation will be made of a detailed schedule into the aggregated project steps. This will be done based on the current supply chain as described in Annex A & Annex C. The project 2 S W of vessel 3 is the example for this translation as seen in Table A 4.

A project with the shortest time for pipeline installation was chosen due to the fact that the other process steps are almost the same for every project. In general the time to prepare a project does not differ much per project. More complex projects are done by more people and therefore the preparation time stays the same.

Table A 4: GANNT diagram

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Aggregated Project Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 2 S -W Vessel 3</td>
<td>228,63 days</td>
<td>Fri 14-12-12</td>
<td>Wed 30-10-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td>Receive WPQ pipe</td>
<td>1 day</td>
<td>Fri 14-12-12</td>
<td>Fri 14-12-12</td>
<td></td>
</tr>
<tr>
<td>Band request</td>
<td>7 days</td>
<td>Tue 13-8-13</td>
<td>Thu 22-8-13</td>
<td></td>
</tr>
<tr>
<td>Prepare DRW</td>
<td>14 days</td>
<td>Thu 22-8-13</td>
<td>Wed 11-9-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td>Requisition</td>
<td>1 day</td>
<td>Tue 24-9-13</td>
<td>Wed 25-9-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td>Prepare calblocks</td>
<td>14 days</td>
<td>Wed 25-9-13</td>
<td>Tue 15-10-13</td>
<td></td>
</tr>
<tr>
<td>Para's 30.000&quot; x 21.5mm</td>
<td>11 days</td>
<td>Tue 15-10-13</td>
<td>Wed 30-10-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td>WPQ Phoenix</td>
<td>0,05 days</td>
<td>Wed 11-9-13</td>
<td>Wed 11-9-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td>Defect welding</td>
<td>2 days</td>
<td>Fri 14-6-13</td>
<td>Mon 17-6-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td>Fabrication</td>
<td>48 days</td>
<td>Fri 14-6-13</td>
<td>Tue 20-8-13</td>
<td></td>
</tr>
<tr>
<td>Delivery @ BOYS</td>
<td>1 day</td>
<td>Thu 28-2-13</td>
<td>Thu 28-2-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td>WPQ manuals</td>
<td>10 days</td>
<td>Thu 12-9-13</td>
<td>Wed 25-9-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td>Requisition</td>
<td>7 days</td>
<td>Fri 14-6-13</td>
<td>Mon 24-6-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td>WPQ flanges &amp; re-do WPQ Fabrication</td>
<td>10 days</td>
<td>Tue 25-6-13</td>
<td>Mon 8-7-13</td>
<td>3. Qualification</td>
</tr>
<tr>
<td></td>
<td>60 days</td>
<td>Tue 9-7-13</td>
<td>Mon 30-9-13</td>
<td></td>
</tr>
<tr>
<td>Arrange equipment</td>
<td>3 days</td>
<td>Thu 26-9-13</td>
<td>Mon 30-9-13</td>
<td>4. Mobilisation</td>
</tr>
<tr>
<td>Delivery @ BOYS</td>
<td>1 day</td>
<td>Tue 1-10-13</td>
<td>Tue 1-10-13</td>
<td>4. Mobilisation</td>
</tr>
<tr>
<td>Ship to vessel &amp; Mobilisation</td>
<td>14 days</td>
<td>Wed 2-10-13</td>
<td>Mon 21-10-13</td>
<td>4. Mobilisation</td>
</tr>
<tr>
<td>Lay pipe 4km 30&quot;</td>
<td>9 days</td>
<td>Tue 22-10-13</td>
<td>Tue 29-10-13</td>
<td>5. Installation</td>
</tr>
<tr>
<td>Demobilisation Audacia</td>
<td>14 days</td>
<td>Tue 29-10-13</td>
<td>Wed 30-10-13</td>
<td>6. Demobilisation</td>
</tr>
</tbody>
</table>

Step 1 & 2 are currently not taken into account from a PPD point of view as seen in the Table. In the improved scenario this will be a part of the process.