NON CONFIDENTIAL VERSION

MASTER THESIS

LINE PIPE LOGISTICS

Improving the workability and productivity of the pipe-lay barge the Stingray

BY

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Van Oord
Marine ingenuity

TU Delft Delft University of Technology

COVER DESIGN

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This version is adjusted, because of confidentiality reasons. Some parts of thesis are excluded.

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Preface

This master thesis is the final part of my master Transport, Infrastructure and Logistics at the faculty of Civil Engineering of the Delft University of Technology (TU Delft). The thesis will conclude my education at the TU Delft. To prepare myself for a career I wanted to do my thesis at my preferred company Van Oord dredging and marine contractors. With the help of a contact of Bart Wiegmans a docent of my I could get a solicitation. In the preface I want to express my gratitude to the people that helped me during the period of my thesis. Without them this period would be less enjoyable and much harder.

First of all I want to thank the members of my committee for their feedback and support during the thesis. I would like to thank from the university, Alexander Verbraeck, Martijn Warnier and Wouter Beelaerts van Blokland, and from Van Oord Rob de Jong and Giuseppe Petrina. I would like to specially thank Martijn for the biweekly meetings where I could talk about the content, but also on the process of writing a thesis. He helped me by supporting me to finish my thesis.

From Van Oord I would like to thank Rob de Jong and Giuseppe Petrina. I would like to thank Rob de Jong for giving me the opportunity to do my thesis at Van Oord and supporting me were needed. I would like to thank him for helping out the moment that Giuseppe was abroad. I want to thank Giuseppe for the daily supervision and guidance. I felt supported by him to develop my own view within the company and explore what is needed for my thesis. Giuseppe, together with the department, made me feel part of Van Oord.

Last I want to thank my friends and family for the support during the thesis period, on the thesis and outside the thesis. I want to thank my parents for the support and comfort during my study period.

Nov. 2014, Rotterdam Rolf van den Broek

Summary

This version is adjusted, because of confidentiality reasons. This can influence understanding of the total report.

Van Oord, a marine contractor, has acquired the Shallow Water Pipe-Lay (SWPL) vessel the Stingray and wants to become a lead-contractor in Engineering, Procurement, Installation, and Construction (EPIC) pipe-lay projects. Within Van Oord an innovation project has started on targeted areas to become proficient as lead contractor.

This thesis goal is to examine how the supply chain of line pipe needs to be structured including a new logistical system. This thesis will assist Van Oord with decisions regarding implementation of a line pipe information system and gives insight in the supply chain. The first and main objective of the thesis is to improve the workability and productivity of the Stingray by managing the supply chain. The second objective is to find a general supply chain structure for the line pipe to an offshore location. The third objective of this thesis is to explore the possibilities of the information system. The fourth objective is to give guidelines to Van Oord in order to develop an information system from a logistical and supply chain perspective.

The objectives are summarized in a main research question.

> *How does a <u>logistical system</u> need to be <u>structured and implemented</u> in the line pipe <u>supply chain</u> to improve the productivity and the workability of a pipe-laying vessel?*

The thesis researches a logistical system that improves the workability and productivity of the Stingray. Workability is the capability of getting work done with means at hand and circumstances as they are. In general terms improving the workability will mean that the supply chain can operate with less influence from external variable e.g. the weather. The improvement of the line pipe supply chain will be done by illustrating bottlenecks and trade-offs within the supply chain and introducing a logistical system. The thesis has examined the total supply chain and has divided the supply chain into two parts the “upstream” part and “downstream” part (Figure 1). The upstream part focuses on the production of the line pipe and the downstream part focuses on line pipe delivery to the Stingray.

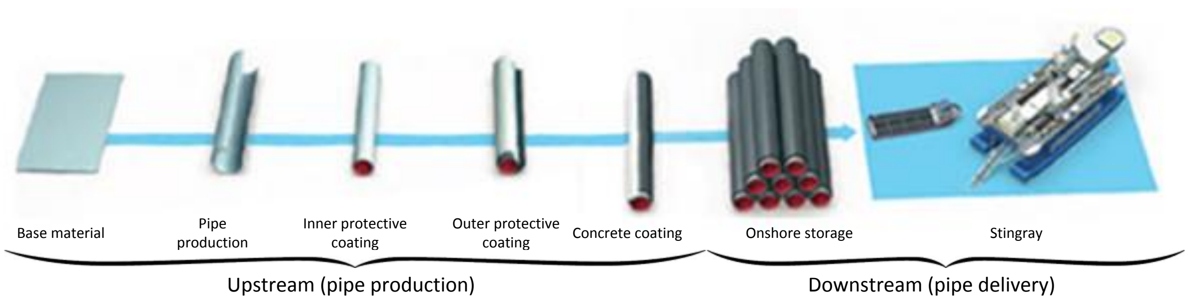

Figure 1 supply chain of the line pipe from plate steel until installation at the Stingray.

The production process of the line pipe is a sequential process of producing steel pipe, applying protective coatings and concrete weight coating. The production process of the pipeline on-board the Stingray is done in the production area. In the production area the pipe following sequential processes of beveling the pipe at the beveling station and welding the pipes together in the firing line. The possible improvements for the supply chain are divided into two parts. Part one improving the delivery of the line pipe at the firing line so that a higher production rate can be achieved. Part two improving the robustness of the supply chain which leads to less production down time.

An entity-based simulation software Arena is used to illustrate the gains of a logistical system and illustrate bottlenecks in the supply chain to find trade-offs in the supply chain. The downstream part of the supply chain is modeled to analyze the improvements (Figure 1). A buffer is placed at an onshore storage location due to production lead time of the line pipe. Two scenarios are set-up and run with the simulation model to improve productivity and workability. The evaluation is done on the output on productivity of the Stingray and the production downtime.

Implementing an inventory system in the supply chain helps to resolve the current production loss by reducing the number of rejected pipes too none. The first step, of the inventory system is to reduce the number of out of specified pipes. All clients provided items that are out of specification should be rejected at transfer to not include those pipes in the supply chain. For the implementation of a logistical system the pipes only need to be categorization in 4 groups, provided that the pipes are within DNV standards. The model illustrates that the robustness of the pipe transfer between supply barge and Stingray is the most sensitive variable for the workability of the supply chain. The transfer connection can have influences depending on sea state and the type of supply barge used. The storage capacity on the Stingray is of large influence on production loss of the supply chain. Another solution possibility is to improve the pipe transfer. This can be done by improving approach systems or using a DP supply vessel. It is calculated for the simulated that using a supply barge is more beneficial then DP supply vessel.

A logistical system can improve the productivity by reducing the number of rejected pipes. The pipes need to be categorized in at least four groups based on the ovality and inner diameter of the pipe. It is recommended to implement a standardized database in a project environment that has information on all the pipe properties. This will help with planning, monitoring and post-processing of a project. Also the number of out of specified pipes in the supply chain should be reduced. Quality checks on client provided items are needed in advance to assess if a logistical system needs to be implemented and to identify problems that may be expected from the pipe properties spread. These checks are done on pipe property detail level. Individual identification technology is not strictly needed for correct delivery of the line pipe. Therefore color coding to identify and classify the pipes is recommended. RFID and Barcode technology is recommended if an information or monitoring system needs individual identification. RFID is more beneficial if accessibility is an important subject. Barcode is a cheaper solution, but needs further field testing on robustness of technology.

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Abbreviations and Definitions

Abbreviations

3-LPP:	Three Layer Polypropylene
ABS:	American Bureau of Shipping
API:	American Petroleum Industry
AIS:	Automation Identification System
AIS-SART:	Automation Identification System Search and Rescue Transmitter
Avg.:	Average
ClassNK:	Nippon Kaiji Kyokai
DP:	Dynamic Positioning
DNV GL:	Det Norske Veritas and Germanischer Lloyd
ECR:	Efficient Consumer Response
EPC:	Engineering, Procurement and Construction
EPIC:	Engineering, Procurement, Installation and Commissioning
ERW:	Electrical resistant welding
FBE:	Fusion bonded epoxy
FJC:	Field joint coating
GMAW:	Gas Metal Arc Welding
HF:	High Frequency
HFW:	High Frequency Welding
Hs:	Significant wave height
IDEF:	Integration Definition for function modelling
ID:	Inner Diameter
IT:	Information Technology
Km:	Kilometre
LR:	Lloyd's Register
LF:	Low Frequency
M:	Metre
Max.:	Maximum
Min.:	Minimum
MM:	Millimetre
MDIR:	Mean Wave Direction
MWP:	Mean Wave Period or Zero Crossing Period
NDT:	Non-Destructive Test
O:	Operations
OD:	Outer Diameter
OCR:	Optical Character Recognition
OR:	Object Recognition
UPC:	Uniform Product Code
QC:	Quality Control
QR-code:	Quick Response code
RFID:	Radio Frequency Identification
SAW:	Sub-Arc Welding
SCM:	Supply Chain Management
Sec.:	Seconds
SWH:	Significant Wave Height
SWPL:	Shallow Water Pipe-Lay
TRIA:	Triangle distribution
UNIF:	Uniform distribution
UHF:	Ultra High Frequency

WS:	Wind Speed
WD:	Wind Direction

1 Introduction

1.1 Problem introduction Van Oord

Van Oord, a marine contractor, is presently changing the company from a sub-contractor towards a company that is a preferred lead-contractor (Van Oord, 2012b). In the offshore construction sector the project set-up or contracts are changing. Big offshore projects of the oil and gas operators change from self-controlled project with multiple different sub-contracts towards, all including Engineering, Procurement and Construction contracts (EPC) or Engineering, Procurement, Installation, and Commissioning contracts (EPIC) (Ranjan, 2009). The clients or operators are oil and gas companies that want to focus on their core business of energy commodities trade and not on the construction of their infrastructure. With the use of EPC or EPIC contracts the operators are able to transfer risks and responsibilities of the engineering, procurement and construction of a project to the contractors (Loots & Henchie, 2007). The contractors accept the risk allocation and additional responsibility, because they are in return extra compensated. This extra compensation can result in higher earnings for the contractor.

Rewarding of an EPC or EPIC-contract is often done in the form of a tender. The operator writes-out a tender and different contractors make a bid to this tender. The contractor with the most competitive bid, i.e. lowest cost, highest quality cost ratio, or highest quality depending on stated criteria, will win the contract. By outsourcing the management of the project the operator reduces control on the quality of project. To keep control on the quality of the project the operator sets standards and boundaries on quality on production products and production processes. Thereby the operators states that the project is done within those certain standards and boundaries.

The procurement of the different production products is a major part of the EPC contract and can be vital for winning a tender. Reducing the costs on production products has a large influence on the costs of the project. For the operator it is important that the reduction of costs is not due to the reduction in quality of the product, but due to better management of the procurement. The procurement is managed with different systems. These systems have to: maximize efficiency by concentrating on core-competences, outsource while maintaining the autonomy of the company, or minimize procurement costs while maximizing security within the supply process. The logistical systems can be divided into separate systems e.g. demand forecasting, inventory management, production support, quality control, just in-time systems, requirement planning, market research, and make-or-buy decision. With these systems procurement becomes more and more supply chain management (Kraljic, 1983). Correctly managing the supply chain is essential for a stable production and can reduce the logistics costs within the project (Christopher M. , 2012).

The multiple logistical systems of procurement focus on the control of the supply chain. Control is visibility on a situation and having measures of intervening. A logistic system for control can be divided into a logistics visibility system and a logistics decision making system (Lopez de la Cruz, 2009). Logistics visibility can be defined as: the extent to which the position or location of an object, service, or information and its status are known in a logistic system (Lodewijks, Veeke, & Lopez de la Cruz, 2006). A logistic decision making system can be defined as: decision support system that will help the decision maker with relevant information to make a better decision. A way to combine the two systems is with an information system. The information system transfer raw data into aggregated information. The logistics models transfer the aggregated information to relevant information for the end user.

Van Oord is diversifying its work-portfolio towards pipe-lay. The Vision of Van Oord is; “to become the preferred (EPC) contractor to the oil & gas industry for specific services like subsea rock installation, offshore pipeline Installation, and installation of offshore related gravity based structure” (Van Oord, 2012b). Thereby instantly setting the goal for the new pipe-lay department that started in 2010. Van Oord commissioned the purchase of their first pipe-lay vessel the Stingray in 2010 and had his first pipe-laying project in 2013 (Chesshyre, 2013). The Stingray is a Shallow Water Pipe-Lay (SWPL) vessel that can handle pipes from 6 till 60 inch in diameter till a depth of 100 meters (Van Oord, 2013d). With the Stingray Van Oord has diversified their work-portfolio to three markets; pipe-laying, wind-energy, and dredging, offering operators a whole in-house pipe EPC project of trenching, pipe-laying, and covering or protection (Chesshyre, 2013). To develop more in-house expertise, the offshore department has started an innovation project on workability and productivity of the Stingray (Petrina, 2013). Part of the project on workability and productivity is the development of an information system for quality control. This project is partly started out of demand of the operators for quality insurance in which the operators want to have information on the line pipe in the system for quality control and liabilities purposes (SAIPEM, 2013). By introducing a monitoring system on the line pipe Van Oord expects to improve the quality assurance of the pipe lay and control the production process. Such a monitoring system could also be used for supply chain or procurement purposes.

1.2 Problem statement

The main goal of the innovation project of Van Oord is to improve the workability and productivity of the Stingray. The production process is dependent on the production product line pipe. The line pipe has variations, e.g. on its length, wall thickness, inner and outer diameter, and ovality, that influence the production process. The production process improvement can be divided in different segments. One segment is the logistic or supply chain. Improving the line pipe supply chain with a logistic system can lead to a higher workability and productivity of the stingray. The supply chain in this thesis is divided into two parts the upstream part of production of the line pipe, and downstream part of delivery of the line pipe at the Stingray. The improvements on the supply chain are divided into three parts (appendix A).

The first improvement is on the productivity by sequencing the order in which the line pipe is delivered. The welding and alignment process in the production area on the Stingray depends on different specifications of the line pipe e.g. length, wall thickness, diameter, and ovality. The same ovality, diameter and wall thickness is needed between two adjoining pipes for a strong weld. A difference between the different pipes in e.g. diameter and ovality is called high-low. High-low is allowed to a certain boundary dependent on the project settings (DNV, 2012). The high-low overcome during the welding process can reduces production time or increase the problem with weld repair. If a weld is identified as faulty the weld may be repaired. If the weld cannot be repaired a cut-out of the pipe is done. A high high-low complicates the repair process.

The second improvement is that the supply chain is robust which lead to less production down time. A robust supply chain of line pipes is needed to be in continuous production. The production process or vessel costs are the largest variable part of the project budget. To be cost efficient the downtime of the vessel needs to be reduced. Faulty line up or faulty pipes on the Stingray and delays in the delivery of pipes can lead to interruption of the production process. This can lead to production down time. Guaranteed continuous right supply is a must for production. Another part of cost reduction is using other transport modes. By better controlling the supply chain warehousing, risks and costs can be reduced.

The third improvement is less waste or defects of the line pipe in the supply chain. Quality control in the supply chain can reduce the number of returned line pipes from the production vessel. Costly transport moves can be avoided by earlier identifying defects of the line pipe.

Van Oord wants to improve its supply chain to better control the procurement part of an EPC contract. Van Oord wants to control the supply chain so that production is increased and costs are reduced within the quality standard set by the client.

1.2.1 Research Goal

This thesis researches how an integrated logistics system for line pipe needs to be structured to assist Van Oord with decisions regarding implementation of a line pipe information and monitoring system. The thesis focusses on the structure and implementation of a logistic system for line pipes. To make recommendations on the logistic system the objectives need to set. The thesis is divided into several sub-subjects with the following objectives.

The first and main objective of the thesis is to improve the workability and productivity of the Stingray by managing the supply chain. The thesis will make clear under which conditions a stable supply of line pipe is still possible and possible bottlenecks can be mitigate. The supply chain should keep the Stingray operational, improve the productivity and reduce the waste in the supply chain (Appendix A).

The second objective is to find a generic supply chain structure for the line pipe to an offshore location. This will be from the start of producing the steel pipe till delivery at the offshore location. This structure will provide information on control system, intervention points, and information system. Possible bottlenecks will be identified in the supply chain.

The third objective is to explore the possibilities on monitoring systems on the information system. The objective is in regards to the possible technological options and how these systems can be used by the logistic system.

The fourth objective is to give guidelines to Van Oord in order to develop an information system from a logistic and supply chain perspective. There illustrating possible trade-offs and consequences. The guidelines will give instruction on information the system should be handled and on the structure of the information system.

1.2.2 Research Question

The thesis focusses on the structure of the line pipe supply chain from the mill until an offshore production location. The supply chain structure will focus on improving the control on the supply chain with a logistic system so the productivity and workability can be improved. This leads to the following research question.

How does a logistical system need to be structured and implemented in the line pipe supply chain to improve the productivity and the workability of a pipe-laying vessel?

Logistical system	A system that logs the location and condition of an entity on which a decision can be made.
Supply chain	The pipe supply chain is the combination of variables involved from fabrication of the steel pipes until the delivery at the production vessel.
Workability	Workability is the capability of getting work done with means at hand and circumstances as they are.
Productivity	Is the ratio between input and output. Input is the material, time and labor costs put in the pipeline production. Output is the number of meters of pipe laid per day.

1.2.2.1 Sub-questions

The research question it is divided into several sub-questions. These sub-questions will address subjects related to the research question. The sub-questions are:

- What are the different characteristics and requirements of the available automated monitoring systems that can be used for a logistic system?
- How is the current supply chain of line pipe structured?
- What are the key output parameters for the supply chain?
- What are the key input parameters for supply chain to increase productivity, and workability of the Stingray?

1.3 Research Model Guide

The research question and sub-question are answered according to the following structure (Figure 2). The problem statement and the research question are introduced in chapter 1. A literature study is performed on the procurement and supply chain subjects 2. The literature study in chapter 2 will illustrate the main concepts on supply chain management, identification systems, and logistics systems. After the literature study a demarcation of the project will be given in chapter 3. From the demarcation in chapter 3 a conceptualization of the supply chain will be made in chapter 4. This conceptualization will be translated to a model. In chapter 5 the model will test improvements on the supply chain. The improvements will be simulated to give quantified support to improvement suggestions. In chapter 6 the outcomes of the scenario will be translated to a supply chain concept. Thereby introducing any trade-offs already found in supply chain decisions. After chapter 6 the thesis will be discussed on limitations and other related subject, to put thesis in perspective to other subjects. The paper will conclude in chapter 8 on the research done and give recommendation for future research and guidelines to Van Oord.

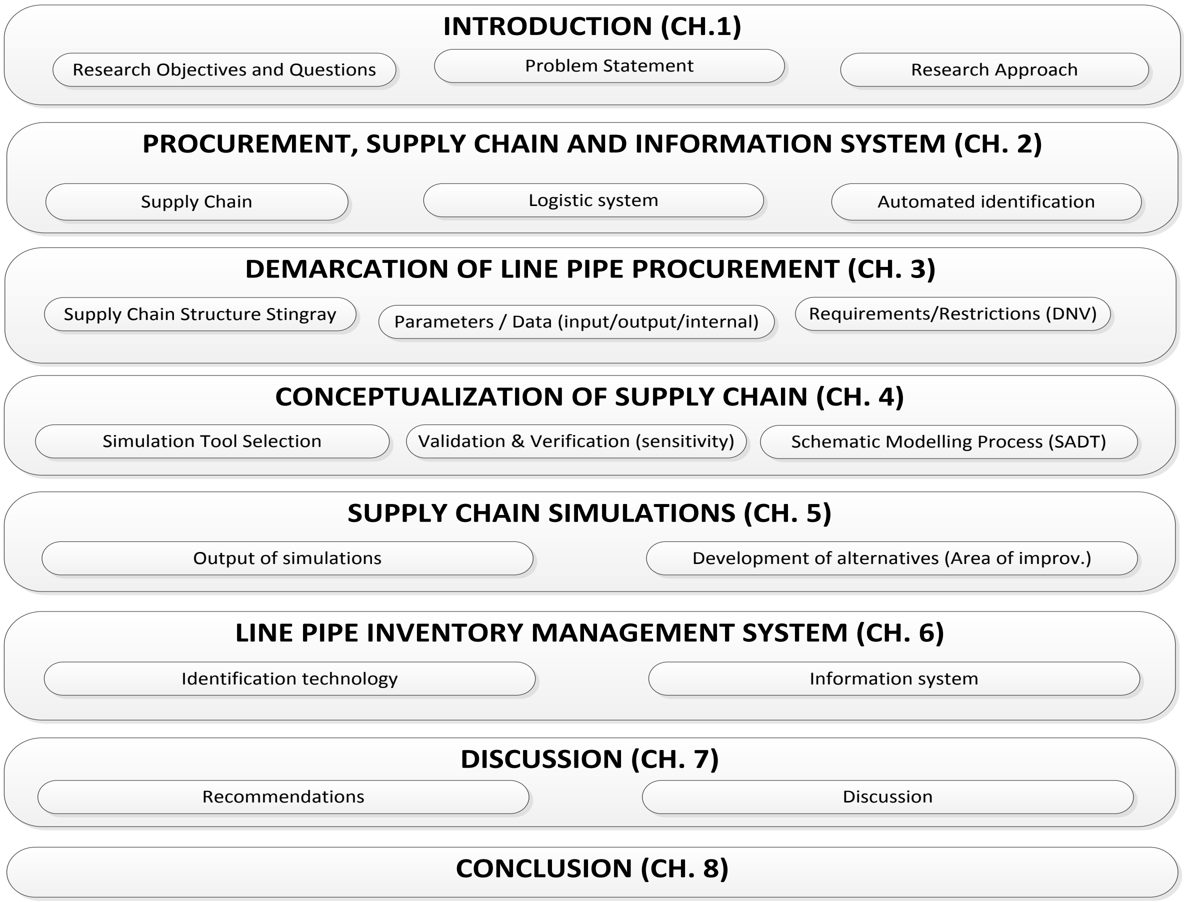

Figure 2 overview of the set-up of the thesis.

2 Procurement, Supply Chain and Information System

2.1 Introduction

A literature study is done to illustrate the subjects' procurement, supply chain and automated identification systems. Procurement is more a container concept that covers multiple subjects and has as goal acquiring products or services. The supply chain is part of procurement and production. The supply is partly the interface between the purchase and operations of a project. The supply chain is about the delivery system of, through procurement, acquired products. The information system depends on a monitoring system. The monitoring system can be done through automated identification. This type of monitoring is part of the monitoring system that Van Oord wants to implement for their quality control and production control. The automated identification is used to examine possible options for information handling. The chapter is structured as follows. A general description of procurement is given. After describing the procurement and supply chain, the possible identification systems will be illustrated.

2.2 Procurement

The procurement part of an EPC contract is a container concept that addresses multiple subjects e.g. quality control, costs, timely delivery, product specifications on purchased products. In this thesis procurement is defined as the acquisition or purchase of goods from an outside external source (Baily, Farmer, Crocker, Jessop, & Jones, 2008). Procurement in a large construction project has multiple procedures for acquiring the needed goods. This thesis is on the procurement of line pipes. This distinction is needed for the setup of the procurement procedure. The distinction in the procured product need to be made e.g. the sub-contracts for bolt and nuts or the sub-contracts for the specialized work-force have a different procurement procedure. Assessing the classification of product helps with addressing or finding a procurement strategy. Different techniques are available to assess the strategy on the purchase of a good. In this thesis the matrix developed by Kraljic is used to assess the product and purchasing strategy of the line pipe (Kraljic, 1983). The matrix has two axes on which the goods or services are assessed. The axes express the level of importance that the good has on a project and the complexity of the product's market (Figure 3).

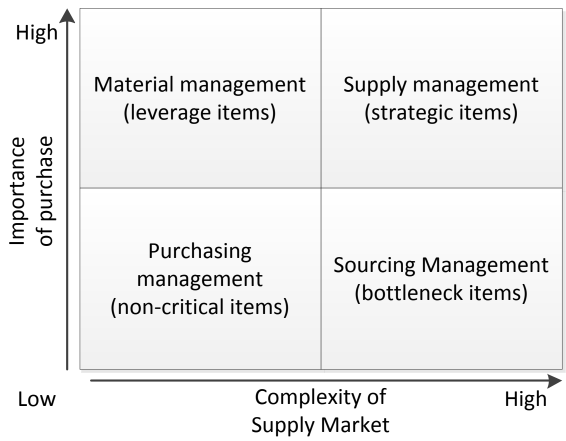

Figure 3 Kraljic classification of purchase strategy (Kraljic, 1983).

For the line pipe the following strategy is advised. The complexity of the supply market and the impact of the line pipe's purchase on the project need to be assessed when applying the matrix on the pipe line's procurement. The importance of the line pipe' procurement is high. This can be subscribed to: the high percentage of the total procurement budget dedicated to the procurement of line pipe, the total product will be used in the final product, and there is no possibility of substitution of the product (Van Oord, 2014b). The complexity of the supply market is more difficult to assess. The product is relative straight forward. The line pipe can be procured worldwide in a mature market. I.e. the accessibility of the product is high, the materials used are common and general agreed specifications on quality are set (Appendix C). It must be stated that some manufacturers can produce on a higher standard than others manufactures. Making them preferred partners. The quality of the produced pipe reduces the number of manufacturers to two production areas Japan and Germany. With this assessment the line pipe becomes a leverage or a strategic item (Figure 3). The quality that is set for the pipes is decisive for this. The quality limits needed by the contractor are the DNV standards or limits (DNV, 2012). This quality can produced by multiple manufactures worldwide. For this thesis the line pipe is qualified as a leverage item. If the contractor wants high quality specialized pipes the line pipe would become a strategic item. The contact with the manufacturer will become more important.

The line pipe is identified, according the Kraljic matrix, as a leverage item and the preferred purchase strategic according to the matrix is material management (Figure 3). Material management main focus is generating a consistent flow of material for a stable production (Akintoye, 1995). This assessment is in alignment with the goal of Van Oord of a stable production rate supported by a continuous supply flow stated in the introduction (Appendix A).

The procurement of the line pipe from an operational point of views has as goal, according to Kraljic, is to ensuring a continuous supply of line pipe from production perspective. This is done by managing the production processes of the line pipe and delivery of the line pipe. The production of a line pipe is a combination of multiple suppliers in succession of each other. The goal is to manage these suppliers through material management, i.e. the suppliers need to be managed so that a continuous production on the Stingray can be reached. To control this procurement, the interfaces of subsequent manufactures need to be controlled and monitored.

2.3 Supply Chain

The control of the interface between subsequent manufactures stages and their suppliers requires a supply chain management. The complexity of the supply chain increases when the number of organizations and interfaces increases. If a single organization is used for procurement the relationship between seller and buyer is just supplier and client with clear goals and dependencies. If multiple organizations are used for acquiring the product a chain of suppliers or a supply chain will form. In this thesis the following definition for supply chain is used:

> *Supply chain is taken as a network of connected and interdependent organizations mutually and co-operatively working together to control, manage, and improve the flow of materials and information from suppliers to end users* (Aitkens, 1998).

In this circumstance, by definition of the supply chain of the line pipe, the end user will be the pipe-lay production vessel, Stingray. The supply chain encompasses multiple organizations and with the multiple organizations an increasing complexity arises. To reduce the complexity, the supply chain is structured in different sub-systems: transport system, information system and logistics system.

These systems can be defined in a number of ways depending on perspective. In this thesis are defined as follows.

> The logistic system is defined as a set of activities whose objective is to move items between origins and destination (Daganzo, 2005).

A transportation system is defined as the combination of elements and their interactions, which produce the demand for travel within a given area and the supply of transportation services to satisfy this demand (Cascetta, 2001).

The transportation of a product is done by a mode that travels by land, water, or air. The common modes are ship, train, plane, and truck. The transportation system connects the product through the different organization within the supply chain. With a product like the line pipe train, boat and truck are used. The preferred modes of transport are train and boat due to low costs and carrying capacity.

The information system is the system that controls the flow of all the information concerning the product. This information can go upstream or downstream of the supply chain (Cascetta, 2001). The direction of the information depends on the type of information and cooperation between the different organizations in a supply chain.

A logistical system, with the transportation system, and information system seen in an integrated system in Figure 3 shows a supply chain described according the Delft system approach (Lodewijks, Ottjes, & Veeke, 2008). The upper block is a control mechanism and can be seen as the logistic system. The system moves products through the different processes by performance and needs. The transport system is the system that transports the different products through the whole supply chain from transformation or operation towards final customer. The information needs to flow through the supply chain back- and forward for optimal synchronization.

Procurement of the line pipe should be organized so the procurement works best for the project. The line pipe is an important product that needs to be delivered in a continuous manner so that production of the pipeline will not stop. The procurement is a combination of different manufactures and combination of multiple systems. The regulation of these systems is done by supply chain management. Supply chain management has multiple forms and can be structured on goals and characteristics of a product.

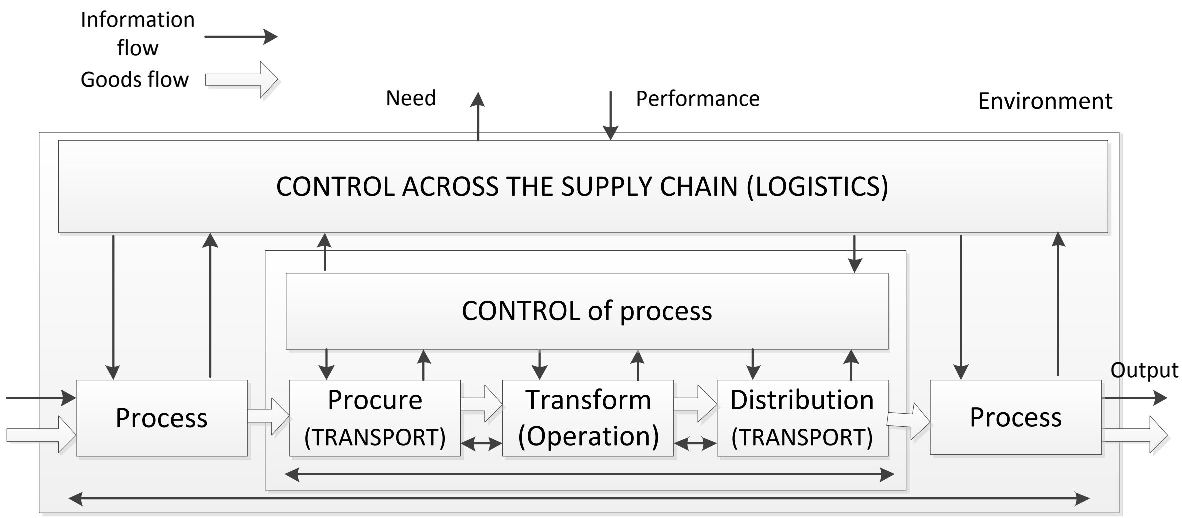

Figure 4 integrated systems of the supply chain (Lodewijks, Ottjes, & Veeke, 2008).

2.3.1 Supply chain structures: Lean, Agile, and Le-agile

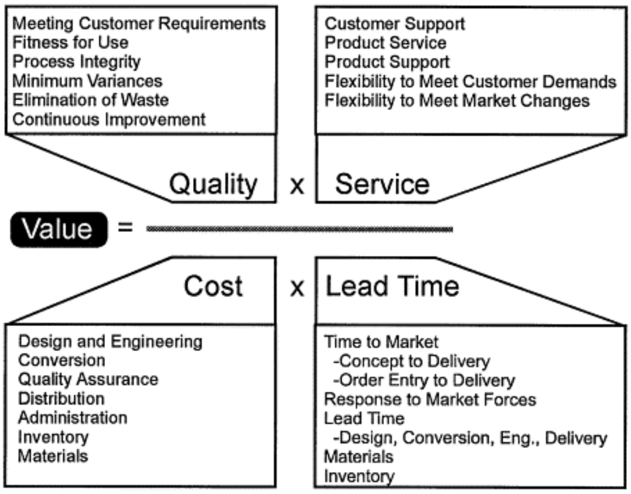

Figure 5 value supply chain in criteria's (Berry, Naim, & Naylor, 1999).

In paragraph 2.2 the term supply chain is defined. A supply chain consists of a transport, information, and logistical system and in accordance with a material, information, and cash flow (Figure 4). The requirements and specification of the system is not enough to set a general structure for the line pipe supply chain. The interaction in a specific supply chain depends on the goal or criteria the supply chain has. Every supply chain's goal is a combination and/or exchange between four criteria; quality, costs, lead time, and service level (Guneasekaran, Patel, & McGaughey, 2004). These criteria are a combination of other criteria and relate in certain manner as can be seen in Figure 5. Setting a clear goal for the supply chain helps define the criteria of the supply chain, which helps to find the structure of the supply chain and the logistical system. Criteria are needed to control and understand a supply chain in a direct view. The supply chain will then be evaluated on the criteria thereby creating the most value to an organization.

No generic frameworks on important criteria exist for a supply chain. Different papers will give different key performance criteria that need to be selected (Guneasekaran, Patel, & McGaughey, 2004; Cai, Liu, Xiao, & Liu, 2009). The lack of general structure for criteria on supply chain exists, due to the different requirement of the supply chain, structure of the supply chain, complexity of supply chain environment, and lack on information on all parties involved. There are some main returning generic criteria like: lead time, costs, quality, and service. These criteria need to be further detailed for a specific supply chain. Illustrating the supply chain in chapter 3 will help with setup of a framework for the criteria that will reflect the supply chain requirements. The criteria will be set in chapter 4.

For a quick total overview of the whole supply chain the indicators should be divided into quality, risks, and costs. Quality stands for result indicator, and costs are a combination of direct costs and risks or effect and chance. Examples of result indicators are; transport costs, storage levels, time at storage, production rate, return of line pipe, down time, utilization, value gathering through supply chain, rejection costs, utilization of production, production batch sizes, and location of production. Relevant criteria need to be filtered and prioritized.

Each logistical system has its own set of criteria. Finding the criteria can be done by assessing the goal of the logistical system. The correct implementation of the logistical system results in the right product, in the right condition, at the right time, at the right place, with the right costs, too the right customer and in the right quantity (Rutner & Langley, 2000). These general criteria need to be further defined for implementing a new supply chain. Setting the criteria of the logistical system depends partly on: the requirements of the supply chain and the product properties. Perishable goods are more time or condition dependent then non-perishable goods. The line pipe is a capital intensive, non-perishable good. This means that it can easily by stored, but due to cash flow the storage should be limited. By defining the requirements on the production process the requirements on the supply chain can be defined. To understand the choices in the supply chain different general supply structures and conditions are illustrated.

Knowing the existing structures advantages and disadvantages helps to develop a conceptual supply chain and identifies possible solutions. The structure of the supply chain partly depends on the goal which is representative of the way the companies want to supply the demand. The demand can be fulfilled through a push or pull system. The difference between a push and pull is illustrated in Figure 6.

A push system leads to a planning or prediction of production and the focus is to produce as efficient as possible. With a push system, products are pushed through the supply chain towards the end user or a buffer (Figure 6). The product then lays in wait in the buffer until end users need it. Examples of this are wholesalers such as clothing shops. The production resources are better allocated. The final product will lay in wait till it is consumed. Thereby the risk and consequences due to damages or badly predicting demand are higher.

A pull system produces more on demand and the focus is to reduce the waiting or storage time from a product ordering until receiving in the company's inventory in a specific place. The time, from product ordering until receiving, is the lead time of a product. The main goal is to reduce the lead time and to have an as low as possible inventory of the final product. A low inventory reduces the risk and costs that exist of storing products. Reducing the lead time is done by putting buffers into place and introducing a tight cooperation between suppliers, so a quick response to an order can be managed (Figure 6). The moment that a product is ordered, the product is pulled towards the client through the supply chain. Examples of a pull system are restaurants or one of kind production facilities that produces the product after it is ordered, but the materials or ingredients are already prepared.

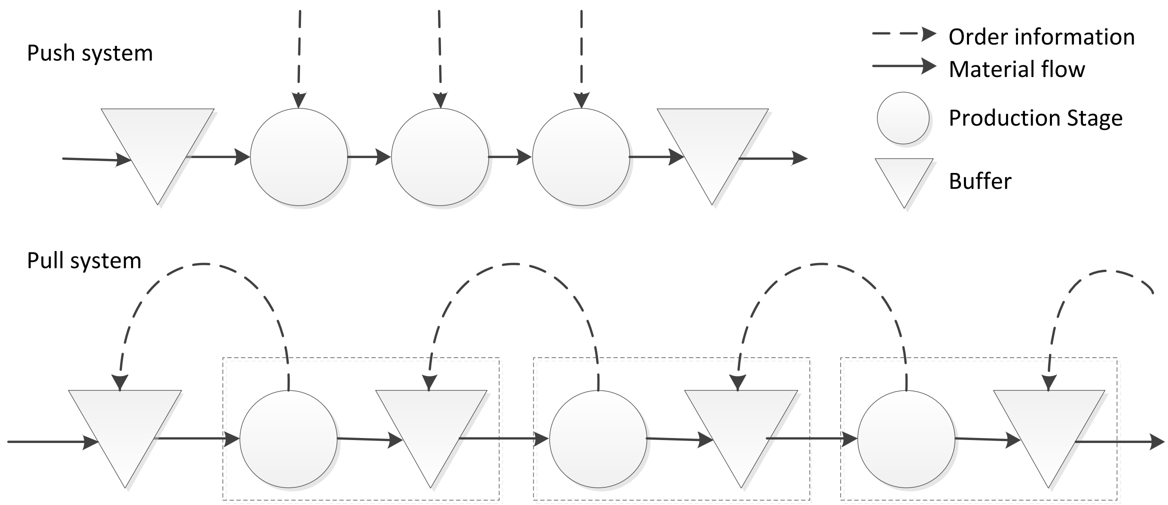

Figure 6 push versus pull system (Olhager & Ostlund, 1990).

The push and pull system are basic system for a supply chain. Related to the structure of a push or pull system is classifying the supply chain by lean, agile, and a combination of lean and agile in le-agile. This classification is more related to the goal of the supply chain. The supply chain can be agile, which means that the supply chain can react fast on and take advantage of changes in demand or market conditions changes. The opposite of agile is lean. A lean supply chain focusses on reduction of waste or costs. Waste is everything that has no added value to the product e.g. waiting or storage time. For clarification the following definitions are used.

> *Agile means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place* (Berry, Naim, & Naylor, 1999).

> *Leanness means developing a value stream to eliminate waste including time, and to ensure a level schedule* (Berry, Naim, & Naylor, 1999).

The choice to have an agile or lean supply chain depends mostly on the range of control on the demand. Part of the control on the demand is the planning and forecasting of the demand. Planning is the input of the operational part of a system and is made to meet the demand that is predicted or forecasted. The demand can be very unpredictable, which lead to uncertainties for the planning and the set-up for the system. The predictability depends on the number of variables used to predict the demand, predictability of those variables, and the level of detail needed. To cope with the uncertainties, according with the supply chain goals, trade-offs within the supply chain will occur. A common trade-off in, quality, cost, lead time, and service level, is (inventory) costs versus lead-time, quality versus lead-time. Storage or buffer gives flexibility in the supply chain, but also leads to higher costs on inventory. Generally it is stated that a lean structure works best in high volume, low variety, and predictable environments, and an agile structure is needed in less predictable environments where demand is volatile and the requirements for variety is high (Christopher M. , 2000). The line pipe is an item that is procured in high volume and has low variety. This could advocate for a lean system. Otherwise the demand is very rigid due to dependency to location and weather. This could advocate for an agile system.

The demands structure and requirement by the company is an input to the structure of the supply chain and classification. Classification of the supply chain of the line pipe will not give the performance indicators. Illustrative for this is that in a market were agile supply chains is dominant, the supply chain that can provide the best service or shortest lead time is often the market winner. In a market were lean supply chain is dominant the supply chain with the lowest cost is the market winner (Agarwal, Shankar, & Tiwari, 2006). Both supply chains could be used and have preferred outcomes. Some companies want both forms of supply chain and need a hybrid system form of lean and agile. These supply chain are called le-agile.

2.3.2 Line Pipe supply chain

A le-agile supply chain tries to incorporate both lean and agile component in a system and the market winner for a le-agile supply chain is on lowest cost, and highest service. These supply chains are partly very predictable and partly unpredictable. An important point of the le-agility system is the decoupling point where a more lean supply chain meets an agile supply chain. In the decoupling point a buffer or stock is located to coordinate the agile and lean supply chain. Some examples of these types of supply chains and ordering are buy to order, make to order, assemble to order, make to stock, and ship to stock (Figure 7).

For the procurement of the line pipe a le-agile system is suggested as supply chain. This is due to the characteristic of the supply chain goal of low costs and high service. The supply chain is in a very predictable environment in the preparation or set-up part of the project. When the Pipe lay vessel is in production a high service is demanded for a smooth production process. The demand part of the supply chain is unpredictable due to uncontrollable events that can occur during the project. The environment can be very versatile and vary highly per project. Due to the high costs of the line pipe and the volatile environment the service demanded is high.

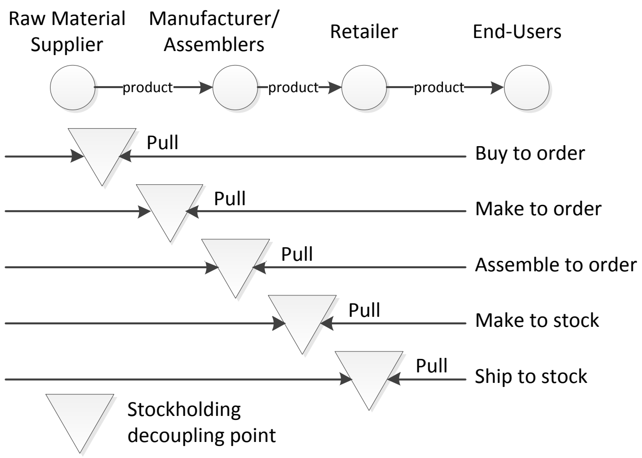

Figure 7 push versus pull system decoupling stocking point.

In a le-agile supply chain it is vital to determine a strategic decoupling point. The decoupling point is the point where the lean structured supply chain is connected to the agile structured supply chain. This reduces costs or increase stability to the supply chain.

2.4 Information System: Automated Identification

Van Oord is developing an information system for quality control that can identify the pipes on an object level. The system is an automated information system and would be part of the information system of the supply chain illustrated in the previous chapter. The information system is now suggested to be an automated tracking system of the line pipe (Petrina, 2013). The tracking is now part of a monitoring system that is used for operational goals. The implications for an automated identification system depend on the technology used. Understanding these implications the different identification systems are illustrated for an information system. In this thesis the following definition is used for an information system:

> *An information system will give timely and accurate information about the current system. Implying that the information should be available when needed, where needed, with no delays, and giving an accurate insight in the system. The information system is divided in a data holding system and information gathering system or an observation system.*

The observation system depends on the product and has the goal of tracking and tracing the steps of the line pipe. Different variances of observation possibilities are available. For this thesis the main automatic identification systems will be examined for observation systems in an information system. Automatic identification refers, in a broad scope, to the methods used to automatically identify objects, collect data, and register it without human involvement (Wyld, 2006). The automatic identification system allows real-time information flow and data capture.

Currently the identifying is done by dye stamped or paint stencil on the outside or inside of the pipe with a letter and number code (API, 2004). The Identification is done by the applied identification number or by the heat number of the pipe metal. The current tracking of the line pipe is commonly done by tally sheets that show the data and the heat number. This is data is manually acquired and processed. Identification is done by visual inspection by quality inspectors.

The current different automatic identification (auto-ID) systems for this thesis researched are; RFID, Barcode, Biometric Systems, Optical Character Recognition, Smart Cards, and automation identification systems (AIS). All these systems are briefly researched on features and usability of the system.

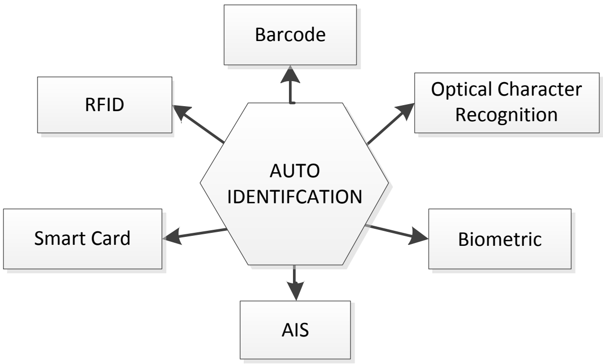

Figure 8 five different auto-ID systems

The characteristics, working principles, working conditions, and the applicability towards a tracking system are given for all the different auto identification systems. This gives an idea about the technology possibilities for an information system.

2.4.1 Automation Identification System - AIS (Ships)

This system, developed for ships, is a transponder that sends a signal though a satellite connection towards a general database. Due to the satellite connection the range is worldwide and can provide information on position, direction, course, and speed. The information provided by the AIS is very useful for a tracking system. The downside of the AIS is that, because it is developed for ships, it is very expensive. This means that attaching an AIS per line pipe is not feasible. AIS will not be used for pipe tracking, but can be part of the supply visibility system of the ships or barges. Commercial ships all have an AIS for safety reasons. Portable or temporary AIS are also available for the barge vessels. The portable beacon is a personal location beacon or an AIS-SART and is part of the navigation systems (IEC, 2011).

2.4.2 Biometric

The biometric automated identification makes use of biometric identifiers. Biometric identifiers are the distinctive, measurable physiological and behavioral characteristics used to label and describe individual persons (Angle, Bhagtani, & Chheda, 2005). These identifiers distinctively differ per individual. This means that Biometric auto-ID system is per definition not applicable on line pipe or objects and therefore not taken into account.

2.4.3 Optical Recognition

Automated optical recognition systems are software based programs that use optical scanners for recognition purpose; it mimics the functionality of a human eye. The optical recognition systems can be divided into optical character recognition and object recognition.

Optical character recognition (OCR) intends to re-create the human function of reading into machines (Mantas, 1986). OCR type of automated identification has applications in the data entry (banking environment), the text entry (office automation) and the process automation (post office). The system consists of an optical scanner and software for analyzing objects. For the optical recognition a clear line of sight is needed. Due to the high price of OCR and the high complexity of the software OCR didn't became universal applicable (Lodewijks, Veeke, & Lopez de la Cruz, Reliability of RFID in logistic systems, 2006).

Object recognition, as the name states, focuses on objects. An application of this kind of automatic identification system can be found in automated driving system. This system can automatically identify characteristics of an object. The line pipes that are subject to the automated identification are too similar to individual identify. However, the object recognition system can have other applications. One application is the identification of the pipe's ovality. The object recognition may have application purposes in the future if the technology is further developed. In the current states the technology is too complex and is costly like the OCR.

Optical recognition system can be used for automated characteristics input and identification by line of sight. An optical recognition system may be partly used in the future for automation. Currently the costs and complexity of the system are too high (Lodewijks, Veeke, & Lopez de la Cruz, Reliability of RFID in logistic systems, 2006).

2.4.4 Barcode and QR code

Barcode is a serial number translated into a one-dimensional reading tag that consists of a black and white striped code (Agarwal V. , 2001). The barcode technology is similar to the optical recognition software, barcode also needs a clear line of sight to read the code. The serial code or barcode can in theory be of any size, in practice they are limited to certain physical sizes. The past 20 year barcode systems have been used as a primary means to identify objects. The barcode is commonly used in all kinds of warehousing, transportation systems and shops (Sun, 2009). The past development of the barcode technology makes the barcode system a reliable and cheap system (Bi, Feng, Liu, & Wang, 2008).

0 36000 29145 2

Figure 10 example barcode.

Figure 9 example QR-code

The system uses printed labels and an optical scanner. These optical scanners can be of a lesser quality compared to an optical recognition system, due to simplification of label or tag. The information is communicated through the use of an optical scanner. The barcode needs to be in the line of sight of the scanner so the code can be read, implying that the objects can only be seen one at a time (Agarwal V. , 2001). Disadvantage is that multiple readings are excluded and if the barcode label is covered or smeared the label becomes unreadable for the optical scanner. The label is one-time printed meaning that the barcode system is a write ones and read-many system. Changing data or the code on the label is not possible. The amount of data that can be stored in a barcode is limited to the size of the barcode. In current practice the barcode has information that is categorized. The barcode is standardized in the Uniform Product Code or UPC. In that system the line pipe can only be tracked by categories, it cannot distinguish one bottle of water from another of the same brand and make. A separate system needs to be developed. The amount of data on a barcode can be increased with longer barcodes or shifting towards a two dimensional barcode. An example of a two dimensional barcode is a QR-code. QR codes work with the same principles as a barcode and is treated the same for this thesis.

The barcode system is a reliable and cheap system due to the years of development and the widespread use of this system. A disadvantage is that the environment of the technology needs to be controlled: the reader needs a clear and clean sight. To summarize: the costs concerning a barcode system are low, the technology is widely used, and a barcode system is sensitive to possible reading problems.

2.4.5 Smart Card

Smart Cards have embedded integrated circuits that can process and store date. It is a self-programmable one-chip microcomputer (Jinn-Ke, Hung-Yu, & Yuh-Min, 2002). Examples of smart cards are credit cards, debit cards, SIM cards, health insurance cards and security passes.

Figure 11 example of smart card

The smart card system uses the chip on the card and a reader device. The chip needs to be externally powered, because no power supply is available on the chip. The most common use of the smart card is by connecting the chip and the reader directly, like a chip-card, through an electronic or inductive connection. Another possibility is to have a wireless connection with the chip and the reader on a radio frequency base, e.g. a security pas. In both settings the reader will provides the power. The wireless connection is radio frequency based and has a limited distance that can be overcome. The wireless connection is based on the same principles as the passive RFID connection. A reader sends out radio frequency electromagnetic waves. The antenna, tuned to receive these waves, wakes up the chip in the smart card or tag. A wireless communications channel is set up between the reader and the smart card or tag.

Smart card is a secure system with relatively high storage capability. To retrieve the information contained in a smart card, it is necessary to make use of a special reader where the card needs to be introduced and the information decoded. This protects the information of undesired access and manipulation. Due to the processing power a smart card is an expensive, but very secure system. The readability is very limited taking into account the limited distance.

2.4.6 Radio Frequency Identification - RFID

The RFID technology can be divided in two parts: the Radio Frequency or wireless, and the identification or chips. The identification part is similar to the barcode and smartcard. On the chip a number can be stored to make a unique identification. The connection with the chip and the reader is done with a radio frequency connection. The radio frequency is divided into three categories; low, high, and ultra-high frequency.

The advantage of RFID is that there is no need for a line of sight when reading the RFID-chip, because RFID is wireless. This gives the possibility of near simultaneous reading of different RFID tags. Another advantage is that due to the development of RFID technology the RFID-tags are relatively cheap (Knuth, Modrak, Sebej, & Hricova, 2009). The downside to RFID is that when the chip is damaged, no data can be retrieve by visual inspection. If the antenna is broken or has interference the tag becomes useless. For the RFID system a reader and tag are used. The tag consists of an identification number that is stored on a very small chip. There are three ways to store on the tag; pre-defined and read many tags, write ones and read many tags, and write many and read many tags. This gives different set-ups and implementations of the logistic system. Apart from this the tag can be passive or active. The difference between passive and active is that an active chip has its own power supply in the form of a battery. A passive tag gets its power by magnetic coupling of the antenna, this like the smart card but with a larger range. The active tag has, because of his own power supply a bigger range of possible wireless connections between the reader and tag. RFID further differ on frequency of transmitting. In Table 1 an overlay is given of the different type of RFID and some features.

RFID is a cheap technology that is in a mature state of development. The downside of RFID is the sensitivity of the radio frequency connection and it is not possible to read the chip without an RFID reader.

Table 1 characteristics of the different frequencies of RFID (Lopez de la Cruz, 2009; Wyld, 2006).

Type of RFID	LF	HF	UHF
Frequency	125-134 kHz	13,56 MHz	868-870 MHz 902-928 MHz
Read Range	0.5~2m (max 0.8m)	< 1m	> 3m
Cost	Relatively Expensive	Less Expensive	Least Expensive
Penetration of Materials	Excellent	Medium	Poor
Affected by water	No	To some extent	Yes
Power source	Passive (inductive)	Passive (inductive)	Passive (propagation)
Data Rate	Slower	Medium	Faster
Reading multiple tags	Poor	Good	Very Good
Memory size	---------------- 256 bits to 4K bits ----------------		

2.4.7 Conclusion on identification system

A short overview of the pros and cons of the different automatic identification technology systems are given in Table 2. From the pros and cons a preliminary system can be selected for the information system. Looking at the information on the automatic identification technology a preference for RFID and barcode technology for the visibility system is given.

The main distinction between the two systems is the need for simultaneous reading, line of sight, and robustness of the system. Choices on one of these systems depend on the development of the supply chain of the line pipe. This will be further researched further the thesis.

Table 2 overview automatic Identification systems.

Auto-ID technology	Pros	Cons
AIS	Safe and reliable system	Very expensive
Barcode	Widely used, Low prices, Standardized	Barcode must be in line of sight of the reader, One code at a time, human interaction, Compromised when damaged, One way communication
Smart Cards	Secure system, High storage capability	Human intervention, the information is decoded,
Biometrics	Secure system	High expensive, Only applicable for humans
OCR	Reads high density of information	Highly expensive, complicated infrastructure, needs line of sight
RFID	Tags are cheap, Standardized, Provides real time information flow, Data acquisition without human intervention, high storage capacity, multiple tags can be read at once,	Security issues, costs, readability problems with metals and liquids

2.5 Comparison information Systems with tracking

The technologies described in in previous chapter are in use in other organizations. Tracking technologies that are currently in practice are mostly used and developed in inventory, warehousing, postal, and security companies. The integration of identification and tracking systems in cooperation with supply chain is currently used in the quick moving consumer goods. This is because the automation saves time in processing packages, ordering and it delivers a vital service of information provision to the clients. For better understanding of the tracking and integrate automated identification system in a logistical system some examples are illustrated

Large postal companies that provided international express mail were one of the first to introduce the integrated logistic tracking systems with help of large IT systems. These IT systems automated warehousing tasks e.g. location, and stock management. An important part of the automation was that tasks were standardized. This became possible when the express mail companies became large enterprises that benefitted from economics of scale. With this increase of economics the complexity and need for control also increased. Due to the size of the company supervision over all the packages was difficult. Packages got lost in within a company. The companies needed to know the location of each package to keep control on their operations. The companies that worked worldwide therefore started in 1994 with integrated transport tracking systems. They wanted to take advantage of IT in logistic system and reduce cost by “efficient consumer response” (ECR), which covers both physical and information logistics. Integrated logistics was started by a conglomerate of telecom and transport companies. The cooperation was named EURO-LOG and was a combination of Deutsche telecom, France telecom, Digital Equipment Corp., TMG Belgian, and Dutch PTTs (Now KPN). The EURO-LOG main product TRANSO-TRACK was used to have more transparency and efficiency in the logistic chain. The tracking information system was introduced to cost-optimized production, increases services, and improve distribution. The transparency and efficiency by the information system of the internal and external processes where seen as major success factors. The IT system made information accessible through the company with lead to better communication.

The subject of information exchanges and information logistics became crucial business processes (Powell & Loebbecke, 1998).

Now tracking systems are common for the large transport and express mail companies like, TNT, UPS, FedEx and DHL. They use their tracking system to support customers and own logistics. The automation through the IT system has benefits for the companies in multiple areas. The tracking system can help with automation of the suppliers' relations communication, help with supply chain decision, and supply chain performance (Viswanadham, 2002). Example of this is providing resellers with instant, on-demand access to information on e.g. tools availability. The need for costly face-to-face meetings and direct mailings decreases.

Important subject for the tracking systems are the need, and possibility for automation of processes. The postal companies became larger so standardization was possible, and they needed to control the growing amount of information on all packages. Inventory management on groceries wanted to automate their suppliers' contact, by automatic ordering, and notifications if product are popular or out of stock. The automation of the information system of the line pipe has similar reasons. The offshore industry becomes more focused on risks control. Therefore information on processes and current status of system is needed to control projects. In some processes quick automated information supply is needed. The automated information system on line pipe is applicable on multiple processes e.g. quality control process and production processes. These processes can be improved with the use of up to date information or with post processing of available information. An automated information gathering system can provide the information needed for these improvements. Automation information processes on line pipe is feasible for production. The repetitive nature of production of the line pipe and the number of repetitions used for production make a lot processes suited for standardizing.

A tracking system commonly addresses the need for information processing or accessibility of information within a company to give an overview of the current status or forecasted status of the system. An information system on quality is already designed to acquire information on the line pipe. The added value of using the line pipe quality information depends on the need of information exchange in a supply chain.

2.6 Conclusion from literature

Procurement is a container concept and the supply chain is part of this. The supply chain is part of the interface between purchase, and operations. The supply chain is responsible for the delivery of the products. The structure of the supply chain depends on the demands of the delivery. The line pipe is, according to Kraljic matrix, a leverage item that needs as procurement strategy material management (Kraljic, 1983). The material management strategy goal is to supply in a manner that the Stingray is in a continuous production.

The supply chain need to be structured accordingly the goal of material management. This structure is not standardized in literature. Structuring a supply chain to optimize the supply chain is difficult because available information is not evenly distributed or available to all the organizations in the supply chain. Other issues like the lack of processing power of information in the organizations in the supply chain, dependencies on other organizations, and no transparency of information through the whole supply chain makes it difficult for all organization to act optimal in the supply chain.

Performance criteria can help to the control, and improve the supply chain. The overall performance indicators of a supply chain are cost, lead time, quality, and service level. These performance indicators are too generic and need to be further specified to be used for control or optimizing.

Structuring the supply chain helps to fulfill a goal set for the supply chain. The supply chain can be structured in a lean, agile, or le-agile manner. The le-agile structure is chosen for the line pipe supply chain. Le-agile strength is a supply chain that focusses on low cost combined with high service. A le-agile system combines lean and agile supply chain. The lean and agile supply chains are connected in a decoupling point or buffer. The decoupling point is important to manage irregularities in the supply chain and still have a stable supply chain.

Identification technology can be used to automate processes in the supply chain. The identification technology needs to help to improve and speed up processes in the supply chain. The best suited examined technology for the environment of the supply chain and the use on the product are barcode or RFID technology. Both technologies are mature. The difference between the two are: the barcode tags are cheaper than the RFID tags and RFID tags can be easier read under harsh conditions then barcode tags.

3 Demarcation of line pipe procurement

3.1 Introduction

The line pipe procurement system can be seen as material management supply chain which means that the supply chain focusses on reliable continues supply for the production process on the pipe-lay vessel. To understand the implication for the procurement process the total process is illustrated from producing the line pipe till the production process on the Stingray. To decrease the complexity in the supply chain, a demarcation of the supply chain is done. The demarcation is on the line pipe supply chain on the subjects: legal, geographical, production processes, and transportation systems. These subjects are translated towards the supply chain structure and goals described in previous chapter. The structure is used for the conceptualization in the next chapter. The demarcation gives the boundaries and illustrates bottlenecks by illustrating the different processes.

3.2 Legal restrictions concerning supply chain

Van Oord mission is to work at a high reliable standard and according the current law at that location (Van Oord, 2012b). This will have implication for the supply chain that often will go through different jurisdictions and so will need to follow different set of rules in one supply chain. Legal restrictions give the boundaries wherein the project needs to be made. These legal boundaries can be of influence on parameters that influence the criteria of a supply chain: quality, lead time, costs, and service. When regulation and rules can be different per country, international or territorial waters also need to be taken into account. Where international waters do not have a tight regulatory body, the national regulatory body can be very strict. Another important aspect concerning the jurisdiction is customs. The control on importing or exporting product into a jurisdiction is strictly controlled by government. To work efficient it is important to Van Oord to streamline production or their supply chain. This can be done by a standardized or uniform working environment. By creating a standard of working, Van Oord creates a safe and reliable working environment that is important for the client and Van Oord.

Van Oord goal is to set their own high standard for operation, rules, and regulation. On top of this Van Oord will also comply with the rules and regulations on the current location or the rules and regulations set by the client. The rules and regulation can be divided into customs regulation and operational regulation. All these rules which can contradict each other or have different boundaries on what is safe need to be structured. Following from this, the main guideline that Van Oord will follow concerning the rules and regulations in a situation is the most stringently rules that apply to the situation, from the perspective from the client or of Van Oord. The rules and regulation with regards to standardization from the client side is often set by certification or quality control agencies. The client often will use this third party to certify or do the quality control for them. These third parties often work with best practices, industry standards, laws and rules form standardizing organizations.

The standards that need to set for the supply chain are composed from different sources. In general this means that Van Oord will work accordingly industry standards. These standards are set by International Organization for standardization (ISO). ISO is an international acclaimed organization that sets standards for worldwide industries. Important aspect of ISO is that it only develops and sets standards. ISO will not do certifications of an organization or project (ISO, 2014). Certification is done by external bodies. The external bodies, often third independent private parties, certify and do the quality control of an operation often commissioned by the client. Some examples of the biggest certification organizations are; Det Norske Veritas and Germanischer Lloyd (DNV GL), Lloyd's Register (LR), American Bureau of Shipping (ABS), American Petroleum Industry (API), and Nippon Kaiji Kyokai (ClassNK). These companies are often specialized in the field of offshore and can be seen as industry standards.

One of the leading certification companies in the oil and gas sector is the Det Norske Veritas and Germanischer Lloyd (DNV GL), a merger in 2013 made it the biggest certification company to the maritime industry (DNV, 2013). DNV GL will give; technical advisor, gives classifications, certify, and advises on energy or oil and gas value chain (DNV GL, 2014). Certification by DNV GL will be done according ISO rules, industry standards, and best practices (DNV, 2012). This use of best practices needs thereby control of an independent controller, because best practice is partly subjective. The DNV guidelines for transportation, storage, and transfer will be used for this thesis. These guidelines will create a safe and hazardous free environment for operations. Besides the use of the DNV guidelines the products acquired and used will be within the tolerances set by DNV.

3.2.1 Overview regulation consequences for the supply chain

The DNV rules will be taken as standard for the supply chain. The base or source of the DNV rules are ISO and API set standardizations and best practices form the industry. DNV uses a document that is combination of the different standardization. The main document on pipeline construction is DNV-OS-F101 document: the submarine pipeline systems (DNV, 2012). For the basic standardization the ISO standardization ISO:13623 is used, this specifies requirements and gives recommendations for the design, materials, construction, testing, operation, maintenance and abandonment of pipeline systems used for transportation in the petroleum and natural gas industries (ISO, 2011). Other documents are; the recommended practice for transportation of line pipe on barges and marine vessels and rail, API 5LW and 5L1 for rail transport, and ISO 31583:2007 (API, 2009a).

Table 3 recommendations on storage, transport, and transfer (API, 2009b; API, 2009a).

Recommended practices
From the ends of the line pipe at least 1 feet of space is needed to facilitate unloading.
The surface where on the pipes are loaded must be free from any foreign objects or material likely to cause physical damage, contamination, or chemical reaction with the pipe.
Draining of water shall be ensured in storage area.
Pipe stack should withhold environmental load like; wind, earthquake, waves.
Equipment used shall not damage the pipe joints.
Transportation and lifting of pipe joints shall be conducted safely to avoid damage to personnel, equipment and pipe joints.
The equipment used for transportation and lifting shall not impose damage to the pipe joints.
Acceptable stacking heights shall be established and documented for temporary storage and transportation.
Storage needs to be flat and so the pipe is supported over the total length of the pipe. This is so no fatigue in the metal can occur.

Important aspect in the regulation and rules are work safety, customs, and damage or corrosion protection during transport. From operations perspective the boundaries are set on storage facilities, transporting, lifting, and transferring the line pipe (Table 3). DNV GL regulation ensures that the line pipe will be installed safely and secure. Safely and secure means that the line pipe is at least as possible damaged (Table 4). Most important to know from this is that the pipe needs to be protected from corrosion, slamming, and tension damages.

Table 4 important risks during transport, storage, and transferring on line pipe (API, 2009a).

Type of Damage	Abbreviation
End damage	Damage to pipe can occur during loading and unloading, or from a longitudinal load shift against a bulkhead or an adjacent pipe.
Abrasions or peening	Damage result from a rubbing or pounding action against some protrusion such as the weld reinforcement of the adjacent pipe. This condition may result in initiation of fatigue cracks at the damaged areas during transit.
Longitudinal fatigue cracks	Damage initiated in the pipe by vertical cyclical forces with no apparent local abrasion or denting. Fatigue crack result from a combination of static and cyclic stresses produced by the weight of upper layers of pipe and/or other cargo giving a static load, and a cyclic load caused by the vertical movement.

The risk or responsibility on damage during operations or transportation can be allocated to other organizations. This can be preferred, because that organization has more control on the operation. Different liabilities terms are predefined for transport liabilities and responsibilities in the Incoterms. The International commercial terms are series of pre-defined commercial terms published by the international chamber of commerce and are widely used in international commercial transactions or procurement processes. These terms are lastly updated on 2010 and can be used to define the risk a company will take on transport (ICC, 2010). The possibility of allocating the risk of transport and storage will mean it should not be a bottleneck. It becomes a choice for the procurement or project manager.

Transport, transfer, and storage are a part of the logistics of a project. Quality control is a part that needs to be intertwined. This part has a strong connection with the risk and responsibilities allocation in a project (Appendix H). Quality control plays an important role for the risk assessment of the client. The client warrants multiple quality checks to control operational execution and risk control. The quality assurance is done by standardization, checks, control, and setting up accountability. For the quality control of the line pipe the DNV GL regulation state minimal quality control intervals. The specifications of the quality control will not be further explored. The consequence of quality control and quality tracking processes will be implied on the supply chain. Outcomes of the quality control will be imported into the system.

3.2.2 Import and Export Customs

Customs is the authority per jurisdiction that regulates the in- and outflow of goods, and uphold the import and export laws per sovereignty. A jurisdiction is a territory of a country. Customs is the authority that will check if taxes are paid on the imported or exported goods and if the goods are no risk for national safety, environment or health. Customs has for this reason the power to put a claim, hold, or place the goods under custody. For the supply chain this will mean calculated delay of deliverance, with additional circumstances that if irregularities occur a knock on effect is delay in delivery. Due the worldwide supplier market the chance that customs can influence the logistics is large.

For customs there are three different situations import, export, and transit or passing through of goods. Importing means bringing goods into a jurisdiction, exporting is getting goods out of a jurisdiction, goods in transit do not have a destination or origin in that jurisdiction. Transit can be seen as importing and exporting a product. For all these situation clearance from customs is needed. Customs check all the situations health, safety, environmental, and economic issues. Customs check the goods according the attached documentation. In these document at least the nature of the good, amount, value, origin, and destination is given. Customs will check the documentation and making sure that taxes are paid (Table 5). Customs can be seen as a risk and not having the right documentation will give problems with clearance. Filling in this document can be done through automated document generation in accordance with a RFID system as suggested in the paper on evaluation of business value of RFID (Fan, Shiou, & Wun, 2008). Hereby reducing the human error and early alert if not all documentation is present.

Table 5 import and export data needed per item.

Documents for customs
Bill of Lading – International
Bill of Lading – Domestic
Certificate of Origin
Claim Form
Commercial Invoice
Company Profile
Credit Application
Dangerous Goods Declaration Sheet
Importer Security Form (ISF 10+2)
NAFTA Certificate of Origin
Packing Slip
Power of Attorney – Export
Shipper's Letter of Instruction (U.S.)

The risk of customs or import and export is different per country that will be used in the supply chain. Countries can try to protect their own business by implying trade barriers. These barriers can be easily calculated and taken into account for the supply chain. Less transparent risk and thereby more problems for supply chain can occur is corruption, strikes etc. These risks have a higher influence on clearances and can give unexpected problems. Corruption can mean that delays, costs, or damages occur. This has direct influence on the main criteria of a supply chain. Each country has unique distinct systems with corresponding risks like clearance procedures can be vague or well organized unions can strike. This means that customs is an area that in every supply chain needs extra research to mitigate the slumbering risks.

3.2.3 Geographical location

The location of the supply chain is of influence on multiple variables, like customs or availability infrastructures, that give the boundaries of the supply chain, e.g. importing equipment into Australia or Senegal has different needs. The impact of the final location of the supply chain will be determined in the reference case. The Stingray is, as a shallow water pipe-lay vessel, restricted in his production location on production depth set by the strength of the onboard tensioners and anchors. The current production parameters of the Stingray are production capacity up to 100 meter of water depth. The definition for shallow water by the industry standard is 500 feet or 150 meters. This means that the supply chain needs to function around the world till a water depth of 150 meters. The Stingray will often work in the vicinity of the shore and so in territorial water. Important factors of world round supply chain are import and export regulations of the different countries or customs.

Production may not begin if correct paperwork is not being handed over. To be able to model the supply chain the delivery location need to be fixed. Due to time constraints the scope has set the production location on Mauritania the West Coast of Africa. The production site is chosen, because of the availability of a reference case that will be used to verify the model. This location will mean the following for customs: on the accessibility of the communality in that country (White, 2013).

3.3 Production process description pipeline

The production process of the whole pipeline from the moment the line pipe will be procured will be illustrated to understand to find the input, output and internal parameters of the model. The production process on the Stingray and the procurement of the line pipe will be illustrated in this paragraph. The production on the stingray will give input on output parameters. The procurement of the pipe will be illustrated by decomposing in two sub systems: the transportation an acquiring part and the consumption part. Understanding of the different processes will lead to understanding of criteria's, solutions possibilities, and gives insight in bottlenecks. Decomposing the procurement of the line pipe will give an insight on which parameters can be controlled in the supply chain.

3.3.1 Production system Stingray: the firing line

The final phase of the supply chain is illustrated for attaining the key output for the supply chain. The supply chain needs to facilitate the key output of the production rate of the Stingray. Facilitating of the production need to be done within boundaries of costs, but production speed of the pipe-lay vessel is key in every pipeline project. In this thesis only the relevant processes, the process that have an impact on the supply chain, on the Stingray will be taken examined. This includes the production process on the Stingray. The subject related on to the Stingray and supply chain is: the crane that handles the line pipe, the storage area, zone A, beveling station, ready rack, and firing line (Figure 13).

Important condition for production of the pipeline is the stresses placed on the pipeline. The stresses depend on the installation method of the Stingray and the weather conditions. The installation method is S-lay. This means that the pipeline is hold horizontal at the barge for installation of new pipes and the pipe line is horizontal at the seabed. Between the two horizontal pipe parts the pipeline is bending like an S-shape (PBJV, sd). The consequence of this S-shape is that there are large strains and stresses on the pipeline. If the strains and stresses are to big the pipeline will bend or buckle. If this happens the pipeline will need to be reeled in and the damaged pipe part needs to be cut out. The occurrence of a cut-out will result in huge time delays and costs. The total stresses and strain are a combination of the bend the pipes makes, the force the pipe is hold with at the barge, and the sea state. Peak stresses and strains are on the most bend parts near the barge and near the seabed. A pipe part should therefore not be too long under these stresses.

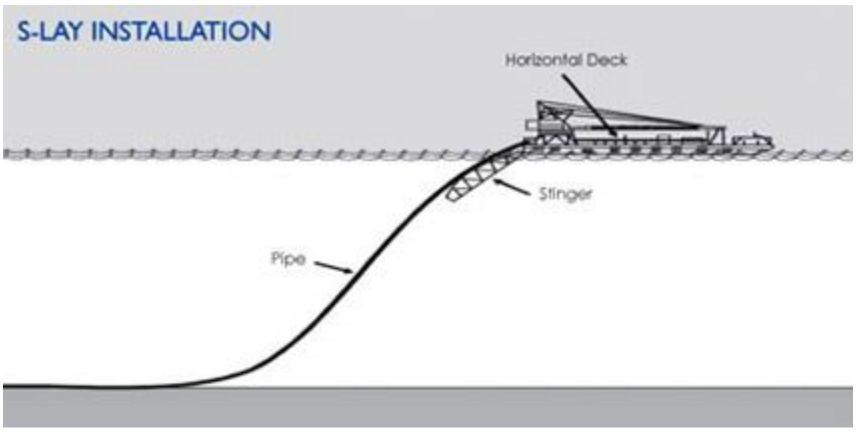

Figure 12 S-lay pipeline installation process (PBJV).

To avoid that a pipe piece will be too long under these stresses a continuous production rate is advised or it if that is not possible the pipe needs to be abandoned and laid down on the seabed. Other reason of abandonment is that the sea state is to rough. The barge movements are of influence on the pipeline. Large barge motion will lead to extra stresses on the pipeline. If the sea state is to rough the pipeline needs to be laid down (Guo, Song, Chacko, & Ghalambor, 2005).

The main goal of the pipe supply chain, stated in the previous chapter, delivers the line pipe in order to guarantee a continuous production process on the Stingray or as the logistical goal states the right pipe under the right conditions. Determining the right pipe depends on the production process. The production process onboard of the Stingray is the firing line. Before the firing line one other process will occur. The pipe joint will be beveled, and then it will be put in the firing line, and welded on the pipeline. Improving the production speed will need future determining of key variables.

[Removed due to confidentiality]

Figure 13 stingray production lay-out (Van Oord, 2012).

3.3.1.1 Production bottlenecks

The pipe-lay vessel will pay out one pipe joint once all the stations in the firing line have completed their operation. That means that the station that takes the longest time will be leading for the total production cycle of the firing line. The first bottleneck will be the bottleneck in the production process. Improving the production rate of Station 1 will improve the total production of the Stingray. Station 1 proceedings are: the alignment of the pipe, and welding of the first weld. Second bottleneck for production is, when rework has to be done. If not all stations can work simultaneous and extra production cycle is needed. The supply chain has influence on both bottlenecks. For understanding of this a small introduction in the production process of the Stingray will be given.

The production process of the Stingray is to weld together line pipe to form a pipeline and protect these welds with applying coatings. Station 1 no coating proceedings are done and station 1 has only influence on the welding part of the production process. The fusion welding that is done to get the strong needed connection is by arc welding, as specific GMAW or MIG welding (Serimax, 2014). The welding is an automated process. Arc welding is one of several fusion processes for joining metals. By applying intense heat, metal at the joint between two parts is melted and caused to intermix directly, or more commonly, with an intermediate molten filler metal. Upon cooling and solidification, a metallurgical bond is created. Since the joining is an intermixture of metals, the final weldment potentially has the same strength properties as the metal of the parts (The Lincoln Electric Company, 1994). To ensure that the weld is correct a Non-Destructive test is done (NDT). Failing the NDT test means that the weld is not within welding specifications and the weld needs to be repaired. Failing the test can happen when: not a full fusion of the two metals has occurred, that porosity occurred, cracks are in the weld, or the welded area is not large enough to have a strong weld. After failing there are two options: a repair has to be done, or a cut-out needs to be done. Both result in loss of production time.

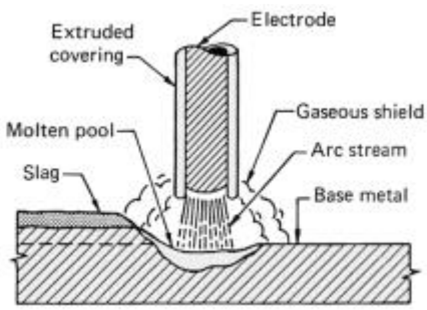

Figure 14 gas metal arc shielding welding (Woodsboro).

The quality of the weld depends on the following factors: the equipment used, the level of expertise of the personal and the quality of pipe. The equipment and expertise of the personal is not an outcome of the supply chain and therefore not further examined. The quality of the pipe delivered at the bead stall is. The supply chain needs to deliver the right quality at the right time. The right quality is that the pipe fit together and the high-low is within specifications (Table 6). The main alignment criteria's set by DNV are that the high-low, illustrated in Figure 16. The high-low is the difference between the highest and lowest point of two adjoining pipes is within set specifications (DNV, 2012).

Table 6 high-low limitations

Wall Thickness Pipe (t)	Allowed High-Low
t ≤ 13 mm	Max. 1.3 mm
13 mm < t ≤ 20 mm	Max. 0.1 t
t > 20 mm	Max. 2.0 mm

The high-low is determined by two factors: the difference in nominal diameter and ovality between to pipes (Appendix B). The nominal diameter is the average diameter of the pipe (Figure 15). The ovality or out of roundness of the pipe is calculated in percentage and in mm (Figure 15, equation 1). In the case of ovality issues, extra alignment time could mitigate the high-low problem (Figure 16). This will then result in extra production time. If the alignment does not fit and the high-low is above the criteria, the pipe will not be welded on each other. The line pipe will be send back to the storage area. If the pipe is out specification when the check is done the pipe will be put in quarantine and returned to the shore. Sending back a pipe is time costly process that will directly affect the production rate of the vessel if the pipe is discovered on the boat. The High Low can be compensated by the internal line up clamp that is used during the line-up and welding process. The internal line-up clamp expands within the pipe fixating the connection for welding. The expansion can be done with more force with a result of pushing out the ovality and expanding the pipe end and its diameter.

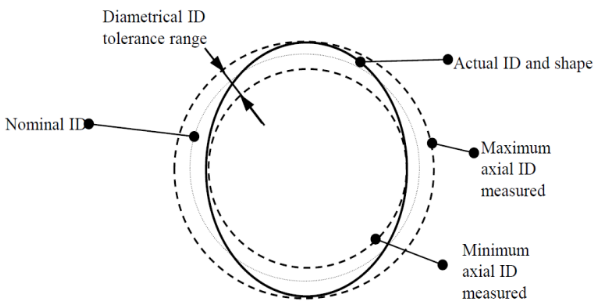

Figure 15 diameter references for the end of a line pipe (DNV, 2012).

Equation 1: $Ovality = \frac{Max\ OD - Min\ OD}{nominal\ OD} * 100\%$

Equation 2: $Ovality = Max\ Inner\ Diameter - Min\ Inner\ Diameter$

The high-low is calculated according the following equation:

Equation 3:

$$High\ low = \frac{1}{2}(\left|Inner\ Diameter_{Pipe\ A} - Inner\ Diameter_{Pipe\ A}\right| + \left|\frac{1}{2}\left(Ovality_{Pipe\ A} - Ovality_{Pipe\ B}\right)\right|)$$

The high-low criteria setting can be multiplied by 2 because the pipe is a circle and the high low can be averaged on both sides illustrated in Figure 16 left part. The ovality can be mitigated by rotating the pipe so both max diameters are aligned. Experienced spaces can easily spot the maximum diameter and align this accordingly, according Van Oord quality controller supervisor.

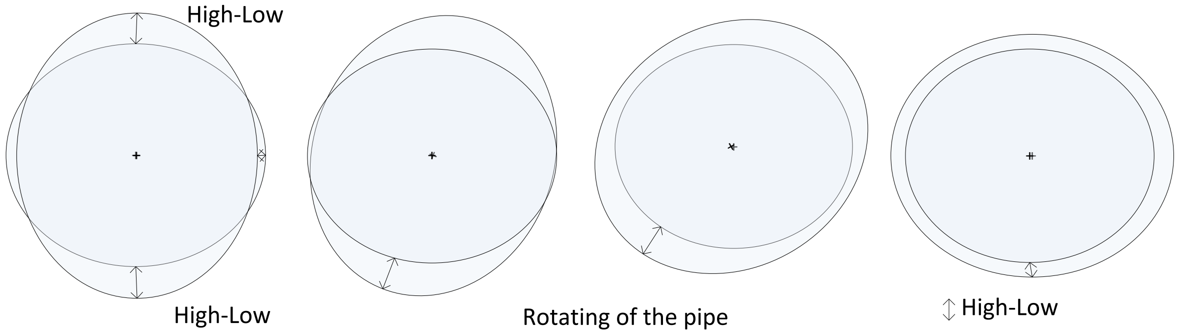

Figure 16 rotating pipes due to high-low difference between alignment of pipeline and line pipe.

Second bottleneck is when all station cannot work simultaneous. If one station is delayed all working stations are delayed. This can occur if not all welds are lined up with the different working stations or one station has to do rework. Than an extra production cycle is then needed for the pipe. An extra production cycle due to rework is not part of the supply chain demarcation this is part of production process improvement. The alignment of the welds with the working station can be influenced by the supply chain. The general deliverable specification of a steel pipe is 12.2 meter with a production tolerance margin of +/- 0.3 meter and an average of that lies between 12.1 and 12.3 meter (DNV, 2012; Van Oord, 2014f).

+/- 0.1 m. The total amount of pipes in the firing line depends on the number of station used added by the two tensioners that are located in the firing line. E.g. this will mean that length of eight pipes will determine if it is possible to work simultaneously at all seven stations (**Error! Reference source not found.**).

It can be seen that the largest cumulative deviation in pipes that will give a problem with production will be in station 6 and station 7 or taken in reverse station 1 (Error! Reference source not found.). This is in the assumption that the tensioners will not move with the seaway to have a relative fix position of the pipes in reference to the ship. So there is limited up to no seaway compensation. No seaway compensation will mean that sooner the pipeline need to be abandoned due to high strain and stresses in the pipeline due to seaway conditions.

Important for the production process, in respect to production cycle and utilization of the stations, is that the variance of the line pipe for the supply chain need to be on the right length, the right diameter, right ovality, and right time as stated on the logistical planning. This so the alignment will go faster and so that the working station always are simultaneously in production.

3.3.2 Production line pipe

The production of the line pipe is done in different sequential production processes. The production will be monitored by the quality control from the production of the steel pipe and the coatings. The main production cycles are steel pipe production, protective inner and outer coating, and concrete weight coating (Appendix B, Figure 17). The production process is difficult to improve and only choices on quality and delivery time can be made by the purchaser. The boundaries of the production processes will give input in the possible intervention methods.

The production of steel pipe is done at large mills around the world and on ordering base (Appendix B). The Steel Pipes are produced to order to specification on diameter, type of steel, length, and wall thickness (Table 7). The machinery of the mills needs to be set-up for every new set. This makes production in batches and all in one run preferable. These large mills produce 24/7 in production slots, which means that orders need to be made in advance to reserve a production slot. The mills produce to order. Steel pipe can also be bought at wholesale companies that have pipes on store. The production rate of steel pipe is relative high, but acquiring a time slot can lead to long lead times (Appendix B).

The inner coating is applied for protection of the product that needs transportation and the pipe. Coating depends on the type of protection and is mostly sprayed on the pipe (Table 7). General the inner coating will be applied direct after the production of the steel pipe. The outer coating is done for protection with the environment and the pipe. Multiple coatings are possible depending on the protection needed (Table 7). The coatings work as with the steel pipe manufactures with slots allocation.

The weight coating production is done by applying a concrete coating on the pipe Table 7. The coating is used to weight done the pipe and to protect the pipe against environmental damages. Most important part of the production of the concrete weight coating is the curing time. Curing takes 28 days. After 28 days the concrete is hard enough to withstand the pressure of other pipes. (Appendix B). Other part is that the wholesale market of total line pipe is bad. The line pipe is now a sunk cost and only can be sold for scrap. This is due to the specific dimensions or specifications given to a line pipe per project.

Table 7 production process references to characteristics of the line pipe.

Production process	Variable	Value
Steel Pipe	Diameter (inner and outer)	Inches or mm
	Ovality	Tolerances
	Wall Thickness	Inches or mm
	Grade or Steel Type	A25,A, B, X42, X46, …, X80
	Length	Meter
	Straightness of pipe	Tolerances
	Weight	Metric Ton
Inner coating	Coating type	Sweet or Sour protection
	Coating thickness	mm
Outer coating	Coating type	3 LPP, FBE, etc.
	Coating thickness	mm
Concrete coating	Weight Coating	Kg/m3
	Wall thickness	

The production process is time consuming including the production of the steel pipe, and applying the protective coating an estimate is made of the lowest lead time of approximately 49 days (Appendix B). The 49 days is an estimation made only on production time and no transportation time. The transportation time depends on the transportation chain. That will be illustrated in the next paragraph. Due to the communality of the line pipe for a project more pipes are ordered then planning needs. This is done to coop with risk of having too few pipes. It is custom for this reason to order ten percent more (Van Oord, 2014b).

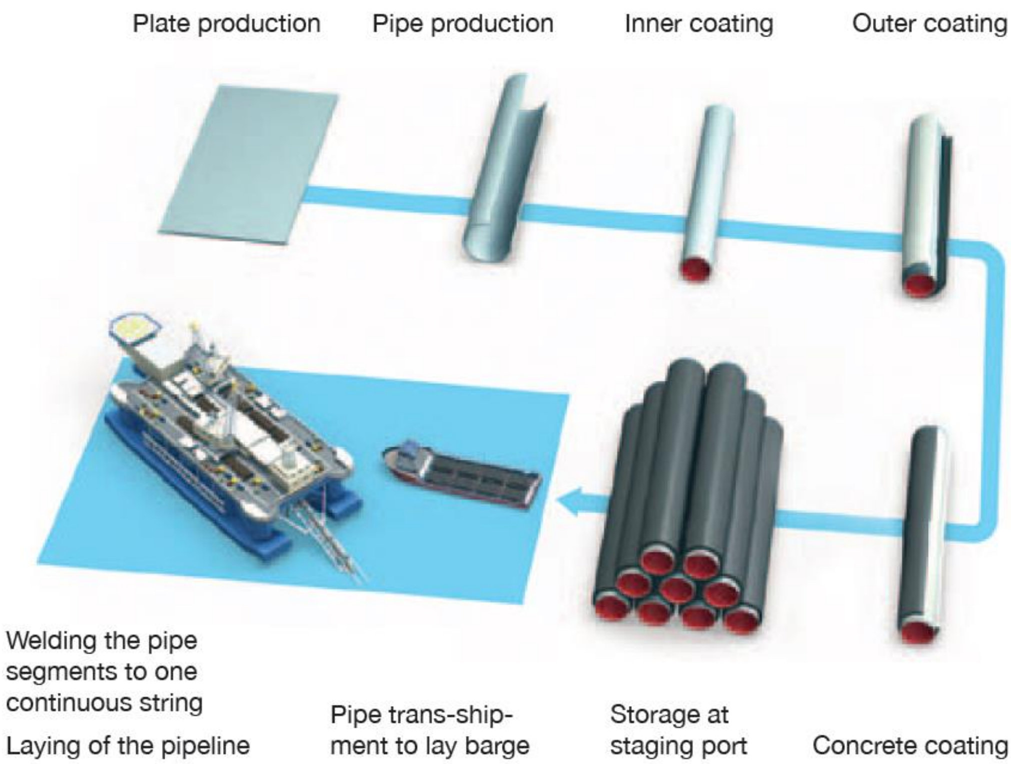

Figure 17 processes in the transportation chain of the line pipe (Nord Stream, 2010).

3.3.1 Transportation chain

The transportation chain connects processes in the cycle shown in Figure 17, from pipe production, inner coating, outer coating, concrete coating, and lay barge. Between al the processes some kind of storage, transfer, or transportation takes place. The only locations that are pre-determined per project are the final delivery location and the storage location of the staging port. The other processes depend on the choices during the selection in procurement. Selection criteria depend on quality, price, lead time, and service of the manufacturers and of the corresponding transport chain. The transportation chain is often chosen for a level of service the lowest costs. This can be arranged by, lowering storage levels, and acquiring the product as late as possible. Benefits are low storage costs and late payments which result in interest gains.

The transport chain of the line pipe includes all the transport and storage, handlings in the procurement of the line pipe till the delivery at the Stingray. The transportation chain depends on choices on location of manufacturers, customs, storage level, ordering, moment of payment, transportation mode, route choice, etc. To find the optimal transportation chain of a minimized costs and low lead-time is difficult to attain in a decision model due to three reasons. First business establishments do not have all the necessary information to make logistics decisions. Therefore they are not able to act optimal. Secondly, the deterministic logistics model requires accurate input on each route or leg. Not all input information is available or accessible. The third reason is that the computation associated with such optimization is very large (Roorda, Cavalcante, McCabe, & Kwan, 2010). Constructing such a model will result often in a sub-optimal tool. To understand the chosen in the transportation chain an illustration of the options will be given.

The transport between the production mills and the stingray can vary much due to location of the mills. The choice for a mill depends on the quality of the product, availability of production slots, and costs of the product and transport costs. The quality of the product has consequences on the production on the vessel and final product as stated in paragraph 3.3.1. For this reason high quality pipes are warranted, but transportation can neglect the gains of high quality pipes for the total project. Customs of countries, slot availability, or transport through dangerous areas can mitigate advantages. The main manufacturing locations for steel pipe are Europe, Asia, and Brazil (Appendix C). Concrete weight coating is often done more close to the final location due to extra costs on transportation due to the added weight.

Transport between the locations can be done by different modes: truck, train, and boat. The main transportation of the line pipe is often done by train and boot due to the size and weight of the product and the carrying capacity and costs. Characteristic of these modes are that they are not fast. The use of a mode depends on travelling distance, available infrastructure, and lead time. The final part from the staging port till the Stingray is done by a small vessel, because the vessel needs to be able to lie next to the Stingray.

Storage capacity determines the ordering rate and size. Due to production efficiency production in large batches is preferred, but this will also increase the storage costs. The transportation between the mills can be done in one batch on smaller batches. Storage capacity of the pipes has its limitation. The pipes can only be safely stacked for a certain height, otherwise the lower pipes will be damaged or deformed by the weight of the above pipes, and under safe conditions (Paragraph 3.2.1). These limits, limit possible storage area in its capacity. Other issue with storage is the accessibility of the pipes. Accessibility of an individual pipe can be difficult due to the position of the pipe in the storage stack. Accessing the pipe may need lot of work. Higher stacking the pipes limit the accessibility of the below pipes.

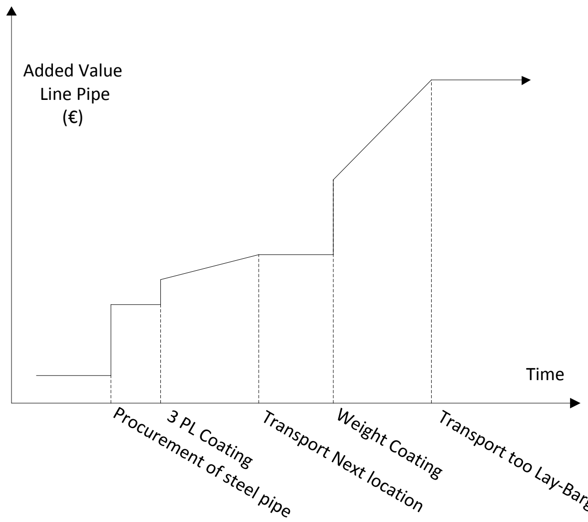

Figure 18 example of added value of the line pipe through production process.

The transportation chain is dependent on multiple choices that need to be made in a project. Time, quality and costs are important criteria for the choice on a transport chain. The costs can be lowered by having ordering strategy, acquiring of the line pipe can be done as late as possible thereby saving costs. In every action or step costs are made and value added to the line pipe (Figure 19). The preference of Van Oord is not to focus on the transportation chain. Till now Van Oord tenders to outsource the procurement and transport till the staging port.

3.3.2 Influences on the supply chain

The weather and responsibility of quality control are off large influence on the supply chain. The supply chain has to deliver to an offshore location and the production process should warrant a zero-defect status for the whole pipe line. The zero-defect status is due to the large consequences when a pipe is damaged. The replacement and repair of parts is difficulty. A defect find in a pipe will mean that the pipe will be quarantined and removed from the supply chain. For the Stingray weather, seaway and safety are leading for production or transport conditions. The uncontrollable circumstances due to the weather will give a dynamic element in the supply demand. On the offshore location on the supply barge or vessel and Stingray the space is limited that means that not multiple solutions can be used. Due to the limited space, accessibility can lead to disruption in the supply. This can lead to production loss.

Weather prediction is used for the prediction of the demand. This is done by using the weather prediction and workability tables of the vessels. The demand can be estimated. The weather factors are taken into account through data acquired from Van Oord. WorldWaves a dataset from Fugro uses buoys and satellites for gathering data on weather or wave conditions of the past 10 years. Through computations of Van Oord an estimation is made of the average weather circumstances. These factors will be used as boundaries settings for processes in the supply chain. Van Oord uses own measurement with water buoys to make estimation or plot of the workability of the Stingray.

3.3.3 Inventory management with information system

To improve the productivity of the Stingray the supply chain need to deliver the right pipe at the right time. This can be done by setting up an automated information system and planning system. The planning system can mitigate problems with alignment between pipes and alignment of the pipes and stations. The inventory system depends on the point, where the buffer connects the line pipe lean production line with the agile demand form the Stingray.

The buffer point in a le-agile system will be used as buffer to coop with the uncertain demand form the Stingray and function as connection between two interdepending supply systems. From an added value perspective and recovery of value the buffer should be before the concrete weight coating production process. From this moment recovery of value is still possible according wholesale representative. Taken this point for storing line pipe can be done when projects have long running times. This is due the lead time of the concrete weight coating production and only relatively short projects are currently done by Van Oord. The staging port is the best location for the buffer. The supply till the Harbor can be as efficient and lean as possible and the buffer will be in place to absorb demand fluctuations. So the Stingray can have a stable production.

3.4 Conclusion from Demarcation

The total production process of the pipeline is from production of the steel pipe, inner protective coating pipe, outer protective coating pipe, concrete weight coating of the pipe, welding line pipe together and transportation and storage between the processes. These processes form the total procurement or supply chain. The supply chain is sequential what means that delays will have a knock-on effect. On every project a new supply chain need to be set up. The supply chain will be evaluated on the criteria quality, lead time, costs, and service level on transport, storage, and line pipe. The interdependency of the different criteria and choices makes is difficult to find an optimal solution on.

Quality of the line pipe has consequences on the production on the Stingray. Quality of the pipe on the ovality, nominal inner diameter, and wall thickness influence the alignment process of Station 1. The length of the line pipe has influence on the production cycles. If the welds are not in line at the working stations at the Stingray an extra production cycle is needed to complete a pipe. By supplying the right pipe, which means that none of the above problems occur, at the firing line problems with pipe length and alignment can be mitigated. The quality is an interaction with costs and lead time. The lower quality can mean lower costs. The supply chain could be used to mitigate quality problems. The level of this depends on setting up of the supply chain.

The buffer or decoupling point will be best set at the staging port. The curing time of 28 days of the concrete coating is too high to have a dynamic ordering strategy based on real production time information or demands for project for Van Oord. Van Oord projects are on approximately up to 2 months. The project till now focuses on production of line pipe. The supply chain from the staging port till the Stingray will assist the most in this. To be able to address the dynamic demand interruption due to the sea state the model will be constructed from the staging port until the Stingray.

4 Conceptualization of supply chain

The previous chapter has set the demarcation for the conceptualization of the supply chain. In this chapter the conceptualization will be further developed to a schematic specification. The specification will be the basis for the simulation model. Firstly, the specification of the whole supply chain from pipe production till production at the Stingray is determined to understand the whole process. Secondly, the specification focusses on the last part of the supply chain, the moment from the staging port till the Stingray. The specification is defined into input, output, and internal parameters are done. These parameters are used for the simulation model. The selection of the conceptual model and simulation tool depends on the type of simulation that will be done. First the model and simulation tool will be selected. Then the model is developed into a simulation. This simulation will be validated and verified with data from the estimation department of Van Oord, experts, and data from projects.

4.1 Modelling and Arena

The specification or modelling of the supply chain depends on the modelling type. The model needs to represent the main processes and gives information on main variables described by the demarcation. Literature describes three modelling types (Appendix D):

1. Discrete event simulation
2. System dynamics
3. Agent based modelling

The model focusses on the last part of the supply chain, which is the agile part. The agile part will have irregularities and need a stochastic approach. The applicability of a tracking system in an inventory system is further examined in the simulation model. The inventory system will make use of an identification or tracking system, for which the data are acquired by quality control. The model will be able to cope with inventory management of individual objects and data processing collection on an object level. The modelling type that fits best the specifications is the discrete event model. The main arguments for this modelling type are the availability of the software program and experience of the researcher (Appendix D).

4.1.1 Object discrete model and Simulation program

The choice for the discrete event modelling has consequences for the specification of the model. The specification focusses on processes and events that are in the supply chain on object level. This is the individual line pipe level. For the specification the IDEF-0 scheme will be used. The IDEF-0 scheme is developed to give an insight in the processes and functions of a business system (Aguilar-Saven, 2004). For each process, an IDEF-0 shows the resources, input, the transformation to the output, and the control mechanism that streamlines the whole process (NIST, 1993). The IDEF-0 approach is to define system requirements, and specify the functions needed in the simulation model. The functions are placed in a hierarchical manner to show the size and relative interdependency along other functions. A top level function is first defined. From this top level the model is further

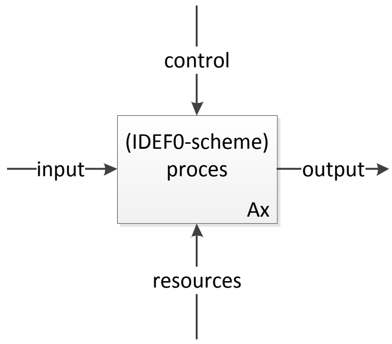

Figure 19 basic IDEF-0 schematic model.

decomposed in other functions. All these functions are based on the combination input, output, control, and resources (Figure 20).

The resources and input of the IDEF-0 will be used as input parameters for the discrete simulation program. The control parameters are used as boundary settings for the processes in the simulation program. The discrete simulation program Arena is used for simulating the supply chain, because it fits the requirements and needs of the discrete simulation program and the thesis. Firstly, it is available to the researcher. Secondly, Arena has an easy visualization program, which helps with the representation to experts. Thirdly, it fits the experience of the researcher (Appendix D).

4.2 IDEF0 Conceptualization of the supply chain

4.2.1 IDEF-0 decomposition of the supply chain

The IDEF-0 model is decomposed into multiple sub-models. The top level IDEF0 shows the procurement process that includes the supply chain process from production of the steel pipe until the final delivery at the firing line of the Stingray. In Figure 20 the model is divided into the subsequent processes of producing the line pipe, showing the following processes: steel pipe, protective coating, and concrete coating, and process of delivery from the harbor until the Stingray (Appendix E). The quality monitoring is taken as a separate process in the supply chain. The data acquired from the quality monitoring will be used for the inventory management of the Stingray. The Stingray production or inventory management will manage the harbor storage and delivery at the Stingray to improve the production process of the Stingray.

[Removed due to confidentiality]

Figure 20 part schematic overview of the main supply chain processes.

The model illustrates that quality control becomes integrated in the supply chain and production process, by supplying information from quality control to the supply chain until operations. The quality control monitors the line pipe quality supplied by the manufacturers through the line pipe production process. This data is currently used in quality control and not as an input in a supply chain management system. The automated inventory management system will use the information that is gathered by the quality monitor system during the production of the Stingray (Figure 20).

4.2.2 Description IDEF0 – A4: Stingray Production

The A4 Stingray production will be further examined to study the possibility of an inventory management system. The inventory management system will be implemented on staging port. The staging port is used as decoupling point or buffer in the supply chain to connect the production of the line pipe and the operations management of the Stingray. The information from the quality control will be used for operational planning (Figure 21 underlined text).

The A4 is decomposed into separate sub-models: delivery of line pipe at staging port, the process of storage at the harbor, pipe transfer to the production vessel offshore, the production process, returned faulty line pipe, and the quality control (Figure 21). The inventory management system will be implemented in the first part of the model on the storage onshore and offshore.

[Removed due to confidentiality]

Figure 21 specification of the simulation model

Further decomposition illustrates the processes that are simulated in the Arena model. The level of decompositions will be used for input, output, control and resources.

4.2.2.1 IDEF0-A4.1 & A4.2 specification of the storage system

A4.1 and A4.2 are the processes concerning the transfer of the pipe, from the moment the pipe is delivered at the staging port until the delivery of the line pipe at the firing line. The decomposed model shows the processes related to inventory or supply to the Stingray. The information of the pipe will be used as control mechanism. The A4.1 model shows the inventory handling on the onshore location (Figure 22).

[Removed due to confidentiality]
Figure 22 inventory handling onshore.

In the inventory management process the accessibility of the pipe is a key product of the function. The accessibility depends on the number of storage piles, and height of stacking. One storage pile means lower general accessibility for the average line pipe, because pipes are stacked on top of each other. The storage pile will have a capacity that depends on the height that will be stacked. The inventory system of the piles is last in, first out. So, the first pipe placed in the pile will be the most difficult to access.

[Removed due to confidentiality]
Figure 23 inventory handling offshore.

The A4.2 model shows the three main processes concerning inventory management on the Stingray (Figure 23). The three processes all concern the crane aboard the Stingray. The crane can transfer the pipes from the supply barge to the storage area of the Stingray, or direct to the production area. With quarantined pipes or rejected pipes the other way is possible too. These pipes are stored on the supply barge and moved back. A limiting factor is the pipe handling due to weather restrictions. Another limitation is the difference in workability between the Stingray and the Supply Vessel. This can lead to stock outs.

4.2.2.2 IDEF0-A4.3

A4.3 is the production process on the Stingray. The sub-model A4.3.1 preparation on the welding procedure is done. The pipe will get a final quality check and will be beveled. The line pipe will be placed in Zone A (the delivery place) to go into the production process. From Zone A the pipe will go through the beveling station to its final place in the ready rack, waiting to put in the production process in the firing line.

At the beveling station a final quality check is done and the pipe will be beveled. At this point the pipe can be rejected and put into quarantine. The quarantine criteria are: the pipe is not within client specification, the pipe is damaged, or the pipe cannot be beveled. Quarantined pipes that are not repairable on the Stingray will send back to the staging port.

Sub-model A4.3.2, which represents the pipe alignment process, is the first step in the firing line. The new pipe will be aligned with the pipeline in the firing line with the help of an internal line-up clamp. The alignment criteria comprehend that the high-low of the inner diameter may not differentiate more than the client has specified (Paragraph 3.3.1.1). The high-low depends on the difference between the nominal diameter and the ovality of the two pipe ends. If the pipes cannot be aligned, the pipe will be rejected and will send back to the storage on the Stingray.

[Removed due to confidentiality]
Figure 24 production process on the Stingray.

The Stingray is influenced by the rejection pipe return flow. The returned pipe blocks the flow to the firing line. This leads to down time in the production process.

4.3 Model parameters

The specification illustrates the structure of the supply chain, which include the following simulation parameters the input, output, resources, and control mechanism (Table 8). The variables need to be further described to be used in the simulation model. The output parameters are the criteria for a supply chain. This is a combination of quality, costs, lead-time, and service. The parameters set in the demarcation and specification will form the input and internal parameters.

Table 8 input, output, resources, and control mechanism of the specification of the supply chain.

Resources	Control mechanism	Input	Output
Beveling Station	High-low criteria	Line pipe (Quality)	Production
Aligners	DNV Storage	Transportation modes	Pipe handling
Quay crane	Load-in sheets	Supply Vessel	Process times
Stingray Crane	Logistical planning		Quality Control
Firing Line	Weather forecast		
Reach Stacker (transporter)	Line pipe quality specifications		
Supply Barge (transporter)	DNV Specifications		
Quality inspector			

Information exchanges between quality inspector and input and output variables. The quality inspector is included in the model to compromise the quality control in the total picture. The combination of quality control and supply chain increases when the information system will be put into place.

4.3.1 Input parameters Base Case

The input parameters in the simulation model are the resources and input from the specification model A4. They are the properties of the line pipe (Appendix F). The properties of the line pipe data is examined with statistics software program SPSS and a distribution is taken. The main input parameters are the properties of the line pipe, storage levels and production processes (Table 9).

Table 9 input parameters for the model (Appendix F).

Input Parameters	Value	Unit
aLength		meter
aNominalID		millimeter
aOvality		millimeter
aBeveled		
vLengthRestriction		meter
vNominalIDRestriction		millimeter
vHighLow		millimeter
vStorageStingray		Pipe

vStorageSupplyVessel	Pipe
Resource Beveling machine	minute
Resource Aligner	minute
Resource Firing Line	minute
Resource AdditionalProductionCycle	minute
Resource Move Up Stingray	minute
Resource Quay Crane	minute
Resource Stingray Crane	second

4.3.1 Output parameters: stock out and loss in production.

The output parameters are the performance indicators of the simulation. The new system will be evaluated on the performance indicators to assess the different implementations on productivity and workability. The output from the simulation is used to understand the consequences of the implementation of the supply system.

[Removed due to confidentiality]

For the workability of the supply chain or the robustness of the delivery of the line pipe another parameter is used. The robustness is can be described by the decoupling of the supply chain. The supply chain, from the staging port until the Stingray, has its decoupling point on the Stingray. The delivery depends on the type of supply vessel used for transferring the Stingray to the supply vessel and vice versa. If the supply vessel has a lower workability than the Stingray the transfer cannot be done. This means that stock-out of the storage at the Stingray is a possibility.

Table 10 output parameters of the simulation model.

Output parameter	Unit
Productivity	Meters per day
Production loss	Hours
Rejected pipes	Pipe
Production hours loss per rejected pipe	Hour per pipe
Quarantined pipes	Pipe
Production hours loss per Quarantined pipe	Hour per pipe
Extra production cycle due to miss aligned welds with working stations	Occurrences
Decoupling	Hours

4.3.2 Internal parameter

Different factors have large influence on the supply chain. These external factors will be used as parameters for the model. The influence of the weather, transport costs, storage costs, line pipe costs, ovality deviation, crane handling on the Stingray. The weather data will be imported from an excel document. The excel document provides the significant wave height and the mean wave period. These two parameters are needed for the workability of the Stingray (Appendix G). Other boundary parameters are the capacities that are fixed for the upcoming projects (Table 11).

Table 11 storage capacity in the production area.

Area	Storage Capacity (# Pipes)
Zone A	

Beveling Area
Ready Rack
Firing Line

4.4 Verification and Validation

The verification and validation done in illustrate that the model is a correct representation of the specification IDEF-0 model (Appendix F). The validation illustrates that the validation case from Van Oord is represented by the Arena model (Appendix F). It must be stated the only one reference case was available for validation. Further validation with future projects is recommended. For the validation the following test are done. A replication validation and a structural validation (Appendix F).

4.4.1 Replication validation

The replication validation illustrate that the reality is reproduced by the Arena simulation model. The validation on the production with the pipe properties distribution is done with one data-set as reference (Van Oord, 2014d). The lack of multiple reference cases weakens the validation of the model, but it will give a first indication of the quality of the model.

The simulation is on stochastic base. The model therefore needs to do multiple runs to mitigate statistical rarities. No conclusive literature is on the number of runs needed to mitigate this. The number of repetitions taken for the simulation runs is fifty runs. This is done on bases of the half width given by the model and on an expert recommendation.

Table 12 validation by data from Cabiunas project (Van Oord, 2014d).

Scenario	Number Runs	Number of Pipes	Record Productivity (m/day)	Record Addition Production	Record Rejected at bead stall	Record quarantined at bevel	Variable KP
Cabiunas Case							
Scenario Base Case							
Min.							
Max.							
Half Width							

[1] Productivity with only productions delays (Van Oord, 2014d).
[2] Productivity from simulation model with only weather delays.

Error! Reference source not found. shows that the data acquired from the Cabiunas project from the Stingray is within the output from the simulation model. The additional production cycles are higher than expected from the simulated output. The additional production is still within the spread from 0 till 7, but outside the half width.

The half width in the Arena output illustrate that: 95% of repeated trials are within the half width, meaning the sample mean would be reported as within the interval sample mean ± half width (Rockwell, 2012).

The replication validation illustrates that the simulation model can be seen as validated model.

4.4.2 Structural validation

A structural validation is done to see if the simulation model reacts as expected on changing input. A sensitivity analysis is done to see the impact that the variables have on the output changes. For the sensitivity analysis the variables are changed by ten percent positive, and negative (Appendix F). Also some outliners are researched to examine certain situations like: extreme bad or good pipe properties, very low storage capacities, very low workability, and extreme bad weather (Appendix F). The reaction on extreme input variables are as expected (Appendix F).

4.5 Conclusion on conceptualization and modeling

In this chapter the conceptualization and specialization of the model is made for the simulation model. The specification is done on the supply chain from the staging port until the Stingray (Appendix E). The supply chain will focus on the correct delivery of the line pipe to the firing line. The specification illustrates two main processes: the production of the Stingray, and the supply of the line pipe to the Stingray. The production of the Stingray depends on multiple variables that cannot be controlled. This gives unexpected changes in production, which leads to demand changes in the supply chain flow. The model needs to cope with this unexpected or stochastic behavior.

The Arena model gives a representation of the transportation and handling of the line pipe from the staging port onward. In the model, the information concerning the line pipe will be seen as input, and known from a location based position. This position is determined by the location of quality checks and documentation provided by the quality control.

5 Supply chain simulations

The simulation model, constructed in the previous chapter, is used to evaluate the productivity and workability of the supply chain. The Arena model illustrates the impact of implementing an inventory management system on different locations and analyzes workability related parameters for delivery of the line pipe at the production area on the Stingray. The workability of the supply chain is defined as: the ability of operating without downtime due to supply of the line pipe. The supply chain workability is analyzed on decoupling of the supply chain. The decoupling in the supply chain is measured by the production downtime due to the availability of the line pipe. The inventory management systems are evaluated on the reduction of rejected and quarantined pipes on the Stingray in accordance to improve the productivity of the Stingray.

5.1 Development of simulation

5.1.1 Base Case model

The base case model will be used for the assessment of the workability parameters and to assess the implementation of the inventory management system. The reference case is the same case used for the validation of the Arena model (Appendix F). The input on pipe properties of the reference case is from an ongoing Van Oord project in Brazil. The production input variables for the Stingray are acquired from the same project (Appendix F & Appendix G). The project variables are supplemented where needed by a tender bid as can be seen in the conceptualization. The bid is used for the input variables on the part of the supply chain from the onshore location until the Stingray and for the wave and weather data (Appendix G).

5.1.2 Scenario development

The workability and productivity of the Stingray is examined. The two subjects are analyzed as on the influence of the supply chain structure on the delivery of the line pipe and an inventory management system for the supply chain. The scenarios for the structure of the supply chain illustrates trade-offs in the supply chain that helps to make choices on e.g. storage capacity or transportation modes. The analysis of the different inventory management systems illustrates the benefits of implementing an information system on line pipe.

5.1.2.1 Workability: Supply chain structure

The structure of the supply is evaluated on the continuous delivery of the line pipe to the production or firing line. An interruption in the continuous delivery leads to down time of the firing line. The sensitivity analysis of the model shows that the difference in workability boundaries of the Stingray and workability of supply vessel and also the storage capacities on the Stingray are leading for disturbances in supply chain (Appendix F). The storage capacity on the supply vessel is of no influence as long as there is a 100 percent supply vessel rotation coverage alongside the Stingray.

The disturbance in the production flow is called decoupling of the supply chain, which stand for no pipes available at the Stingray for production; leading to loss of production time. To illustrate the means of reducing the risk of a decoupling, the reference case is run under: different work circumstances e.g. different types of sea state, different workability boundaries, and different storage capacities.

The focus of the scenarios is on decoupling due to the sensitivity of the pipe transfer connection between the barge and the Stingray. Thus, the model is constructed so that the supply barge has a

100 percent coverage on supplying the Stingray, which means that the cycle time of the supply barge is shorter than the offloading time at the Stingray.

5.1.2.2 Productivity: Inventory management

The goal of the inventory system is to reduce the number of quarantined and rejected pipes at the production area to improve the productivity on board the Stingray. The inventory management system is evaluated in reference to the base case model. The pipe properties of ovality and nominal inner diameter in corresponding to DNV standards on production and pipe dimension determine the rejection and quarantining of the pipe (DNV, 2012). The choices for these input parameters are based on key parameters to the production determined by the sensitivity analysis (Appendix F). Correctly sequencing the line pipe, before arrival at the production area on board the Stingray, can reduce the rejection and quarantine of the line pipe. The sequencing of the pipe can be done on location during storage periods and during transfer processes between storage and transportation vessel.

Sequencing on location is done by rearranging pipe sequencing on the storage location e.g. on the onshore harbor location or Stingray. All pipes will be inventoried, and the pipes are sequenced in the manner that results in a smooth production by correct supply of the line pipe. The advantage of such a system is that, when correctly sequenced at the storage location, the supply chain produces a continuous flow to the production area and no pipes will be rejected. The next advantage is that the problems are resolved in a short period of intervention. The downside of sequencing on storage location is the potentially needed multiple costly and potentially damaging handlings per pipe.

Sequencing during transfer processes is done by selecting a certain pipe at hand to take out of a stack during offloading or by selecting which stack to put a pipe in storage. This selecting alters the sequence or categorizes the pipe on certain stacks in a storage area, which can have benefits further down the supply chain. The benefit of this system is that the number of handlings is reduced in comparison to sequencing on location, but if the property spreads are too high, a batch of faulty can still disrupt the production process.

The availability of the information on the pipe properties determines which sequencing system can be used per location or process in the supply chain. The availability of the information is determined by the accessibility of the information on that line pipe on location. The accessibility depends on the level of detail required on the pipe and the technology used for information transfer e.g. color coding, barcode or RFID tag. The use of technology is determined by the quality and detail of the information needed. The pipe needs to be sequenced in order to deliver the pipes within production standards. The following two pipe properties are taken as boundary for the pipe: ovality and inner diameter. The difference between the adjoining pipe properties is the maximum allowed high-low.

The information needed for the inventory management system can be supplied up front, by the client or manufacturers, as part of an integrated process in the supply chain, or as part of another department e.g. quality control. The location of acquiring the data on the line pipe determines the moment that sequencing of the line pipe is possible.

The inventory management system is setup to improve the productivity. The productivity is improved by reducing the number of quarantined or rejected pipe in the production area. The rejection depends on the pipe properties in combination with the DNV production specification set by the client. Sequencing the pipe order will reduce the rejection rate. The sequencing can be done according two systems during transfer and during the storage period. The systems choice depends on the moment and location Van Oord has control over the pipes. Ideally, the numbers of handlings are reduced to save time and reduce the risk of damaging the pipe.

5.1.2.3 Scenarios setup

The inventory management system and supply chain structure are examined by running different scenarios. The scenarios are run with the process analyzer which is part of the Arena simulation program.

Table 13 scenario input parameters supply chain structure.

Scenario variables Supply chain structure	Values
Storage capacity Stingray	100%, 150%, and 200%
Storage capacity supply vessel	50%, 100%, and 200%
Stingray workability limits	
Supply Barge workability limits	
Sea state	expected, rough, calm

Table 14 scenario input parameters inventory management.

Scenario variables Inventory Management	Values
Pipe properties (Ovality, inner diameter)	Increasing difference in distribution spread
Location of control on inventory system	Moment from the boat, acquiring at the yard, besides the Stingray
Sequencing by category	

The first scenarios setup focuses on the workability of the supply chain. The scenario is examined on decoupling of the supply chain on different workability boundaries to understand the sensitivity on the pipe transfer connection in the supply chain. The input variables for the scenario are the sea state, storage capacities, workability's of both the Stingray and supply vessel (Table 13 and Table 14). For the workability, it is key that the difference in the workability of the supply vessel and the Stingray is in favor of the Stingray. If there is no difference in workability, the supply chain will not decouple at the interface between the supply vessel and the Stingray (Appendix G). The scenario included the expected new workability boundaries of the Stingray (Figure 26).

The second scenarios setup focuses on increasing productivity by inventory management and reduction of rejected or quarantined pipes at the Stingray. The input parameters for this scenario are the pipe properties, location of acquiring the information on the pipe properties, and the number of storage stacks used. This illustrates the level to which the system can cope with a spread of quality of the pipe properties. The choices that can be made by the project manager are: the number of piles, the categorizing system, the strictness of the sequencing procedure, and the place where the information is acquired and managed.

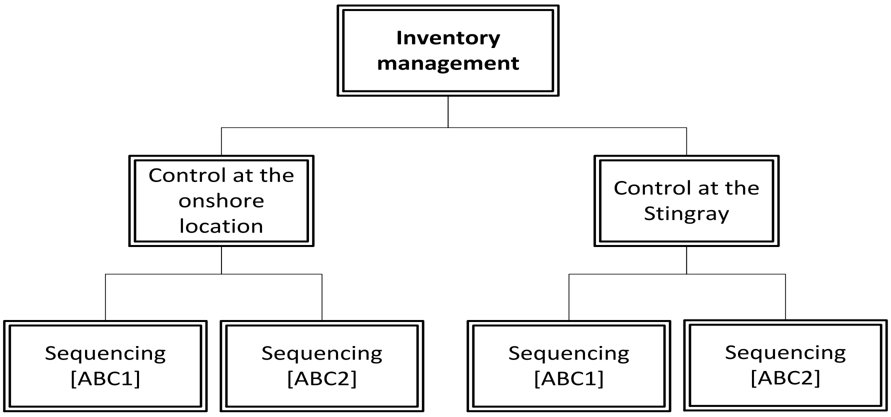

Figure 25 scenario build-up of the inventory management system.

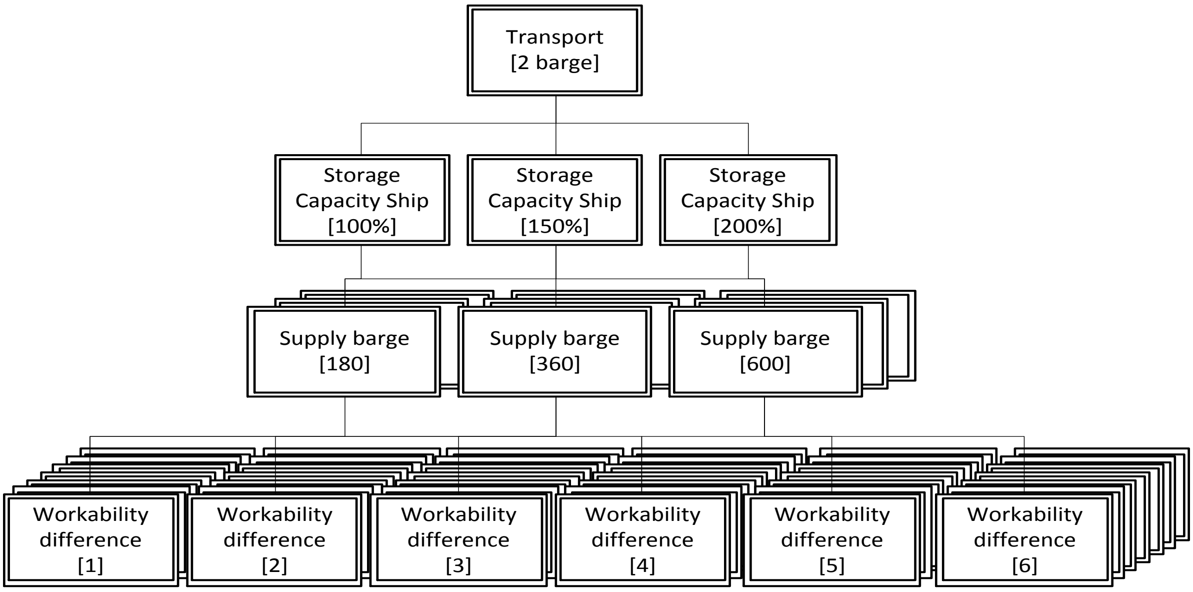

Figure 26 scenario build-up of the workability and the storage capacity.

5.2 Output from Simulation

All the scenarios are set-up in the process analyzer as part of the Arena simulation software. The output can be found in the appendix J in two tables. In the next paragraphs an overview of the data is presented, followed by an interpretation of the data.

5.2.1 Data from behavior of supply chain on sea state

The simulated scenarios of the supply chain structure illustrate the relationship of the weather on the supply chain in combination with the storage capacity on the Stingray (Figure 27, Figure 28 and Figure 29). The bar graphs do not show all the simulated scenarios, but only the scenarios that show a significant downtime or lost production hours due to supply to the Stingray.

The lost production hours in the supply chain are caused by the availability of line pipe on board the Stingray and the ability to still be in production. In the model, the production rate will not be lowered to cope with a decoupling situation. This is done to illustrate lost hours of production. Two possibilities are available to bridge the moment of no production. This can be done by using a technique of slow lay meaning slowing the production or an abandonment procedure of the pipeline. The bar graphs are categorized on the workability difference between the supply barge and the Stingray. The difference is expressed in the zero crossing periods, which is one of the standard methods to calculate a wave period expressed in seconds. This method is chosen because the zero-crossing period is identified as decisive in workability boundaries for the vessels. The bar-graph shows the expected period during which the project had no line pipe onboard the Stingray. The expected production down time is the combination of the average hours of a stock-out and the expected occurrence of a stock-out per scenario run.

The bar-graphs in Figure 27 and Figure 28 illustrate the consequence of using different supply barges in combination with the Stingray workability using the current storage capacity onboard the Stingray. The sea states are made rougher and calmer to illustrate the sensitivity. If the sea state is rougher than anticipated, the supply chain will have more and longer disturbances than with the regular expected sea state. If the sea state is calmer than expected, the production loss time of the supply chain can only be expected on a very sensitive supply barge connection (Figure 28).

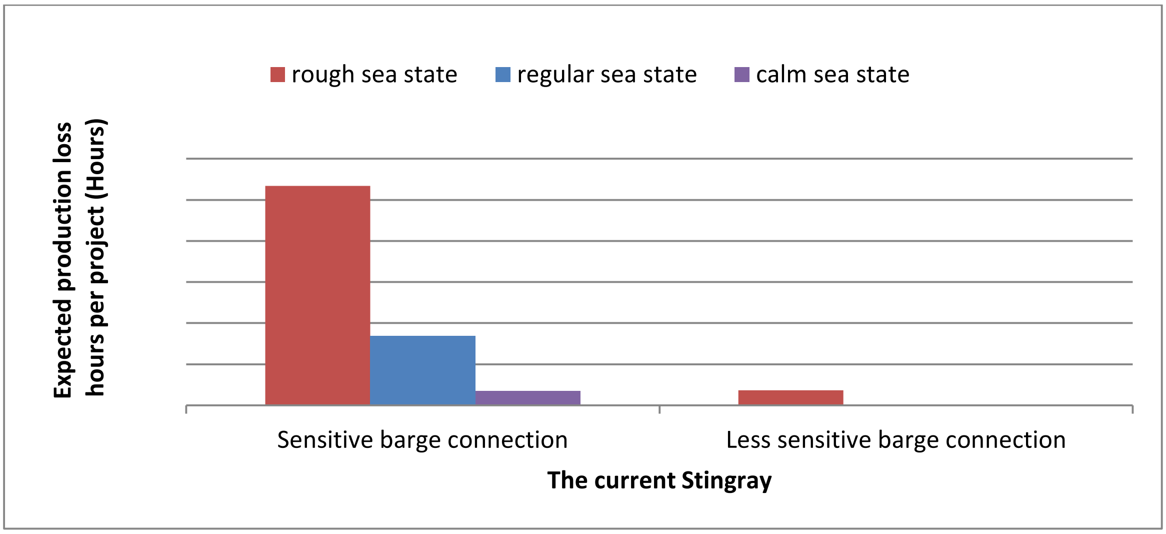

Figure 27 bar-graph expected production loss with current Stingray workability boundaries with a storage capacity of 63 pipes on the Stingray.

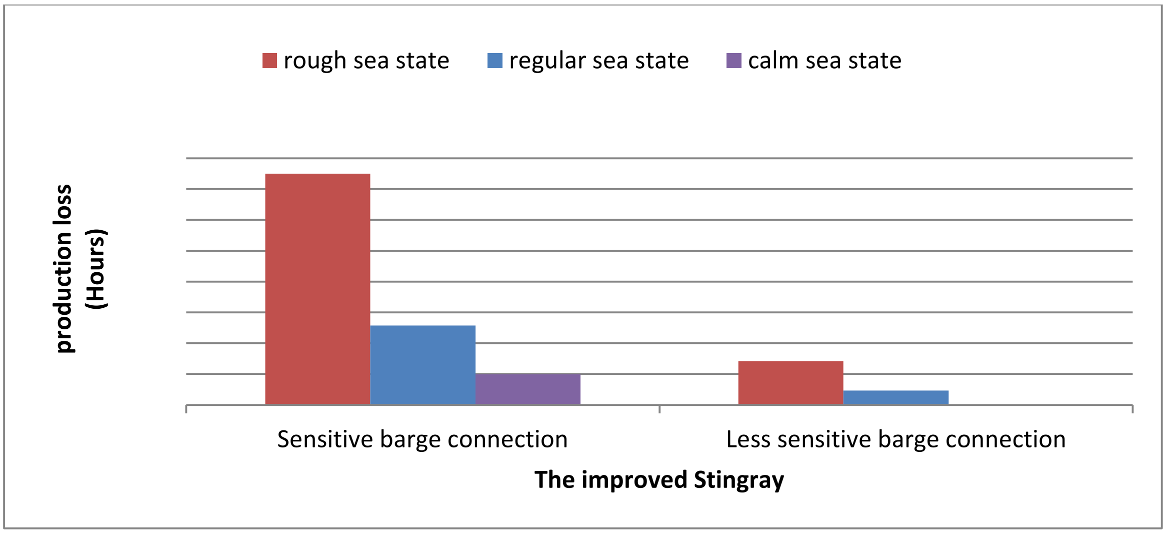

Figure 28 bar-graph expected production loss with expected future Stingray workability boundaries with a storage capacity of 63 pipes on the Stingray.

The bar-graph in Figure 29 illustrates the relationship between storage capacities on the Stingray and production loss on the supply chain. The scenario with the most sensitive line pipe transfer connection between the supply barge and Stingray is taken as the base case. The independent variable is the storage capacity onboard the Stingray. The storage of the supply barge is not of influence on the supply chain when the supply is organized to have a barge continuously present besides the Stingray.

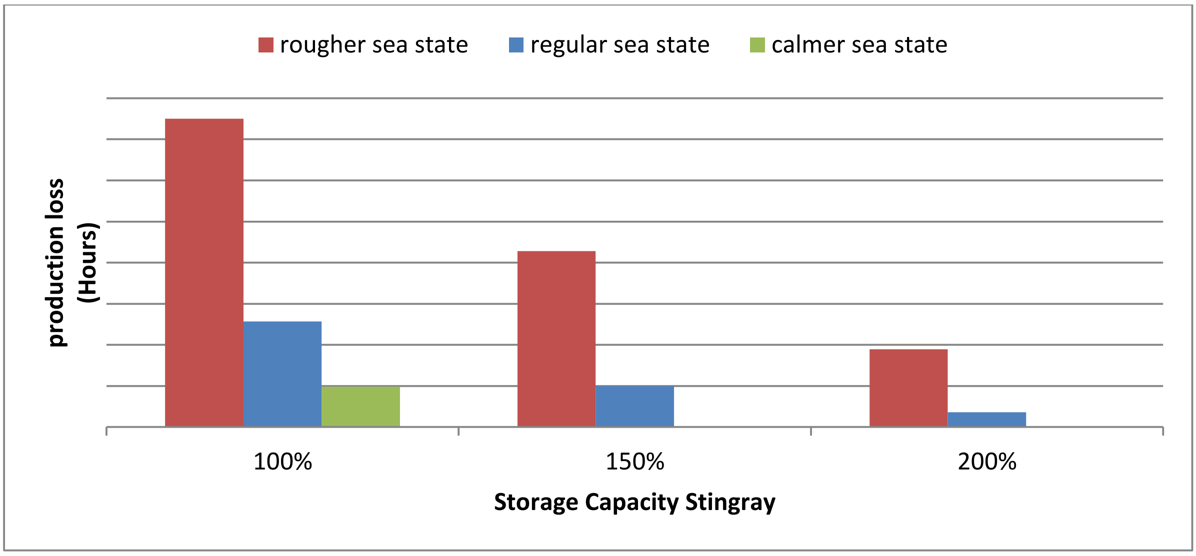

Figure 29 bar graph on the average production loss with the most sensitive barge connection.

5.2.2 Data from inventory system scenario

This paragraph illustrates the output of implementing an inventory system to control the sequencing of the line pipe to the production area on the Stingray. The inventory management system should provide a smooth production with reduced rejected pipes at the bead stall. The sequencing of the line pipe can be manipulated on different locations in the supply chain. These locations are the transfer moment of the line pipe (e.g. between transportation per barge) and storage on the Stingray. The full data on all the different scenarios can be found in appendix J.

Table 15 average outcome implementation of inventory control on different locations.

Case	Number of Cate-gories [stack]	Quaran-tined loss [Avg. Hrs. / Pipe]	Rejection Loss [Avg. Hrs. / Pipe]	Quaran-tined [pipe]	Rejected [pipe]	Produc-tivity [m /day]
Base Case						
Information at Harbor						
Arrangement on the Stingray						

The data represented in Table 15 shows the implementation of an inventory control system in comparison to the base case. The manipulation of the sequencing can be done on multiple locations. Van Oord can manipulate the sequence of the pipes when the pipes are placed on the stack onshore when delivered at the harbor, the pipe is placed on the barge, and delivered onboard the Stingray. The control of the pipes all focus on the least of handlings per pipe. The higher the numbers of handling per pipe, the higher the costs of storage, and the higher the risk of damaging the pipe are.

Figure 30 and Figure 33 show the production loss and the productivity with current pipe property and the maximum spread that is still within the DNV standards in blue.

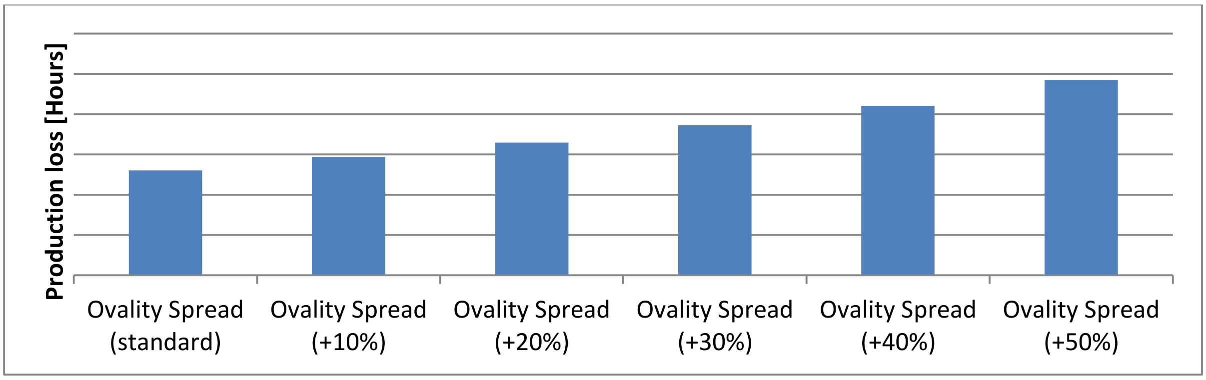

Figure 30 production loss with no inventory management system and different pipe properties spreads (appendix I).

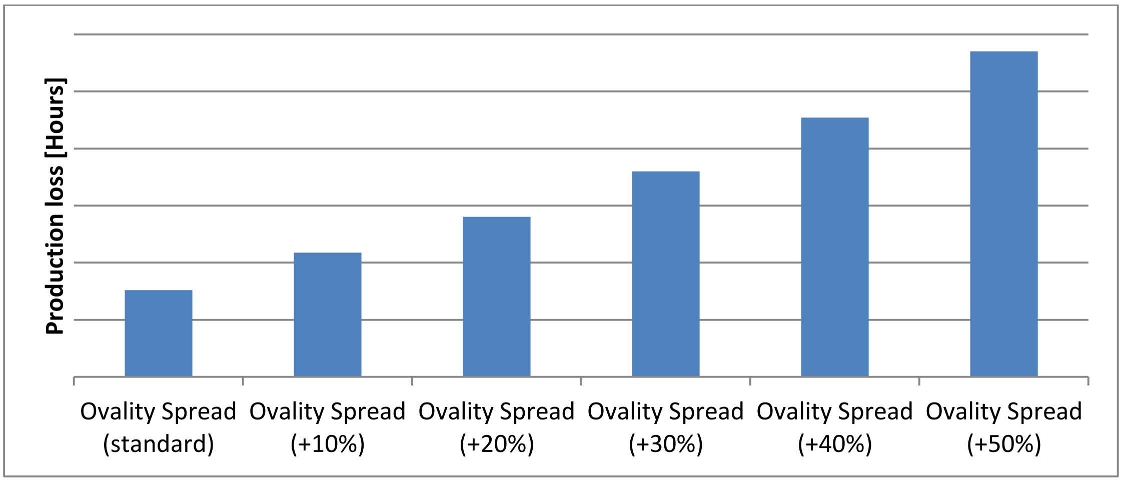

Figure 31 production time lost due to rejection at the bead stall when all out of specification removed pipes (Appendix I).

In Figure 32 a small exponential relationship can be seen.

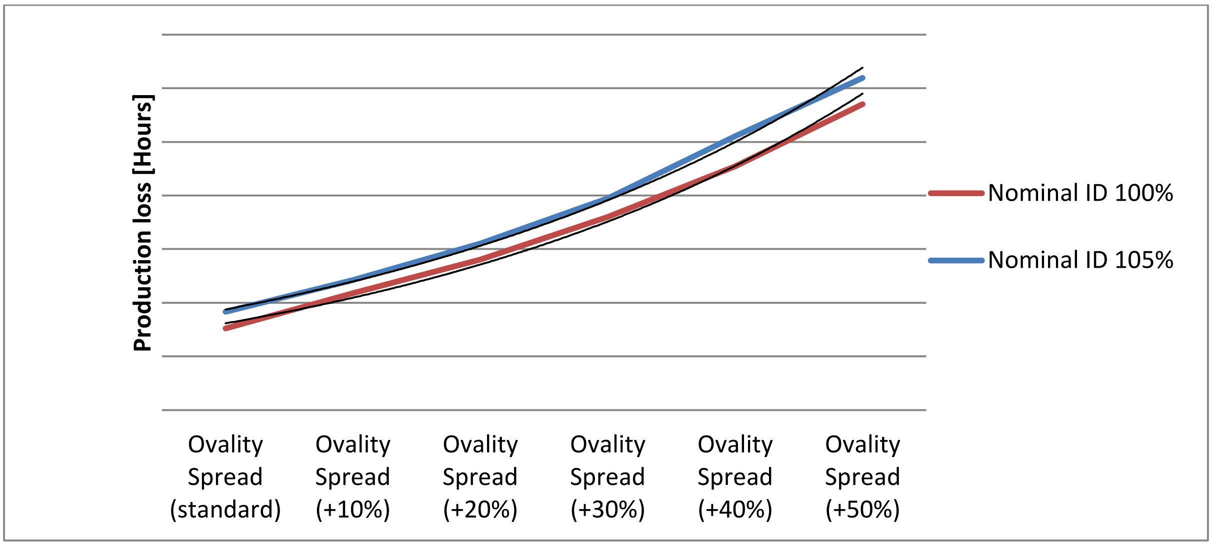

Figure 32 production loss due to extra increase in nominal spread (Appendix I).

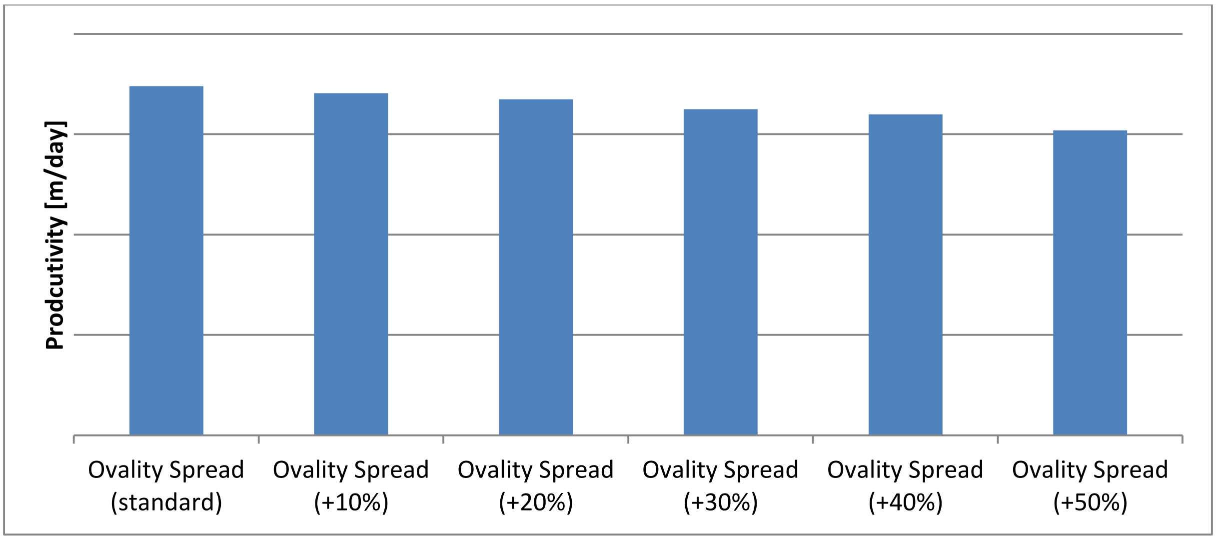

Figure 33 productivity of the Stingray with no inventory management system and increased pipe properties spreads.

The implementation of an inventory system, in order to control the sequencing of the pipes to the bead stall, has a positive result on the productivity of the Stingray and on the rejection rate at the beveling station and bead stall (Table 15).

5.2.2.1 Inventory management systems data

The sensitivity of the inventory management system is also examined by using/evaluating different scenarios. The difficulty is to handle a broader distribution per pipe property of ovality and inner diameter. These distributions will mean that more pipes will be outside the DNV standards (DNV, 2012).

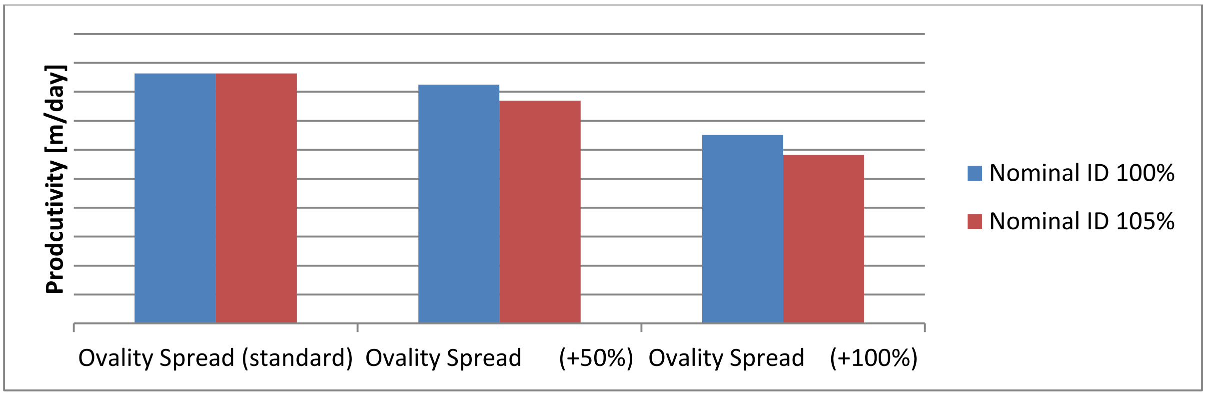

Figure 34 productivity of the Stingray with increasing spread on the pipe properties and an inventory system arranging the pipe sequence onboard the Stingray.

Figure 34 illustrates the ability to handle different spreads of distribution per pipe property when an inventory control system is implemented on the Stingray. The sequencing of the pipes will be done onboard the Stingray. The productivity decreases when the distribution spread is increased due to the number of handlings needed to sequence the pipe onboard the Stingray.

The inventory management system that works by controlling the pipes at the onshore location shows that the productivity increases. If the spread is increased outside the DNV standards, the system does not function well. This is partly due to the rejection of the pipe at the onshore location and the number of categories which solve the inventory issue.

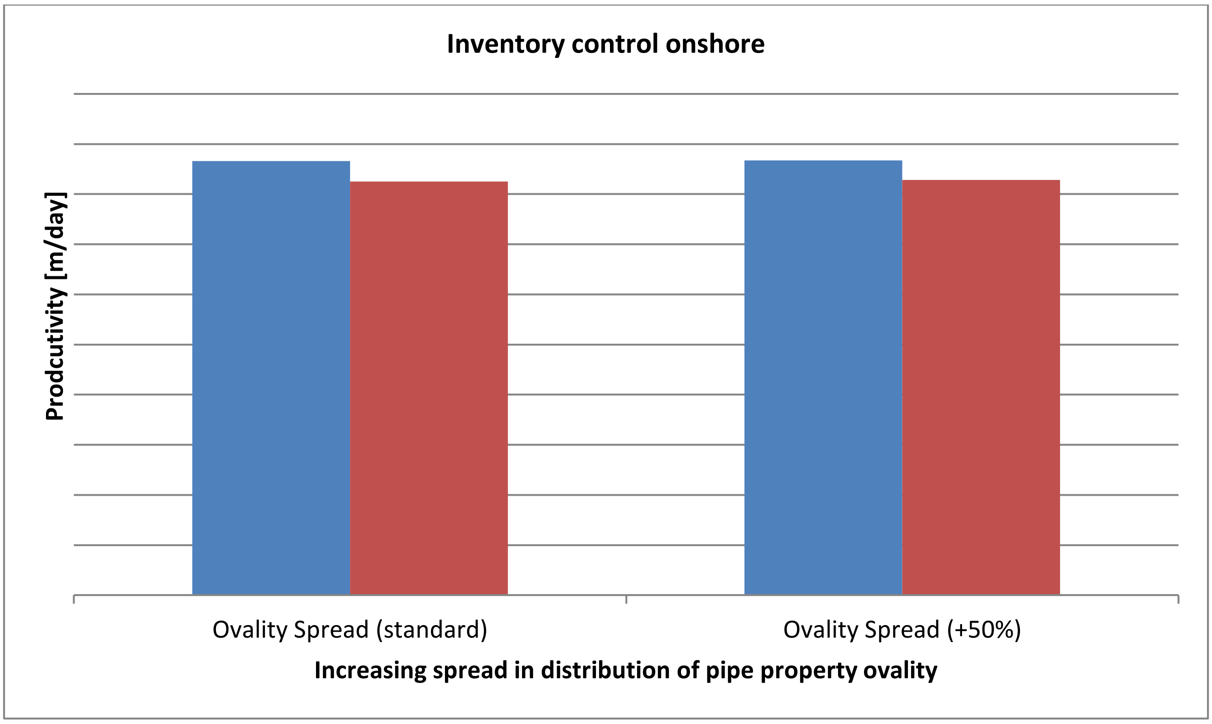

Figure 35 productivity of the Stingray with increased spread on pipe properties and an inventory system arranging the pipe sequence on the onshore location.

5.3 Interpretation of the simulated data

5.3.1 Supply chain behaviour workability.

The scenarios are evaluated on the production loss, which are a result of the supply chain. The scenarios are run with different storage capacities on the Stingray and supply barge under different workability limits and sea states (Table 13). From the data from the simulations the following can be concluded on the three subjects: sea state, workability limits, and storage capacities (Figure 27, Figure 28 and Figure 29).

The effect of the sea state on the production loss in the supply chain shows an exponential relationship; if the sea state is rougher the production loss increases more than the decrease of production loss with calmer seas. The effect of the sea state on the supply chain shows an exponential relationship. This means that if the weather is worse than expected, it could be recommended to invest in reducing the sensitivity of the transfer connections between Stingray and supply. This can be done by hiring another supply vessel, e.g. a DP supply vessel, or by investing in a docking structure.

The production loss time in the supply chain is increased if the Stingray's workability capacities are increased and the supply barge workability boundaries stay the same. If the Stingray's workability is increased by changes in the firing line, the storage on the Stingray is not of significant influence on the occurrence of production loss. With the current workability capacities, production loss due to the supply chain is limited compared to increased workability. The data shows that if the difference between the zero crossing periods limits of the supply vessel and Stingray is approximately one second, the chance on production loss of the supply chain is high. The increased chance of disturbances in the supply chain, when increasing the workability of the Stingray, can be explained by the higher difference in workability with the supply vessel. Extra research is needed on the pipe transfer from supply barge to Stingray. The storage capacity on the Stingray is of large influence on production loss of the supply chain. The current storage capacity with the use of these size pipes on the Stingray limits the supply chain.

5.3.2 Inventory management system

The scenarios are evaluated on the rejection rate at the beveling station, the bead stall, and the productivity of the Stingray, with different pipe property spreads. The Evaluation is done by comparing the inventory system with the base case on productivity increase and reduction of production loss.

The base case illustrates conflicts with pipes that are out of specifications and problems with alignment of the pipes at the bead stall. The pipes need to be sent back through the supply chain. Multiplying the average pipes lost with the number of pipes rejected and quarantined will give the total loss of production time.

Implementing an inventory system in the supply chain helps to resolve the current production loss. The first step, in the sequencing or ordering, is to reduce the number of quarantined pipes at the beveling station. The bevel station is the location where the pipes have their final check if the pipes are within specification. Identifying the pipes earlier in the supply chain, and removing these pipes out of the supply chain is the largest reduction. Another way to reduce the production time loss is sequencing the line pipes for better alignment at the bead stall.

The inventory system, with the base case input on the pipe properties, improves the delivery of the pipes with both systems. The rejections at the bead stall, and quarantine at the bevel station, are in all variance of the inventory system reduced to zero. The inventory management systems are then tested on the different pipe property spread in accordance with DNV. Not every inventory management system can manage the same spread on the different pipe properties. The nominal inner diameter cannot increase more, because too many pipes will be rejected on their specifications set by DNV. The ovality still can vary more within the DNV standards. If the spread increases above the DNV maximum limits, it can give issues on productivity and rejection at the bead stall rates. The rejection rate is lower, but still more than zero when not using the inventory management system onshore location on categories. The contractors should focus on knowing the spread of the pipe properties before production starts. It needs to be clear what to expect before a project starts. This can be a-selected sample testing done by quality control during production. The contractor can decide at the moment the pipe is acquired which inventory system should be used. The pipe properties could determine which inventory system should be used.

6 Pipe line supply chain system

In this chapter, chapters 3, 4, and 5 are used as input in order to give advice on the line pipe supply chain and on the logistical system for the handling of the line pipe in the supply chain. In this chapter also trade-offs that come from the simulation are discussed. The data from the simulations and the analyses performed are the base for the advice on the setup of the inventory management system. The supply chain of the line pipe has connections with multiple departments within Van Oord. Procurement, quality control, logistics, and operational departments are responsible or dependent on the supply chain or logistics of the line pipe. This chapter will address were the department will come into place. The set-up of the system depends on multiple facets, which need to be incorporated in the supply chain. These facets are: information handling system, identification system, and a structure for the supply chain.

6.1 Information system

The logistical system is a combination of an information system, an identification system, and inventory or logistical concept. The information on the line pipe is the backbone of the supply chain logistical system. On the information of the line pipe choices and decisions can be made for the supply chain inventory system setup.

The line pipe information system needs to acquire information on the pipe properties pipe length, inner diameter, and ovality for production process purposes. With this information possible bottlenecks in the production process can be identified. The information is needed before the pipes are delivered by the manufacturer for two reasons. First reason is to reject and quarantine the out of specification pipes and the pipes that are having extreme pipe properties. These pipes will not move through the supply chain into the production area on the Stingray. This saves production time and money. Second reason is to make a decision on the setup of the supply chain and logistical system. To make this choice an assessment of consequences the pipe properties distributions are made by running the model with those pipe properties distribution.

If the choice is made to implement a logistical system the information system should have information on all the pipes and the selected pipe properties. This data needs to be linked to an identification system. The current identification system is a heat number imprinted on the pipe. The information is difficult to access. In the thesis are other possibilities e.g. barcodes and RFID systems examined on its applicability. This topic will be further addressed in the next paragraph.

The inventory information system should be a database that stores information on pipe properties in a central database. The information needs to be available on every pipe. The central database than provides access to the data on the moment that it is needed on a location. The responsibility and control of the line pipe database should be dedicated to the quality control department.

6.2 Identification Technology and Costs

The identification technology is a part of the inventory management system. The identification is the process of accessing information on the pipe.

The identification of the pipes can be done using different technologies, these have been described in chapter 2. Choosing the appropriate identification method depends on the inventory requirements. These include the level of detail of information that is needed for the different locations and under which conditions the data is needed. These conditions are safety, surroundings, day/night, and task description.

The following environments can be identified. The onshore or offshore location, and handling during transferring of pipes or pipe storage. The onshore and offshore location has influence on the accessibility of the information. On an offshore location the space, movement, equipment, and time constraints are limited in comparison with the onshore location. Working on solid ground is safer than working on water. This will result that an offshore system should be robust, and relatively simple in use. Offshore can have a harsh environment that includes higher safety standards for personal, so the equipment used for the identification should be controllable or usable with protective clothing, and resist the harsh environments e.g. the equipment should resist water and be controllable with gloves on. Onshore have relative lower demands on the equipment.

Table 16 identification environments requirements.

	Transfer pipe	Storage pipe
Onshore	Quick, Clear system, direct influence on sequence pipe	Accessibility, non-changeable of sequence pipe
Offshore	Quick, Clear, Simple system, Few Handlings, direct influence on sequence pipe	Accessibility, non-changeable of sequence pipe

The state of the pipe, as part of a process or in storage, is also part of the environment. During storage the time pressure is lower than during transfer of pipes. In the storage area the pipe can be checked, without delaying other processes. The data can easily be collected and processed in the information system. During transfer of the pipes the data collection and processing should be quick and robust to not have a large delay or knock-on effect on other processes. The identification system during transfer needs to be quick, clear, and simple (Table 16).

The identification level of the pipe can be on multiple levels e.g. exact pipe property per pipe or in categories. If the pipes only need categorizing the pipes could make use of relative simple techniques e.g. color coding of the pipes. The inventory system becomes more complex if the pipe have a large spread in the pipe properties and need to be sequenced onboard the Stingray. If the complexity of the logistical system increases it is advised to use a more complex identification technology that can identify pipes quick and clear on individual level e.g. RFID or Barcode system.

The choice for an identification system depends on the requirements of the identification system. This is different per project. The recommended technologies for an identification technology on the line pipe are RFID or barcode technology. The costs of these systems are divided into a variable and fixed part. The variable part depends on the technology used. The applicability of the different technologies still needs further research on robustness of the technology on offshore environment.

Table 17 estimate on technology inventory management costs (appendix H).

	Cost Barcode	Costs RFID
Fixed		
Variable		

Table 17 illustrate an indication of the inventory management system costs based on cost made on a field testing of RFID technology. These costs do not include the costs of operating the system. No clear estimation could be made on the extra costs versus the benefits from a personnel point of view due to many uncertainties. With the help of an identification technology some processes like quality control will go faster. On the other side extra processes are introduced.

6.3 Supply chain structure decisions

In this paragraph the trade-offs are discussed on the setup of the supply chain on a project. The recommendations come from the scenarios run. The process of setting up the supply chain structure depends on the moment of acquiring responsibility on the line pipe, the weather, the sea state and the pipe properties.

First the moment of acquiring the line pipe needs to be identified. This can be at the boat location before the boat is offloaded or when the pipes are in storage on the onshore location. From the onshore location or the moment the pipes are put on the Stingray. With this information the contractor knows when it can intervene in the supply chain.

To identify and make choices in the supply chain setup predictions and knowledge of the sea state need to be known and information on the distribution of the pipe properties. The need for a strong transfer connection between the Stingray and supply barge depends on the weather and sea state. The connection can be improved by using a dynamic positioning supply vessel that is not attached to the barge. Depending on the project size it can be stated that for one day of reducing production loss the supply vessel can be used for a month. If the project has delays the supply vessel option becomes more expensive. The day rates are not the only costs associated with the transport vessels. The vessels have mobilization and demobilization costs. These costs depend on the accessibility of the vessel to the location. The DP (dynamic positioning) supply vessels are less accessible worldwide than the barge option. The supply barge option is the best option.

Implementing the inventory system depends on the gain versus the costs of such a system. For a comparison, the number of rejected pipes needs to be weighed against the costs of the system. An assumption is made that with increased quality handling the quarantined pipes will be reduced to zero. It should be expected that in future project the pipes that are out of specification will not be in the supply chain. Comparing the production time gain from implementing an inventory management system the barcode system has the lowest variable costs for an inventory system. The RFID system is more expensive, but maybe better equipped for offshore circumstances.

7 Discussion

In this chapter the thesis is discussed on assumptions made in demarcation, on related subjects on the supply chain and monitoring systems options. These subjects help to put the research in perspective in a whole pipe-lay project and illustrate the possible implementation in future projects. After the thesis is discussed on assumptions, the limitations of the thesis are addressed to put the outcomes in perspective. To understand predictions made with this model.

7.1 Thesis in project perspective

In the thesis assumptions are made and thereby a demarcation was made on the line pipe supply chain. The assumptions have an influence on the supply chain structure, the trade-offs in the supply chain, the requirements of the supply chain, and identified or possible problem areas. To put the thesis in perspective assumptions and demarcations are further discussed.

The structure of the contractors supply chain is determined by the moment that the contractor takes control of the supply chain process. In the thesis, the moment of control is the moment the line pipe is delivered at the onshore storage location (Figure 36). The locations were the line pipe is fully fabricated. Choice has been made due to the long lead time of the concrete coating production. It is difficult to have a dynamic ordering system that has a buffer before the concrete weight coating facility. This is examined, but not taken into the thesis due to the average length of the expected projects by the contractor. The benefit of having the buffer before the concrete weight coating is that pipes with no concrete weight coating are easier resold and that the concrete weight coating is a large portion of the line pipe costs. Postponing the concrete weight coating has a positive influence on the cash flow. Pipes with a concrete weight coating are sunk costs and can only be sold for scraps or material value. For a project, always more pipes are purchased than strictly needed are ordered. This is done to cope with any scope changes and possible quarantined pipes due to damages to the pipes.

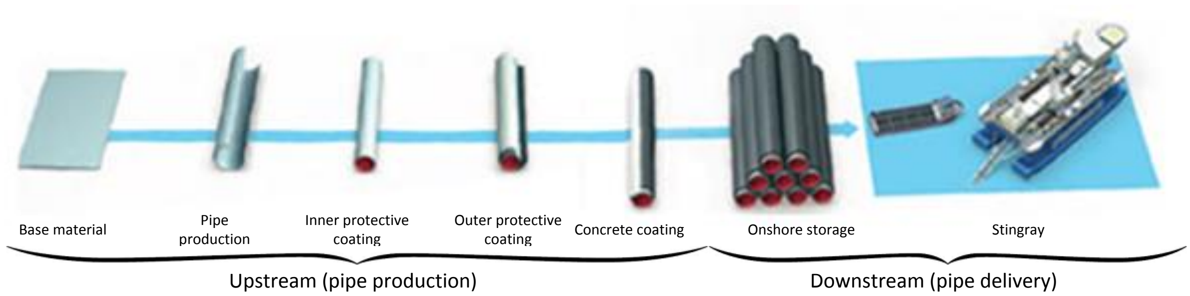

Figure 36 supply chain from plate steel till Stingray.

A possibility to increase the cash flow is to work. A framework contract could be used to deliver the pipe in batches. This has risks if the planning and storage capacity are strict. Projects can easily be delayed on the last moment due to weather or construction permits. Another risk is that the pipes will not clear customs in time to be processed properly. This risk depends on work's location and the country the work is done. This subsequently has consequences on the framework contract. The lead time of the delivery is often two months or more. Pipes can already be made by the manufacturer. This could give problems with the storage of pipes. It is advised to use a type of framework agreement on long projects that entails multiple months. Money can be saved on inventory space and cash flow by spreading the pipe delivery in batches during a project.

Another assumption is the distance of the onshore location of the pipe storage towards the offshore location of the Stingray. If the distance is too far, the risk on supplying on time the right pipes will increase. The lead time of the supply vessel needs to be adjusted to scheduling and forecasting of the production speed of the Stingray. The Stingray and supply vessel need to synchronize so that the Stingray is in a continuous production. This is not necessarily the fastest possible production speed, but the production speed that will meet schedule with the supply vessel. To improve the synchronization of the supply over long distances, an AIS monitoring system should be implemented in combination with a forecasting and scheduling.

It is assumed that the handling per pipe is done one by one. This assumption is valid for on the Stingray, but not for all the transfer connections. On some projects multiple pipes are transferred per transfer to save time. This depends on the cranes available and size of the pipes. Sequencing problems can occur if the transfers of pipes are done with multiple pipes. Odd pipes can be placed in the wrong categorized stack. This problem will mean that part of the pipe population stays mixed. The mixed population of pipes is less of an issue if the numbers of categories are low. Also no problems with multiple pipes per crane handling are expected if the pipes are one-time correctly sequenced on the right stack. Transferring multiple pipes then will not give further problems. The number of pipes used per transfer partly depends on the degree of separation from the population needed of the pipe e.g. special pipe with an anode on it.

The advised identification system for sequencing the supply chain is very basic. Color coding is enough to apply a right sequence for production process to the pipes. Other identification technology could also be used, but then in combination with another monitoring systems where the pipes are the main subject, e.g. quality control. The different departments need to monitor different processes.

7.2 Limitation on the thesis

The thesis is done with the resources, time, and data available. These are the limiting conditions for the thesis. The main limiting condition was the availability of empirical data and tacit knowledge on the subjects of operations of a pipe-lay project at Van Oord. This limitation was due to the number of projects done and recorded until now by Van Oord. The fact that Van Oord is setting up multiple new procedures for the supply chain made it that assumptions on procedures had to be made.

The amount of data available on the behavior of supply chain and the Stingray was limited. Not enough empirical data on supply chain related subject is available at Van Oord to evaluate the total supply chain. Due to the availability of empirical data, the model could only be validated on one reference case. The use of one reference case and the fact that each offshore project has a different supply chain set-up with multiple differences in the set variables, will make it difficult to assess the use of the model for upcoming projects of the Stingray. Another part of the limited available empirical data is that variables can be under- or overestimated on its influence on the supply chain. The estimations made on workability boundaries of the Stingray and supply barge were based on one data point and the help of an expert. The set-up of a standardized assessment of the workability of the vessels is still under development. Workability of the vessels has a significant influence on the supply chain. Detailing the workability and acquiring more data can influence the outcome and have as result that workability boundaries will shift. The dependency on workability is still valid and can be used as reference for further research on this subject. More empirical data will be available when more projects will be done over time. The relationship between workability and supply will be better known.

All projects are one-off project with separate contracts. This means that the input together with the output criteria can change per project. If the project is a lump sum project, the goal of the contractor will be most likely to reduce cost by reducing production time. A contract agreement wherein the client agrees to reimburse the cost of all labor and materials plus profit will determine other output parameters. The goal of the project is then on quality. Reducing quarantined pipe is less important than rightly sequencing the pipes. That together with every project being one-off will make that the simulation model needs to be adjusted for every project to assess the applicability to the project.

The main limitation on the thesis was the available data and tacit knowledge. Different new available data could have been incorporated in the model. This will not be done due to the limitation of time in the thesis. The limitation of the model is that it is only validated on one available reference case. Another point of the model is the set-up of every offshore project being different with a different supply chain and supply chain goals. This makes the model less generic and therefore limited to the outcomes of the reference case. The predictability of the model for other future cases is difficult to assess.

8 Conclusion, Recommendations, Guidelines

8.1 Introduction

The conclusion will be build up as follows. First the sub-questions are answered. After the answers on the sub-questions, the main question is answered. In the discussion following the conclusion the limitations on the thesis, the relevance of the thesis, and possible future research are discussed. The chapter ends with a personal reflection on the thesis.

8.2 Conclusion

8.2.1 Answers to sub-research questions

8.2.1.1 *What are the different characteristics and requirements of the available <u>automated monitoring systems</u> that can be used for a logistic system?*

A short overview of the different automatic identification technology systems are given in Table 19. The technology need to be proficient in the following environments an onshore or offshore location, and during transferring of pipes or during pipe storage. The onshore and offshore location has influence on the accessibility of the information. On an offshore location the space, movement, equipment, and time constraints are limited in comparison with the onshore location. Working on solid ground is safer than working on water. This will result that an offshore system should be robust, and relatively simple in use. Offshore can have a harsh environment that includes higher safety standards for personal, so the equipment used for the identification should be controllable or usable with protective clothing, and resist the harsh environments e.g. the equipment should resist water and be controllable with gloves on. Onshore has a relative lower demand on the equipment. From the advantages and disadvantage on the automatic identification technology and the needs from the inventory management system the RFID and barcode technology can be seen as best suited individual technology. This is based on the maturity of the technology, the usability, and robustness of the technologies. The differences between barcode and RFID are the ease of reading one or multiple tags, costs per technology, and robustness of the system.

Table 18 identification environments requirements.

	Transfer pipe	Storage pipe
Onshore	Quick, Clear system, direct influence on sequence pipe	Accessibility, non-changeable of sequence pipe
Offshore	Quick, Clear, Simple system, Few Handlings, direct influence on sequence pipe	Accessibility, non-changeable of sequence pipe

Table 19 overview of identification technology.

Auto-ID technology	Advantage	Disadvantage
AIS	Safe, and reliable system	High costs
Barcode	Widely used, Low prices, Standardized	Barcode must be in line of sight of the reader, One code at a time, human interaction, Compromised when damaged, One way communication
Biometrics	Secure system	High expensive, Only applicable for humans
OCR	Reads high density of information	Highly expensive, complicated infrastructure, needs line of sight
RFID	Tags are cheap, Standardized, Provides real time information flow, Data acquisition without human intervention, high storage capacity, multiple tags can be read at once,	Security issues, costs, readability problems with metals and liquids
Smart Cards	Secure system, High storage capability	Human intervention, the information is decoded,

8.2.1.2 How is the current supply chain of line pipe structured?

Describing the structure of the supply chain depends on the role of the contractor in the total project. If the contractor is responsible for the total procurement process of the line pipe or uses a subcontractor for this. The client can choose from which moment the contractor will have the responsibility of the pipe line. From that moment the supply chain is also the responsibility of the contractor. The structure of the supply chain is divided in the production of the line pipe, and the installation of the line pipe with. The choice is made, because the curing that is part of the concrete weight coating process takes average 28 days. The expected total production cycle will be at least 40 days plus transport to location. The expected production project of the Stingray is now estimated on a month. This makes a system that will be reactive changes onboard the Stingray impossible. Therefore the decoupling point is after finishing the concrete weight coating process. Parts of the supply chain are the transportation chain and quality control system (appendix B). This system connects all the production processes and installation processes.

The production of the line pipe is done in different sequential production processes. The main production processes are the steel pipe production, protective inner coating, protective outer coating, and concrete weight coating (Appendix B, Figure 37). The second part is the installation or connecting the line pipe at the Stingray to make a pipeline.

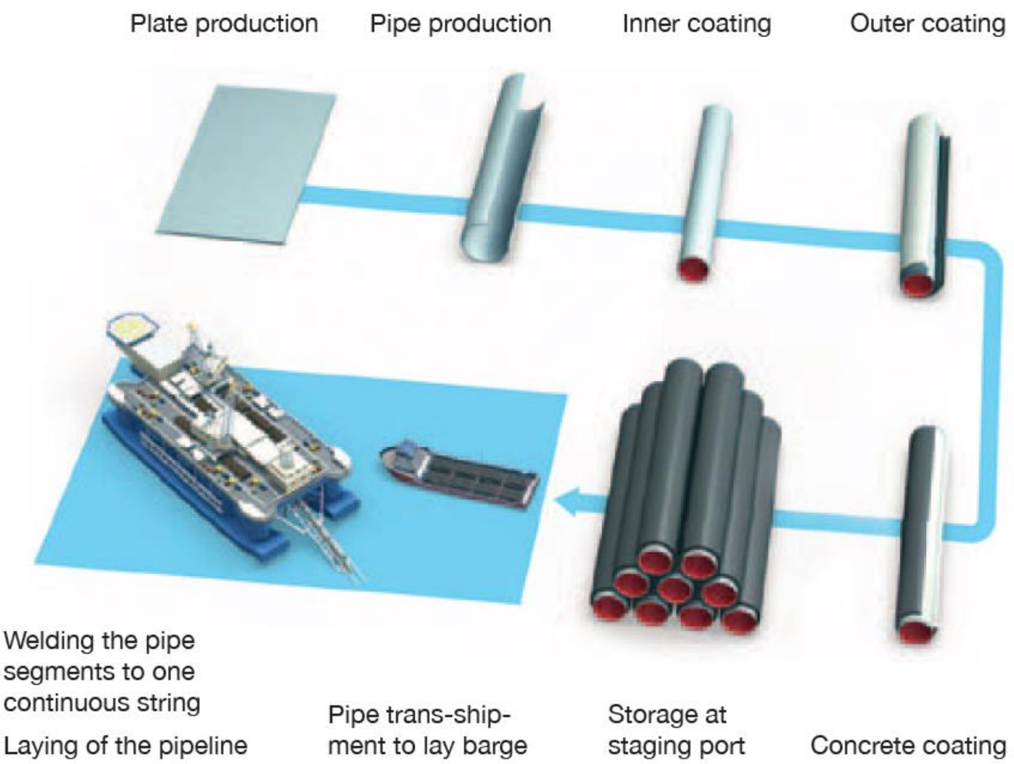

Figure 37 processes in the transportation chain of the line pipe (Nord Stream, 2010).

The transportation chain connects processes in the cycle shown in Figure 37, from pipe production, inner coating, outer coating, concrete coating, and lay barge. Between al the processes some kind of storage, transfer, or transportation takes place. The transport chain of the line pipe includes all the transport and storage, handlings in the procurement of the line pipe till the delivery at the Stingray. The transport between the production mills and the Stingray can vary much due to location of the mills, availability of production slots, and current transport costs. Weight coating is often done more close to the final location due to extra costs on transportation due to the added weight, and increased size. The final part from the Staging port until the Stingray is done by a small vessel or barge.

The installation of the line pipe is structured from the delivery of the line pipe at the onshore storage location until the installation of the pipeline at the Stingray. The Stingray can be the decoupling point in the supply chain, but only when the workability boundaries of the pipe transfer from barge to Stingray is signification lower than that of the Stingray. The thesis focusses in the supply chain from delivery at the staging port or onshore storage location until the delivery at the bead stall.

8.2.1.3 What are the key output parameters for the supply chain?

The output parameters are the performance indicators of the simulation. The new system is evaluated on the performance indicators to assess the different inventory systems. The output from the simulation is used to understand the consequences of the implementation of the supply system. The main output parameter is the productivity. The productivity should be increased. This can be done by reducing the production time loss.

The simulation model gives information on structure, and corresponding trade-off of the supply chain. The decoupling of the supply chain is therefore examined. The decoupling is evaluation on the production time loss dedicated to stock-out. This is the moment that the Stingray has not pipe onboard, and still has the ability to be in production (Table 20).

The simulation also shows the gains by the inventory management system by correct delivery at the Stingray at the production area. Correct delivery is evaluated by the rejected pipe at bead stall due to high-low, and the quarantined pipes at the bevel station. The benefit of the system is calculated by production time loss due to rejected and quarantined pipes. The average time per pipe is calculated.

Table 20 Output parameters model.

Output parameter model	Unit
Productivity (lay-rate)	Km/Day
Loss of production	Hours
- **Rejected pipe**	Pipe
- **Production time loss per rejected pipe**	Hours/Pipe
- **Quarantined pipe**	Pipe
- **Production time loss per quarantined pipe**	Hours/Pipe
Decoupling	Hours

8.2.1.4 What are the key input parameters for supply chain to increase productivity, and workability of the Stingray?

From the sensitivity analysis of the simulation model the key input parameters that influence the productivity, and workability of the supply chain were determined. These input parameters were further examined in chapter 5. From this analysis the following key input variables were determined.

The key input variables for workability are storage capacity Stingray, difference in workability boundaries of the supply barge, and weather conditions. The supply chain limitations are the weather conditions, and workability boundaries of the supply barge. The chance of a decoupling can be reduced by increasing the storage capacity on-board the Stingray.

The key input variables for productivity are firstly the pipe properties distribution spread. The pipe distribution spread is limited by the DNV standards that the contractor works by. The relation is between this is that increasing the spread more pipes will be rejected at the bead stall so productivity will decrease. Secondly, the inventory management system in combination with a type of pipe spread can lead to increase of pipe handlings so that the productivity is decreased.

8.2.2 Answering main question

The main research question is.

How does a logistical system need to be structured and implemented in the line pipe supply chain to improve the productivity and the workability of a pipe-laying vessel?

8.2.3 Social and scientific relevance

The social relevance of the thesis is from doing the graduation at a company, and answering a relevant question for the company. With this research Van Oord will have more knowledge on their line pipe supply chain.

The scientific relevance of the thesis is based on the on the set-up of the model. Literature shows many papers on supply chains modeling with discrete and continuous simulation tools (Angerhofer & Angelides, 2000). The difference with current literature is that the supply chain is often researched on inventory levels, in-process inventories, and not on improving the delivery by sequences of products (Petrovic, 2001). There are papers on the automotive industry that focus on sequencing delivery of different products to increase differentiation in output product e.g. different features per car. The models often analyses circumstances as bullwhip or reduction of transport times. The demand of the supply chain is taken as the most dynamic input not the properties of the delivered product.

8.2.4 Next future research

From the discussion, conclusion, and the limitations on the thesis some future research is recommended. These research subjects are divided into the supply chain structure, production processes, inventory system, and identification technology.

Not all causalities of the pipe properties on the production process on the Stingray are illustrated. A key causality is the high-low criteria and weld connection. Research should be done on the use of stricter high-low criteria's will improve the production process on repairs or cut-outs.

Future research should be done on pipe supply of large scale projects. If projects are planned to take longer than 4 months a frame contract can be advisable for acquiring the line pipe. Money can be made by buffering before the weight coating. Pipes before the weight coating are more easily to re-sell. Example concrete coating plants are constructed for the Nord Stream project done by SAIPEM (Nord Stream, 2010).

8.3 Recommendations and Guidelines to Van Oord

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8.4 Reflection

In this paragraph I will reflect on the months of doing my master thesis. The months of my master thesis went faster than anticipated, and this thesis took therefore also more months than I expected. I experienced this fast pace positively and negatively. The mixed feelings come from the nice part of researching all aspects to understand a subject and the negative part of continuously thinking of the thesis. I thought I learned from my preceding graduated friends, and would not fall as hard in some known graduation traps, as they have done before me. This became partly true during my thesis. To I will reflect on the different aspects of the process of completing my master thesis.

8.4.1 Planning and execution

My planning was better than the execution of that plan. I started with a tight planning. I had the advice to plan regular meetings with my supervisor and to keep pace in writing the thesis. The kick-off document was well prepared and I already was able to do some preparing work for my thesis. From then on the delay piled up. The delay had some causes. I had trouble with determine the scope of the thesis and I subconsciously waited a period to get some data from a project that was postponed.

8.4.2 Determine the scope of the research

Although the subject was set by the company (Van Oord), the final focus of my thesis still needed to be determined. Van Oord was interested in possibilities of a tracking system on line pipe for supply chain purposes. I know this was a broad subject, and I anticipated that I could narrow the subject with the data that would come or during some research on the subject. The data on supply was in the beginning for me not enough to set a clear scope, and the starting research was not conclusive on scoping. At the start of my thesis I took a lot of time of investigating different subjects concerning the supply chain and the procurement of the line pipe. The relative importance of every subject was difficult for me to assess, because not much literature and experience was for me available to assess the importance of every subject related to the supply chain. I learned that a lot of knowledge within the offshore industry is based on experience of the personal. Due to the few projects van Oord has done, there was not a lot of data or experience to rely on. The planning was that the data would follow from a project that would be executed a few months after I started my thesis. This project was delayed due to the client of Van Oord.

8.4.3 Gathering information, literature review, modelling

Besides the use of the facilities of the TU Delft, Van Oord helped me with by providing/ disclosing their data to me. The problem was that the information on this subject was limited by the number of projects Van Oord had done, and the limited data they had collected during that period.

More data was available on problem areas when a project of Van Oord was executed, and I could start with validating my simulation model. The new data flow resulted in a new challenge. Input variables changed rapidly due to new insights. I tried to keep my model up to date and included the new insights. In the offshore industry problems are often resolved on the spot. These interventions in the production process are good for production, but are difficult when set in strict processes. Furthermore every offshore project is a project on its own. The Offshore surroundings are difficult to standardize. Sea state, pipe properties, logistic routes and available equipment change per project.

8.4.4 Guidance

I experienced the guidance of my supervisors as help- and insightful throughout the whole thesis process of writing the thesis. My supervisor at Van Oord helped me with getting accustomed to Van Oord, and to gain access to the information that I needed from the different sources within Van Oord. I felt part of the organization. My supervisor from the university really helped with finishing the thesis. He put me right on track when I was wavering.

8.4.5 Graduating at a Company

I started my thesis at a Van Oord with the idea to get the feeling with a company and experience the offshore industry. The thesis period has been a valuable experience and I can recommend every student to get in contact with a company of their interest during their study period. The experience working in a company and being part of company gives notion on the value of the study subjects, skills, and knowledge gathered during your study. Also getting in contact with companies of your interest helps with formulating your future. Enjoyed my graduation time at a company and I can recommend every student to graduate at a company.

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