Master's degree thesis

LOG950 Logistics

Error and variation order handling in shipbuilding - case study VARD

Asbjørn Tøssebro

Number of pages including this page: 90

Molde, 27.05.2013

Molde University College

Mandatory statement

Each student is responsible for complying with rules and regulations that relate to examinations and to academic work in general. The purpose of the mandatory statement is to make students aware of their responsibility and the consequences of cheating. Failure to complete the statement does not excuse students from their responsibility.

Please complete the mandatory statement by placing a mark ***in each box*** *for statements 1-6 below.*		
1.	**I/we herby declare that my/our paper/assignment is my/our own work, and that I/we have not used other sources or received other help than is mentioned in the paper/assignment.**	☒
2.	**I/we herby declare that this paper** 1. Has not been used in any other exam at another department/university/university college 2. Is not referring to the work of others without acknowledgement 3. Is not referring to my/our previous work without acknowledgement 4. Has acknowledged all sources of literature in the text and in the list of references 5. Is not a copy, duplicate or transcript of other work	Mark each box: 1. ☒ 2. ☒ 3. ☒ 4. ☒ 5. ☒
3.	I am/we are aware **that any breach of the above will be considered as cheating, and may result in annulment of the examinaion and exclusion from all universities and university colleges in Norway for up to one year, according to the Act relating to Norwegian Universities and University Colleges, section 4-7 and 4-8 and Examination regulations** section 14 and 15.	☒
4.	**I am/we are aware that all papers/assignments may be checked for plagiarism by a software assisted plagiarism check**	☒
5.	**I am/we are aware that Molde University college will handle all cases of suspected cheating according to prevailing guidelines.**	☒
6.	**I/we are aware of the University College`s rules and regulation for using sources**	☒

Publication agreement

ECTS credits:

Supervisor:

Agreement on electronic publication of master thesis

Author(s) have copyright to the thesis, including the exclusive right to publish the document (The Copyright Act §2).
All theses fulfilling the requirements will be registered and published in Brage HiM, with the approval of the author(s).
Theses with a confidentiality agreement will not be published.

I/we hereby give Molde University College the right to, free of charge, make the thesis available for electronic publication: ☒**yes** ☐**no**

Is there an agreement of confidentiality? ☒**Yes** ☐**no**
(A supplementary confidentiality agreement must be filled in)
- If yes: **Can the thesis be online published when the period of confidentiality is expired?** ☒**Yes** ☐**no**

Date: 27.05.2013

Høgskolen i Molde

SUPPLEMENTARY AGREEMENT/CONFIDENTIALITY AGREEMENT

(Supplement to Point 5 of the Standard Agreement)

This agreement is between

Asbjørn Tønnebro ....(Student(s)),

Hajnalka Vaagen .... (Faculty Advisor at Molde University College),

.... (Company/Institution),

and Molde University College/MSc logistics Program Coordinator. This is a supplement to the Standard Agreement, which defines the use of specifications and results reported in a Master's degree thesis in accordance with the study plan for the Master's degree program in Logistics at Molde University College.

1. As stated in Point 5 of the Standard Agreement the parties named above agree to limit access to the Master's degree thesis for .5. Year(s) from the date of this agreement. The limit should be 1 to 5 years, for longer confidentiality periods, contact the program coordinator for a special agreement.

2. The reason for keeping the thesis results confidential is so that the company/institution can avoid giving away information that would give others a competitive advantage.

3. The thesis must be submitted to Molde University College. It will be kept in a secure room in the main archive at the College during the period agreed upon. The thesis can be borrowed during this period if a written request is submitted and the company/institution gives permission. Academic staff members can access the thesis after signing a declaration of secrecy. After the period of confidentiality is ended the thesis will be placed in the library for general use.

4. Four copies of this agreement must be signed so that each party will have a copy. The agreement is valid when it has been approved and signed by the program coordinator or Dean at Molde University College.

5. The confidentiality agreement does not exclude members of the academic staff from being present at the final oral presentation of the thesis.

Place...Molde.................. Date of last signature..................................

Student(s) Faculty Advisor

Company/Institution

Agreement approved by:

Program Coordinator/Dean

Abstract

In Norwegian offshore shipbuilding, industrial actors offer the possibility to customers to delay specifying outfitting details into the production. This provides competitive advantage to the shipbuilders. On the other side, late changes potentially disturb the production processes and increase the costs considerably, unless the conditions to handle unexpected changes are created. This thesis addresses the subject of variation order handling in the offshore shipbuilding industry. Theories from Decision Making under Uncertainty, Lean, Product Variety, and Communication and Information Sharing are applied to answer the research questions. Findings from a rather comprehensive case study has been highlighted and analysed, and potential solutions to handle variation orders are discussed.

Contents

1 Introduction

The offshore shipbuilding industry contributes substantially to the Norwegian economy and maritime industry. Norwegian shipbuilders' competitive advantage is the high technical complexity of the vessels, high quality and the ability to deliver the vessels with short lead, compared to the competitors. In addition, Norwegian shipbuilders offer the possibility to postpone outfitting detail specifications until a late point in time, into the production.

The industry works in a volatile market when it comes to both number of vessels built and what technology these vessels should contain. This means that demand can change quickly, and the shipbuilder must be able to adapt when required, since changes may occur during an on-going project. Shipbuilders that can demonstrate the ability to adapt late changes, are those that will survive in a global and competitive market characterized, with an increasing share of Chinese and Korean produced vessels. One major advantage of the Norwegian shipbuilders is their closeness to the market in the North Sea. Closeness to the customer drives technological innovation, but also demand volatility in technological solutions from the customers. This makes it difficult to build standardized ships on the assembly line, since there often are changes from vessel to vessel. Such considerable presence of changes, gives shipbuilders opportunities for profit driven variation orders (as customers value the possibility to postpone outfitting details specifications), but at the same time there is a risk for cost driven error orders. This thesis tries to find ways to handle these change orders the volatile market conditions highlight, by considering both to the possible profits of customer required variation orders, and ways to handle and avoid error orders. Especially the error driven orders hold a great cost for the industry, and a solution could free up substantial resources.

The thesis has been built up with a theoretical approach in Section 2, to emphasize the issues involved in the Error and Variation Orders, and why they occur. In Section 3 the chosen research methodology is described, together with the data collection methods that have been used. The literature review is given in Section 4, containing Lean theory, Product Variety and Platform Planning, Decision Making under Uncertainty, and Communication and Information Sharing. The case company VARD is introduced in Section 5. The case study, with detailed description on the data collection process and findings from this are presented by Section 6. The findings are analysed and discussed in Section 7, with a conclusion in Section 8. A suggestion on further research has been highlighted by Section 9.

2 Theoretical Approach

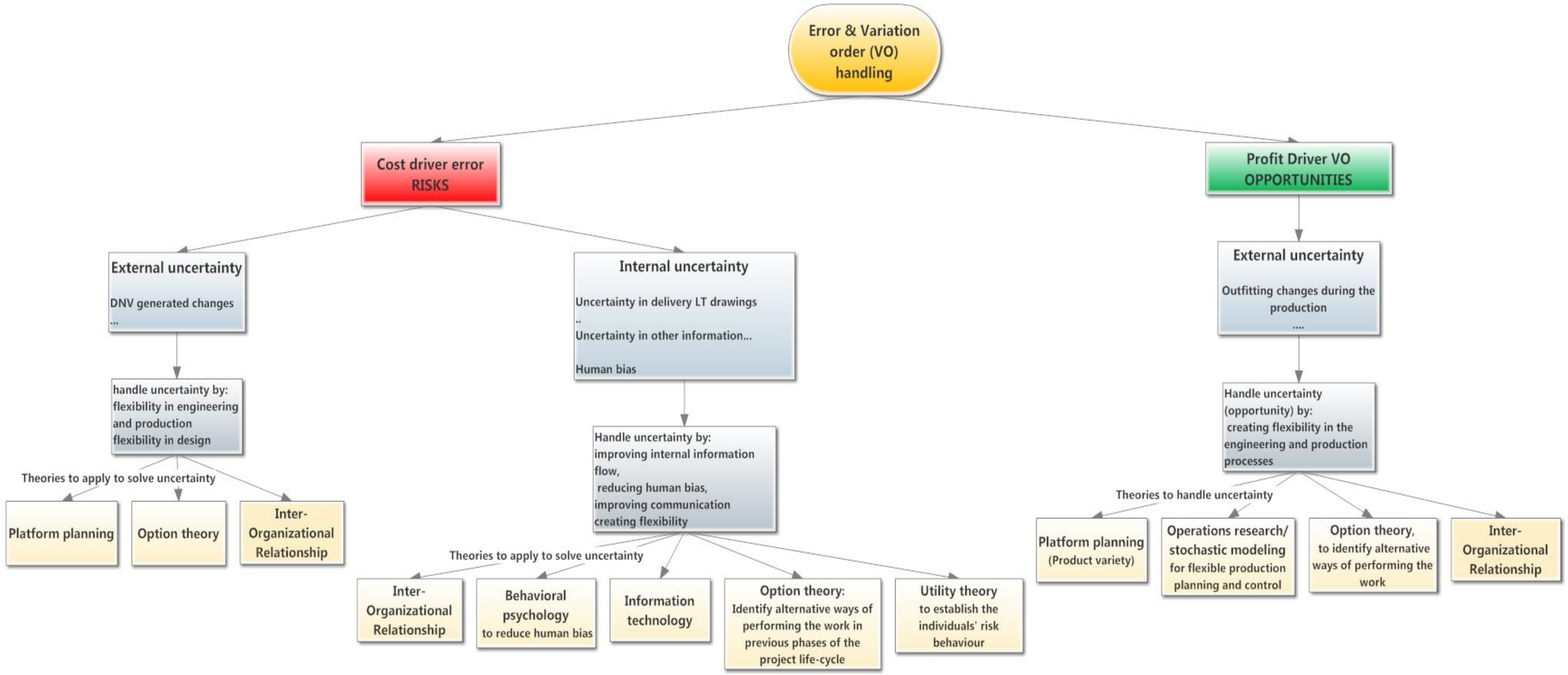


Figure 1: Theoretical Approach

In the Theoretical approach the different theories and literature needed to answer the research question, are presented in an illustrative way. The different theories are discussed in more detail in the Literature Review chapter, and linked up to the Theoretical Approach.

As **shown by figure 1**, the research question is how to handle Error and Variation Orders. Error and Variation Orders are categorized by whether they are cost or profit drivers; internal errors and changes driven by DNV are cost drivers, while variation orders generated by the customer are profit drivers.

Variation orders occur because the customers do not specify all outfitting details under the contracting; meaning that there is uncertainty to deal with. Note that the customer is paying the requested changes; this uncertainty is therefore an opportunity, and it is to be handled differently from the cost driver errors. Since this is an external uncertainty, it cannot be eliminated, but it can be handled by creating flexibility in design, engineering and production processes to handle the unforeseen changes without disturbing the production considerably. The theories to be applied to handle this uncertainty are; **Platform Planning**, creation of flexibility through standardization of the product platforms that are perceived by the customer as more-or-less common across several ships (Product Variety Theory); **Option Theory**, to identify alternative ways of performing the work (Decision-making under Uncertainty). Note that Flexible design is one particular option to handle uncertainty in outfitting details; **Inter Organizational Relationships**, to improve communication, **Operation Research**, stochastic modelling for flexible production planning and control (which will be suggested as Further Research).

Cost driver errors, risks, can be both internal and external uncertainties. For an example, such Internal Uncertainty can be the uncertainty of late delivery of drawings to the production, distorted information, organizational relations failing, Human Bias, and more. One can handle the internal uncertainty by improving Internal Information flow, reducing Human Bias, improving Communication, and more, and by the creation of flexibility. The theories to apply to solve the internal uncertainty here can be; **Utility Theory** (Decision-making under Uncertainty), **Option Theory** (Decision-making under Uncertainty), **Information Technology**, **Behavioural Psychology**, **Inter-Organizational Relationships**, and more.

The cost driver External Uncertainties are risk factors that you cannot control; meaning that one is not able to eliminate the risk of an error order to occur. Such factors can be DNV (Det Norske Veritas) generated changes, missing technical data, lack of communication due to mis-functional Inter Organizational Relationships, low functional data-bases, and more. Such factors must be handled through the creation of flexibility to minimize the risk of Error Orders to occur. This can be done by e.g. the creation of flexibility in engineering and production flexibility in design. Theories to apply to solve this uncertainty can be; **Platform Planning** (Product Variety), **Option Theories** (Decision-making under Uncertainty), **Inter Organizational Relationships.**

The context of error and variation order handling is **Lean theory**, given that VARD (attempts to) implements Lean in the organisation, and strives for continuous improvements, by Kaizen for example , (which means continuous improvement and is central in Lean philosophy).

3 Research Methodology, Data Collection Methods and Findings

After defining the theoretical approach in the previous section, the methodological approach and data collection methods are introduced below. To ensure a good understanding of the decision problem at hand and for a good quality analysis, the Research Design is crucial the methodological approach is described below by the Research Design and Data Collection Methods.

3.1 Research Methodology

There are several definitions of Research Design; Yin (2009) defines it as *A logical plan for getting from here to there, where here may be designed as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions (Yin 2009).*

One major purpose of defining the research design properly is to prevent collecting data that do not address the research question. Furthermore, to be able to obtain the desired quality, Yin (2009) describes five necessary components to be explored by the research design:

1. Study Question, which explains the type of research the paper applies

2. Study Proposition or Objectives, highlights some of the theoretical issues, and finds evidence for those
3. Unit of analysis, is where the subjects of the case are defined

4. Link data to proposition and criteria for interpreting the findings, which contains tools and techniques for data-analysis
5. Criteria for interpreting a study's findings, is e.g. where you explain your findings and discuss different explanations of your findings

The methodological approach chosen in this thesis is multiple case-study design, to discover drivers of error and variation orders in shipbuilding, and analyse how these drivers can be reduced in the organisation. The research methodology applied requires gathering of relevant data from documents, reports, accounting data, and more, from the shipbuilding organisation VARD. These are described below.

The Case Study is a research method that focuses on understanding the dynamics of single settings. Although it can be used for description and deduction (Yin, 1994), our focus is on inductive theory development, an application for which the method is particularly well suited. In comparison with aggregated, statistical research, the primary advantage of case study research is its deeper understanding of specific instances of a phenomenon. Multiple case study is a variant that includes two or more observations of the same phenomenon. This variant enables Replication that is, using multiple cases to independently confirm emerging Constructs and propositions. It also enables extension that is, using the cases to reveal complementary aspects of the phenomenon. The result is more robust, generalizable.

3.2 Multiple case study design

A case-study is a way to define a research method that focuses on exploring and understanding the problem at hand in single real-life contexts. Yin (2009) defines Case Study as: *An empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin 2009).* Single case studies can be used for description and deduction (Yin, 1004), and the primary advantage is the deeper understanding of specific phenomena. Single case studies, however, cannot provide understanding whether the phenomena are replicated, and findings cannot be generalised. Multiple case studies are a variant of case-study, analysing the chosen phenomena in two or more cases. Multiple case studies enable replication, and provide deeper understanding on different aspects connected to the chosen phenomena. The results of multiple case studies are more generalizable.

There are several methods and tools to conduct a case study, where you e.g. want to gather data from numerous units by direct observations in a normal and single situation. One must avoid data that can be tampered, as it can affect the result of the collected data. There are both quantitative and qualitative methods in the case study that can be used, and both qualitative and quantitative data collection is needed to be utilized. That said, the qualitative aspect will be the epistemological emphasis of the thesis, to identify core elements of handling Error & Variation Orders. It is also important assure the accumulation of multiple entities as supporting sources of evidence, to ensure that data collected are truthful and precise (Meredith 1998). Hence all data gathered are crosschecked to ensure truthful and correct data material for the case study.

3.3 Data Collection Methods

Data collection itself was carried out at the two shipyards, VARD Brattvaag and Søviknes, and consisted of analysis, observations, interview-/conversations, accounting data, project accountings, etc.. Conversations and observations is called Primary data sources, while accounting data and the like are Secondary data sources (Hox and Boeije 2005). Primary data can be defined as *Data collected for the specific research problem at hand, using procedures that fit the research problem best*, while Secondary data is defined as *Data originally collected for a different purpose and reused for another research question* (Hox and Boeije 2005). Primary and Secondary data are divided into two different categories, namely Qualitative and Quantitative data (Hox and Boeije 2005).

	Solicited	Spontaneous
Quantitative	◦ Experiment ◦ Interview Survey ◦ Mail Survey ◦ Structure diary ◦ Web Survey	◦ (Passive) Observation ◦ Monitoring ◦ Admin. Records (e.g. statistical records, databases, etc.)
Qualitative	◦ Open Interview ◦ Focus Group ◦ Unstructured Diary	◦ (Participating) Obsevations ◦ Existing Records (e.g. ego-documents, images, etc.)

Figure 2: Different techniques of Primary data (Hox and Boeije 2005)

It comes with a higher cost to collect primary data than secondary data, but primary data gives better results (Gratton and Jones 2010). In this thesis two primary data collection methods are used: interviews-/ conversations and observations. When it comes to secondary data sources, accounting data, project accountings, engineering internal data-bases, and more, has been used.

Data collected by informal conversations within the organisation is categorised under "Other Data-Gathering Methods"; one of four data collection methods for qualitative research in Thomas, Nelson et al. (2011): Interviews, Observations, Focus Groups, and Other. During one's research at the shipyards, there was another project conducting data-collection; the NextShip Project on Robust planning in shipbuilding. There were two researchers from the project holding interviews with different employees at the site, where questions were answered after the best standards of primary data collection. However, it is one's opinion that a plain interview situation has the drawback of an artificial situation, where the interview- obligation towards their employer might prevent them to give exact and fully credible answers. Furthermore, it is one's opinion that using more informal data-gathering methods ("Other Data-Gathering Methods", Thomas et al. (2011)) strengthens the information quality.

> *Among the many sources of data in qualitative research are self-reports of knowledge and attitude. The researcher can also develop scenarios, in the form of descriptions of situations or actual pictures that are acted out for participants to observe. The participant then gives her or his interpretation of what is going on in the scenario. The participant's responses provide her or his perceptions, interpretations, and awareness of the total situation and of the interplay of the actors in the scenario.*
>
> *Other recording devices include notebooks, narrative field logs, and diaries, in which researchers record their reactions, concerns, and speculations. Printed materials such as course syllabi, team rosters, evaluation reports, participant notes, and photographs of the setting and situations are examples of document data used in qualitative research (Thomas, Nelson et al. 2011).*

Concretely, the data-gathering for this thesis was conducted through recording devices, reports, diaries, other written material, conversations with key-personnel at the yards, and more.

There are several things that can cause problems in obtaining secondary data. The *first* problem is that it can be difficult to get useable data for the research. Secondly, the researcher must be able to collect the needed data. The *third* aspect relates to evaluating the quality of collected data (Hox and Boeije 2005). The mentioned data collection methods are used to answer the research questions of this mater thesis.

3.4 Objectives

The objectives of this thesis through case-studies, was to highlight the impact Error and Variation Orders have on on-going projects in the shipbuilding industry. The "impact" in this context is analysed from an economical point of view, and from LEAN theoretical point of view. Recall that the implementation of LEAN principles is an objective in the VARD organisation. .

Two research questions were drawn up:

1. What is the impact of Error and Variation Orders on Lead Time and costs, and how can these be handled without extending the Lead Time?
2. What are the main causes that Error and Variation Orders occur?

3.5 Quality of the research

To evaluate the research quality, the information reliability and validity is to be ensured through the applied methods. Validity and Reliability relates to how well different phenomena are measured (Gripsrud, Olsson et al. 2004).

The use of Multiple Sources of evidence contributes to increasing the validity of the case study (Yin 2009). In this master thesis this has been emphasised as mentioned above, through; Observations, Interviews-/ Conversations, different documents and literature, Project Accountings and other Accounting data, and more, to increase the validity of the paper.

The "reliability" indicates whether the results gathered can be trusted, and if the measurements are done over again, if the result would have been the same (Gripsrud, Olsson et al. 2004). The Reliability minimizes the biases and errors in a study (Yin 2009). The higher the number of observations you have of gathered data, the more reliable the analysis will be.

4 Literature Review

4.1 The Lean Thinking

4.1.1. Introduction

The Lean Thinking and principle comes from Dr. Edward Deming's Plan-Do-Check-Act cycle (PDCA), which he taught Toyota in the years after World War II (ArtofLean 2013). Figure 20 is a graphical presentation of the PDCA cycle, with examples on what each step in the cycle means.

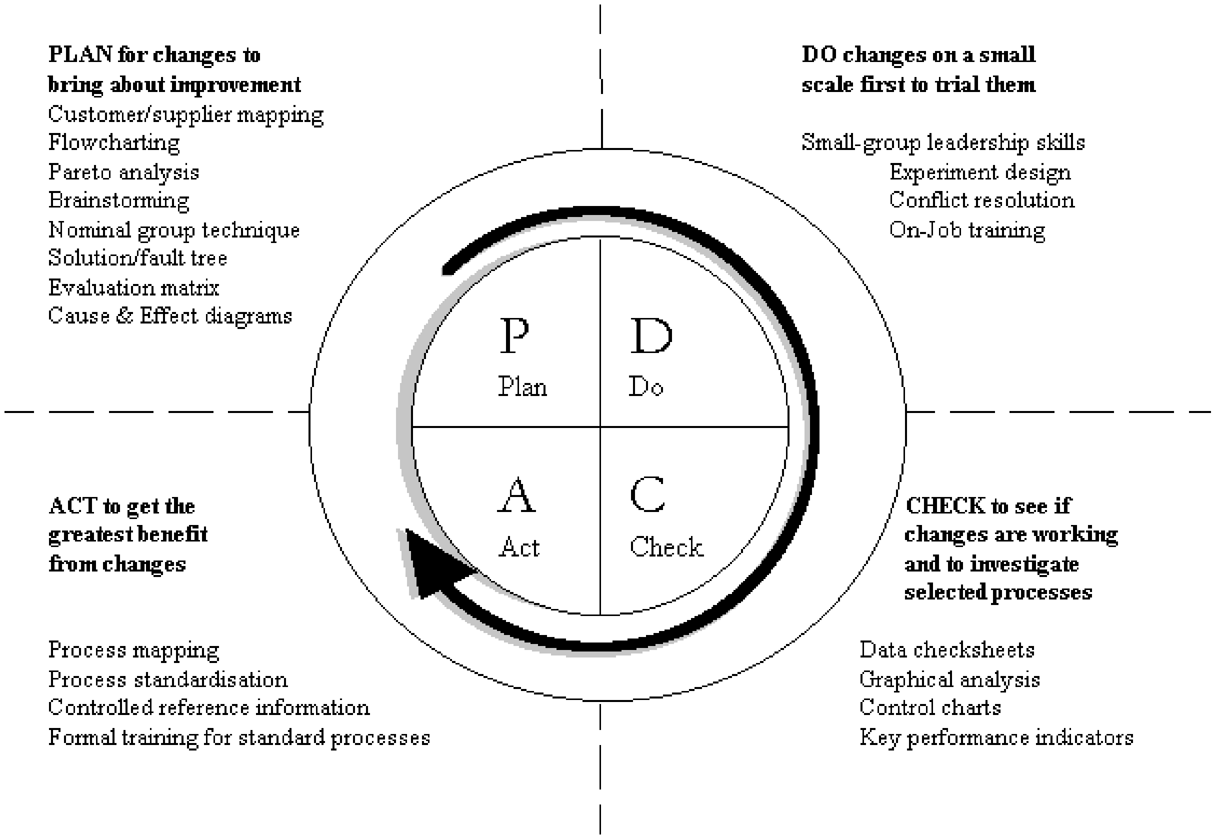


Figure 3 http://www.hci.com.au/hcisite3/toolkit/pdcacycl.htm

Every action in this cycle is to search for continuous improvements, and it goes through four different steps:

- **Plan** is about setting the objectives and processes according to the probable outcomes based on the facts
- **Do** is the implementation of the new processes
- **Check** is measurement of the result of these new processes and to compare this with the expectation to be able to find any deviations

- **Act** is to have countermeasures ready to eliminate or reduce deviations to be able to be as close the objective as possible. Here there is also a focus on changing standards (Best Practice) to avoid a fallback in the process after improvements.

Lean Production System has its origin in the Toyota Production System (TPS), where the thought of a system like this started when the Toyota Motor Company was founded in 1937 in Japan. TPS started to improve their production through the use of lean tools such as Kanban, Just-in-time (JIT), Kaizen (continuous improvements), and Takt Time (ArtofLean 2013). TPS is using the thinking of the PDCA in their continuous improvements.
Toyota implemented some techniques by using PDCA as a concept in their new plants. These because they wanted all operations to go in a Flow Production System in order to produce with as little waste as possible. Meaning that they strive to produce at all time the needed items in the necessary quantities. This is the precursor of Just-In-Time (JIT), which emphasizes to not overproduce or make things to early (ArtofLean 2013).

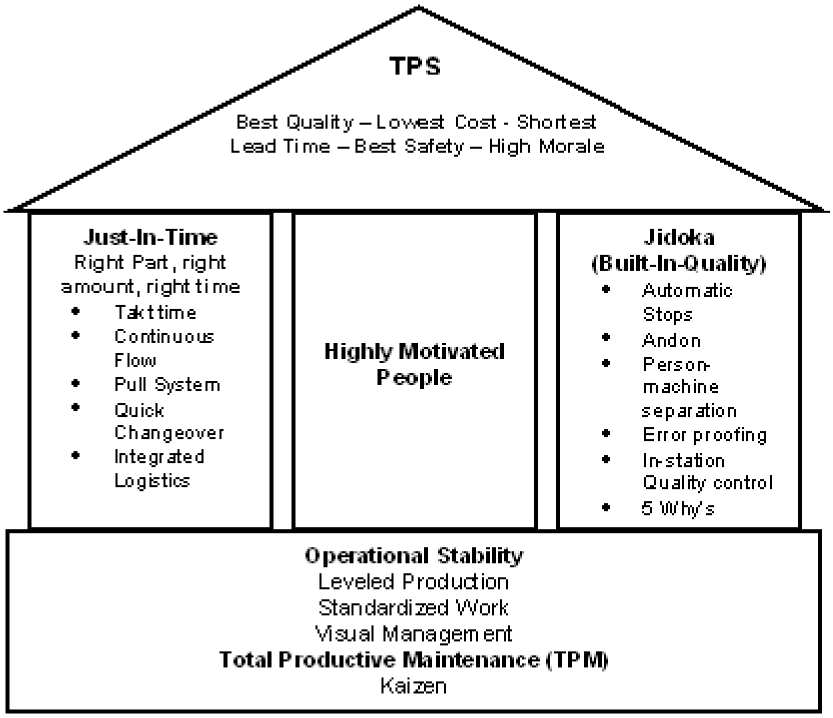


Figure 4 httpwww.emsstrategies.comdm050104article2.html

In figure 21 we can see that the TPS is based on two main pillars, namely JIT and Jidoka, where Jidoka is so called automation with a human touch, meaning that any abnormal situations in the production will stop the machine in the production and the product line will be stopped by a worker. This will help in not producing defect products, overproduction, and focus attention on problem solving to prevent stops to occur ones more (Toyota 2012).

As in all TPS philosophy it is important to have highly motivated and skilled workers to be able to implement and maintain the desired activity levels.

JIT refers to Flow, Takt-time, and Pull-system for production and inventory control. Jidoka focuses on Building-In-Quality, Person-machine separation, and more for effective work. This means automation with human intelligence. The Lean Thinking is about the knowledge on how and why different activities occur to be able to have simpler methods, eliminate waste, and highlight continuous improvements through better information sharing and decision-making at each level of the production. TPS have tree main operating goals, namely Achieve the highest possible quality, At lowest possible cost, and With the shortest possible Lead-time (ArtofLean 2013). It is important that the employee are involved in the Lean Thinking and especially when implementing such a system in a production. To be able to have a success in e.g. a Lean-transformation, it seems important to develop high commitment levels for the employees, experience a strong belief in Lean, and that they get exposed to good communications and cultivate improved work methodology. Involvement and influence is the keywords (Losonci, Demeter et al. 2011).

Above, the Lean Thinking origins are discussed by (1) the PDCA cycle of Deming and(2) the Toyota Production System, These systems gave rise to various Lean concepts, adapted to different industries. Lean Construction and Lean Planning is developed for construction projects, Lean Engineering applies lean concepts to the engineering processes, with focus on eliminating waste, improving Cycle Time Quality Also in the Supply Chain Management Lean has become an issue through Lean Logistics and we see it in the software industry where they uses Lean in software development. All these Lean Thinking as mentioned above has the common goal to meet customer’s value expectations for the right price in the right quality to the right time and at the right place. Lean Construction and Lean Planning is a Project Management approach for projects through their new way of designing, plan and build e.g. a Specialized Offshore Vessel by the use of some Lean techniques.

4.1.2 Planning and implementation

From early stages of this thesis work it was clear that engineering and planning activities represent major challenge with respect to Error and Variation Orders (VO). This section of the Literature review, therefore, highlights these two activities. .

Implementation of Lean principles in the shipbuilding industry allows for improvements in the planning and engineering activities. In this case we would be able to see improvements in the numbers of VO's, and reduced lead times in the project as a whole. This industry is complex due to the uniqueness of each project. Customer requirements changes from ship to ship, and level of complexity differs from the complexity faced in industries that produces more or less high quantities of homogenous products (Ballard 2000). This comes from the highly technological demand from constructing offshore and specialized vessels used in the offshore oil and gas exploration & production and oil services industries. The oil companies are oilfields at increasing depth, and therefore the demand for even better ships with even higher technological solutions are required. Due to the rapid development in the oil industry, almost every new vessel will have new specifications and customer requirements. This mentioned complexity makes the organization engaged in each project quite complex and relatively large. Participants span from customers, sales-staff, design, suppliers, subcontractors, and other involved in the execution of a product that satisfies the customers' needs. The actors in the shipbuilding supply chain may vary strongly from project to project, both in numbers and who these participants are. It is, therefore, crucial to have an overview of the main factors influencing the shipbuilding project; factors discussed above and illustrated by Figure 22.

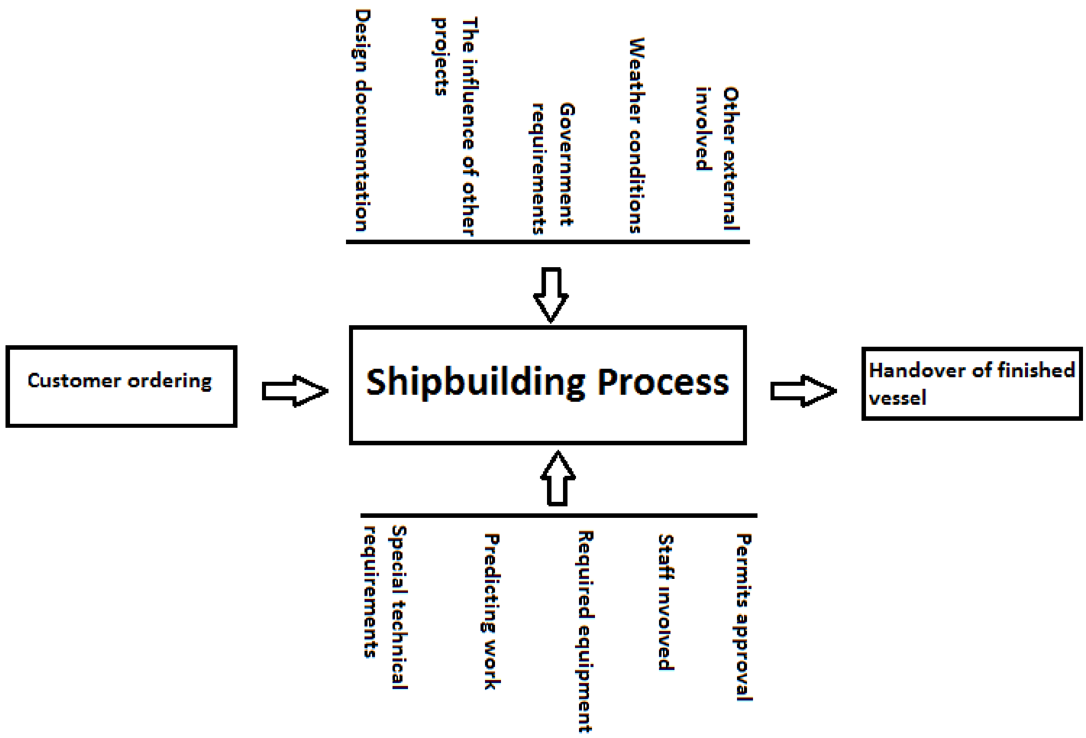


Figure 5 Factors influencing the shipbuilding processes

All activities involved are influenced by different factors that decide how these specific activities are conducted. In the engineering activities these factors are highlighted in figure 23 below.

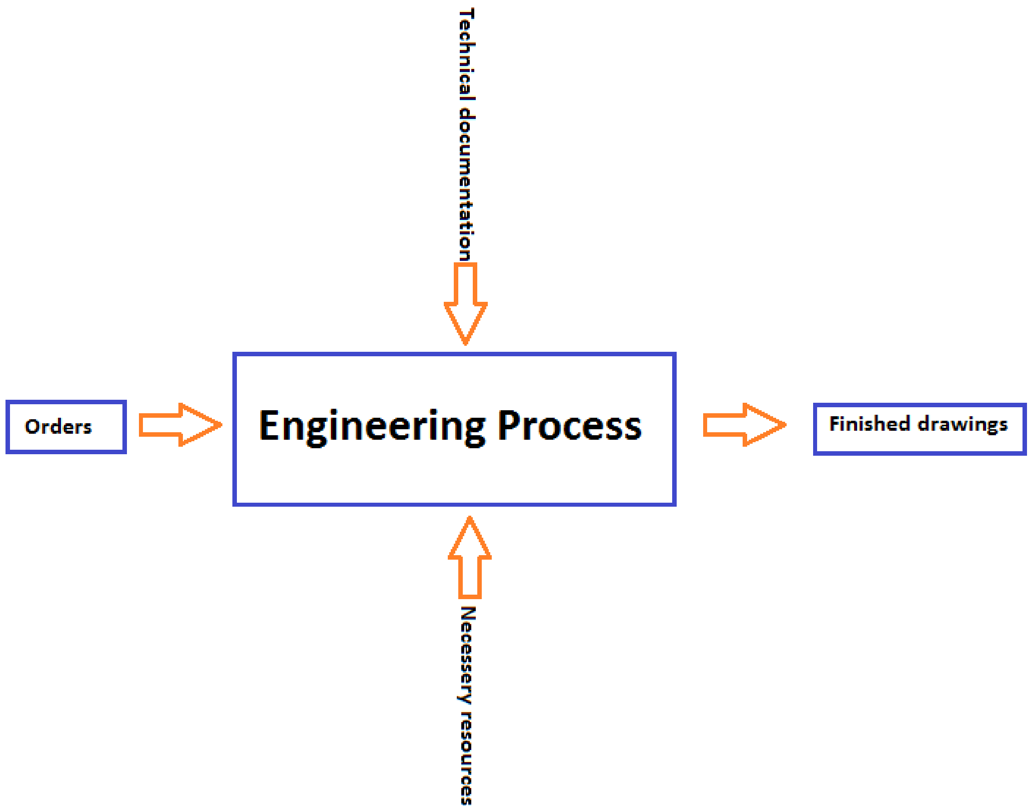


Figure 6 Factors influencing engineering activities

To ensure efficiency and high performance in the different processes, focus on planning activities and coordination is needed. If the focus is on individual task level and on maximizing the local performance, you will risk the overall performance. One needs relevant planning and coordination to ensure the release of work downstream, avoid the increase of duration in projects, less complicated coordination, and to prevent conflicts between parties in the project (Ballard 2000). This means that a project should be conducted in a way that emphasizes on the overall project efficiency, and not on sub-optimization. Here Lean Planning would be appropriate tool, and by implementing Lean principals in all planning, the accuracy and efficiency on project deliveries will improve.

The Table below is an overview of the Lean principles in planning, as summarized by Emblemsvåg (2012).

Table – A brief overview of relevant lean principles and their application in planning.

Lean Principle	Description	Relevance to planning
Total quality	The voice of the customer is to permeate everything we do.	Negligible relevance.
Teams	Problems are best solved by cross-functional teams	Planning is best performed when coordinated among all disciplines so the totality is understood.
Measurements	Problems are best solved scientifically and this requires measurements to establish facts	The calculation of PPC allows us to identify who is good at delivering as planned and who is not. Those that fail over time will be subject to treatment.
Work Balancing	To ensure the production system is balanced from step to step.	No application in planning, yet.
5S	System for order and discipline.	Partial application in planning by focusing on keeping promises, that is, being disciplined.
Pull system	The amount of work planned is based on actual needs and not prognosis.	The planning applies this partially by making sure that participants only work on what is necessary and/or possible.
Pokayoke	Mistake-proofing, that is, to prevent mistakes from having negative effects on the outcome.	The period plans serve as checking points to avoid previous mistakes in planning and execution from having negative effects in current execution.
Autonomation / *Jidoka*	Stopping the work when something does not work as intended	Negligible relevance for planning.
Elimination of waste	Waste is everything the customer does not want to pay for, and it should be eliminated.	Many implications for planning: 1. Starting work that cannot be completed is waste, and lean planning reduced this problem. 2. Unproductive meetings the lead to lack of commitment and poor decisions are also waste, which is reduced by lean planning by imposing structure and clear goals and follow-up.
Continuous flow	Wait for as long as possible to avoid inventory, then execute swiftly and continuously.	The check for sound activities prevent inventory built-up, the focus on these activities supports swift execution. This principle is therefore supported.
Standard work	Work is standardized (not products)	In lean planning the planning process is standardized.
Visual control	Make problems visible.	The follow-up process in lean planning makes problems more visual than otherwise.
Production leveling	To ensure the production system is not stretched beyond capabilities.	Lean planning is based on pull system and hence prevents over-stretch.
Kaizen	Continuous improvement.	Lean planning is based on the PDCA circle, which is the basic mechanism behind kaizen improvements.
Gemba	The actual place where work is performed – the factory floor.	In lean planning, planning is moved all the way to the front-line (work leaders) where work is performed. Hence, the term *last* planner.
Supplier development	A value chain is not stronger than its weakest point, and supplier development aims at improving the entire value chain.	Some application in planning by incorporating the most important subcontractors in the planning.

Table **(Emblemsvåg 2010)**

The table shows a brief overview of relevant Lean principles and their application in planning. Lean Planning is a methodology that uses the particular features in Lean Production, and put them in the context of, in this example, shipbuilding. Glenn Ballard (2000) divides this planning into four different levels:

1. Milestone Plans, that uses the reference point of different milestones made for periods of 12-18 months, which shows the completion of different work packages and-/ or larger phases of the project.
2. Discipline Plans, where more detailed information are highlighted than in the Milestone Plans, planning period of 6-9 month
3. Period Plans, where details of the Discipline Plans is set into sound activities, deviations reports back to the Discipline Plan, Planning period of 5-8 weeks
4. Weekly Plans, which contains executable sound activities, reports deviations back to Period Plans, and 1-2 weeks planning period

We will find the Master Plan in the Milestone and Discipline Plans, where the Master Plan contains several important issues like e.g. formulations on how the long-term contracts should be handled (payments, deliveries, etc.), project resources coordination throughout the project period, and more. But since there is difficult to be in the possession of detailed information on events to come 6-18 month in advance in the project, it will be hopeless to describe activities in detail. The Period and Week Plans will inform all staff involved like Project Managers, Coordinators, Work Leaders, and more, what should be happening in the project the next 1-8 weeks(Ballard 2000). The Period and Weekly plans gives the opportunity to plan for required tasks and take action in good time before execution. If there is a deviation in the plans, this must be reported to the nearest plan-step above so that this can be taken into consideration in the further planning. Ti is also important in this issue to always have in mind the fact that work is not started before it can be fully executed (Emblemsvåg 2010). This requires a good planning and coordination throughout the whole planning periods, and hopefully with the help of this approach, Last Planner.

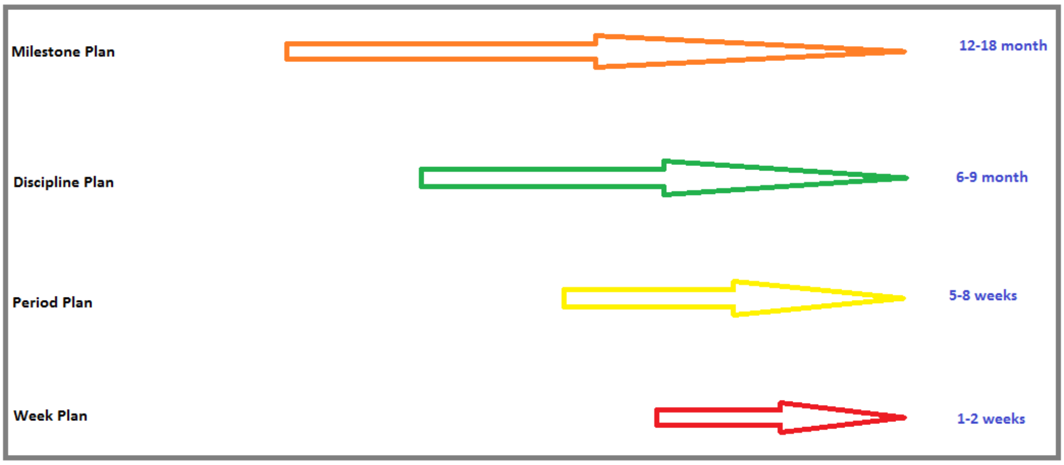


Figure 7: Planning period's duration

In figure 24 the duration of the different planning periods is shown in a graphical way. The different departments at VARD are using the Period and Week Plans on a regular basis to be able to plan and coordinate the use of e.g. resources at all-time throughout the project period.

The Last Planner is an approach to improve the planning processes in e.g. design, engineering, construction scheduling, and to get better predictability. It helps to transform what should be done, to what can be done when it is required. This to protect the planning integrity and predictability (Ballard 2000).

The volatile and uncertain market for Offshore Specialized Vessels (OSV) gives a greater risk of errors in the engineering and planning activities at VARD. VO's may occur throughout the whole project period, both due to errors in engineering and planning and-/ or change in customer requests. This problem is common in the shipbuilding industry, but the building of Offshore Specialized Vessels is particularly vulnerable to such VO's due to the mentioned uncertainty. There is a direct link between the quality of design, engineering activities and the organizational planning. Traditionally planning which often has planning horizons of years, quarters, month, and where daily activities are carried out through those. The difference to the Lean Shipbuilding is that the last mentioned recognizes the complexity of the activities.

By elaborating e.g. period- and week plans in Lean Thinking, and the formation of assignments in the Last Planner Process is the production planning and control principle of Lean Construction, where such planning is a commitment to the organization as a whole.

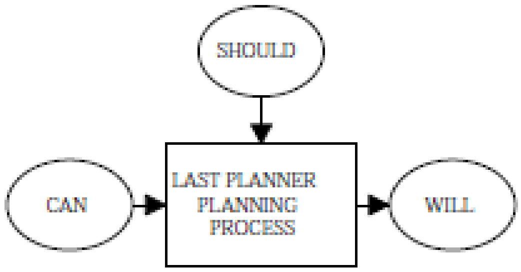


Figure 8 The formation of assignments in the Last Planner planning process (Ballard 2000)

They say what will be done, the planning process results in assignments where "Will" matches "Should" within the constraints of CAN (Ballard 2000). Control of the production is of the most importance since failure to do so increases uncertainty and deprives workers of doing planning as a tool to shape to future work. There is here a need for focus on control of the work that links the workers together, The Last Planner production control system is a philosophy, rules and procedures, and a set of tools that facilitates the implementation of these procedures (Ballard 2000).

Percent Plan Complete (PPC) is an index that evaluates the execution of a plan, and can be a proportion of work effort in weekly plans that are completed on time. PPC is an index where the number of planed activities completed is divided on the total number of planed activities. The PPC index depends on several factors from which both quality and productivity depends. If the PPC deviates from the actual goal of completion, there is a strong need to know the actual reason, and take measures to improve the deviation.

As shown in figure 9, the activities that are not satisfactory completed is moved back upwards in the Last Planner system for improvements, and hopefully the activity will come out with "100% - PPC".

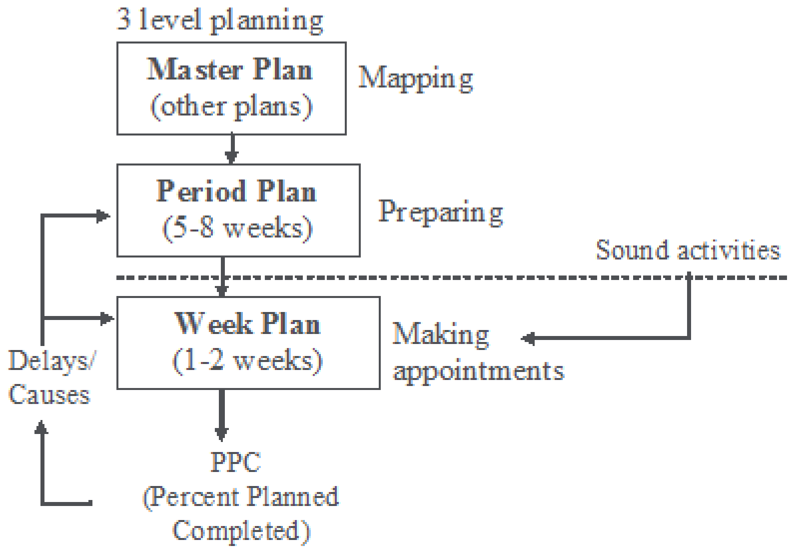


Figure 9 Conceptual model of the Last Planner Approach (Emblemsvåg 2010).

Ballard (2000) studied several companies in practice which where applying Lean Planning, and there was found some inconsistencies among these companies

- Inaccurate information or incorrect guidelines received by the Last Planner, meaning that the information available on resources is not correct
- At the Last Planner level there are inaccuracies, overloaded week-planes
- Priorities changes in the middle of e.g. the weekly planes
- During a work-assignment, it turns out that there are errors in design or the technical documentation

PPC value in the engineering processes gives the information to help Continuous Improvements in the shipbuilding industry, and it provides opportunities for the use of PDCA cycle to be able to reach 100% completion in the planning periods, with as few Error Orders as possible. As mentioned earlier in the thesis, the Error Orders represents a major cost for VARD in the projects which have been reviewed in this paper.

The mentioned approach gives the opportunity for real improvements in both productivity and quality, and Lean Planning takes into account the complexity in the shipbuilding industry and the risk and uncertainty of error and failure throughout the whole project period. This is a systematic problem throughout the whole industry, which means there is a need for a systematic solution. Managers with a good insight in the Lean thinking are fully aware of the key factors like material availability, technical documentation, and so on, that are needed to minimize the probability of errors and such. Even if the decisions of resource planning often are high up in the hierarchy, deviation will occur with a high probability due to e.g. weaknesses in the information flow and coordination of activities, and more. We can today see a large number of Error Orders derived from the design and engineering processes, especially in the information flow between Tulcea and Norway, there is a very high rate of Error Orders derived. When implementing Lean Thinking one should be able to see if there are any improvements, which can be done by using different indicators describing the different performance in the different stages and departments. The use of e.g. PPC would make it easier for the organization and participants to actively contribute in a hopefully more transparent planning process like Lean Meetings etc. by having such transparent planning processes you will get a common understanding of the direction of improvements in activities, and decide what measurements to take and implementing them in an effective way. One of the solution sketches could be to have a “Bank” of resources ready to be activated by a task ready for execution, a Sound Work or Sound Activity (Ballard 2000, Emblemsvåg 2010). With such a “Bank” of resources you would get a clearer information flow and more alignment of tasks ready for execution.

The mentioned Sound Activities are the main drivers of the Period and Week plans at VARD. Sound Activities in e.g. the engineering processes are activities that are executable activities that have the technical documentation required and the resources needed to be able to start a task, as shown in figure 27.

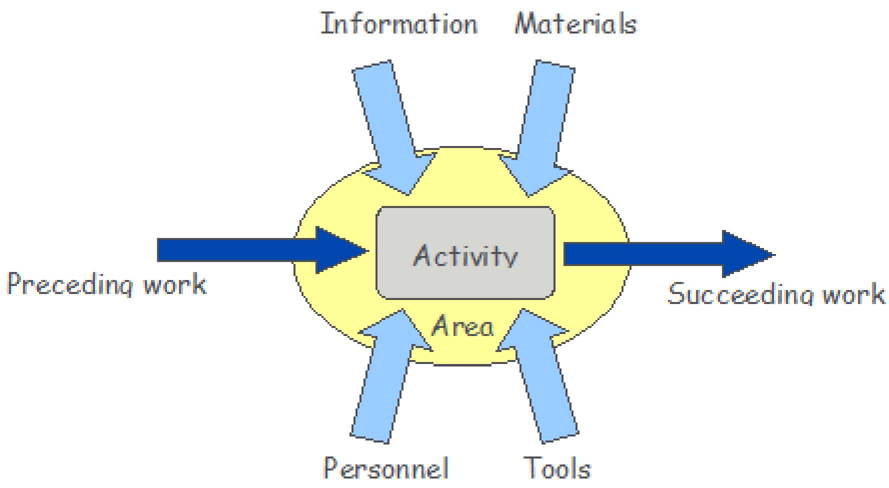


Figure 10 Sound Activity(Emblemsvåg 2010)

When we uses figure 27 in the engineering process, the information tab here illustrates the information on the project as a whole needed to be able to succeed the activity, Materials is the technical documentation needed, personnel illustrates needed resources like in qualified engineers, and Tools showing the needed tools like e.g. computer, software for 3D-modelling, etc. to be able to have a effectiveness and continuity in the engineering process according to the Sound Activity, all the mentioned preconditions must be satisfied. From the moment there are preceding works aligned up, there must be a complete technical documentation ready for the chosen engineer on time, and the engineer-resource must be available and qualified.

The Period Plans are developed by the Coordinators where they divide discipline plans into Sound Activities. There is considerable focus on eliminating waste in the planning process by getting rid of sources of error, lack of information, and wrong sequencing, which are the three main sources of uncertainty. Due to the fact oriented approach in the Lean Planning, people have to be on the actual project site to see the “activity-problem”, and find feasible solutions. The Work Leaders on the site have to plan the activities in such a way that there is no information distortion and all requirements for Sound Activities are in place. Therefore the Work Leaders has the responsibility to run the Week Plans. The aim of this approach is to create flexibility and by that minimize uncertainty through reducing the time used to process the different activities and improve continuously the opportunity of a solution space by e.g. extending the timeframe of the earlier mentioned milestone. By the use of Lean Planning you get an advantage through a better way of communication of information in a dynamic world (Lacksonen, Rathinam et al. 2010). And perhaps one of the most important things in the implementation of Lean Thinking is that Lean is a human based system that requires high involvement from the employees since they are doing the Lean Activities and takes decisions due to Lean every day (Steve 2003).

To recapitulate the section of Lean Thinking it is important to see that the Lean Planning you have to see that high quality and the right planning will prevent Error Orders by aligning the assignments as Sound Activities. The quality can as mentioned be measured by PPC indexes to ensure that you have activities ready for work, and that those activities are placed in the right level of the planning process (if not satisfied with PPC, send back to the previous plan-level). By having measurements like the PPC index, one can also see the quality of the whole production system. The larger the imperfection in the production system you have, the larger numbers of e.g. Error Orders will occur. It requires a systematic approach to this index to ensure improvements of all planning, activities and the project as a whole, and in the long-run using the PDCA cycle secure the improvement processes throughout the whole organization. Continuous improvements has been revealed by the Lean Thinking, and the focus on activity based on real facts, which can be measured through the use of PPC indexes so that one can be able to see the system performance at an operational level of management.

By directing attention towards problems of high imports, and not to a large number, you will see results in the shortest amount of time. Since the shipbuilding industry is much more complex and dynamic than traditional manufacturing, the challenge of having high quality and performance throughout the building process, is quite challenging. This fact has been recognized in the literature of Lean Thinking and Lean thinkers have seen the complexity and the probability of errors in these projects as a whole, and the uncertainty involved in the shipbuilding industry. This problem is systematic throughout the entire industry, and therefore it requires a systematic solution. Improvements in Lean will result in less Error Orders, and this gives automatically higher profits in every projects carried out by the yards. Less costs and higher quality gives VARD an advantage in the market, both in the setting of price, and not at least a better lead-time and satisfied customer.

The use of the Last Planner and PPC indexes gives a common understanding of directions of all activity improvements, and helps managers to make the right decisions and take action according to that. Specialists in Lean talks about having had a "Bank" of resources ready to be activated by a task ready for execution, this is a Sound Work or Sound Activity. This will be to have reasonable reserves of excusable work ready to be activated. This ensures the right alignment of work flow and can prevent tasks from being started without all needed resource or technical information. Variations Orders (VO) can often emerge from such issues where e.g. all information needed are not in place when the activity starts. Drawings and work plans for different jobs can be produced without the right information, which leads to rework later on and costly time delays in the project. It is of the most importance for managers to have measurements this "Bank" of Sound Activities ready for execution, to constantly be able to improve the right alignment in the planning process of such activities.

The aim of this thesis is to find ways to handle Error and Variation Orders in such matter that both customers and owners maximizes their utility, in the context of Lean Thinking since VARD strives towards Lean. To be able to have a success in e.g. a Lean-transformation, it seems important to develop high commitment levels for the employees, experience a strong belief in Lean, and that they get exposed to good communications and cultivate improved work methodology. Involvement and influence is the keywords, and there is a need for highly motivated and skilled workers at the production site as well as engineering staff or other levels of the organization as a whole. Implementation of Lean principles in the shipbuilding industry allows for improvements in the planning and engineering activities. In this case we would be able to see improvements in the numbers of VO's, and even better Lead Times in the project as a whole. If you have a good implementation, you will get less Error Orders. This will be discussed later in this paper.

Also the sharing of information is important in the Lean Concept, the Lean Thinking is about the knowledge on how and why different activities occur to be able to have simpler methods, eliminate waste, and highlight continuous improvements through better information sharing and decision-making at each level of the production. A success here will give a better result in the Error and Variation Order handling.

4.2 Decision-making under Uncertainty

4.2.1 Introduction

VARD is operating in a market where the demand for vessel outfitting of the customer's customer (e.g. the oil companies at the Norwegian continental shelf) is quite volatile. Therefore, the 'mass' production of standardised vessels, where the shipbuilding projects are similar, is not appropriate. Most projects differ with respect to outfitting details;, so a production like the production lines at Toyota (Toyota 2012) would be difficult to directly implement in a ship building process. This outfitting demand volatility introduces uncertainty in the decision-making processes, and such decisions needs to be handled in a way that maximizes the utility of both the shareholder and the customer. Uncertainty also arises from elsewhere, both internally and externally. Examples of externally uncertainty could be delays from sub-contractors, extreme weather conditions (the towing of a hull from Romania to Norway), and more. When it comes to internal uncertainty there could be lack of planning, errors during the design phase, communication problems within the organization, and more. Such uncertainty must be taken into consideration when making decisions.

Decision-making in the organisation happens on all levels in the shipbuilding project life-cycle, and the decisions can be divided into Programed- and Non-programed decision(Gordon 2002). The programed decisions are those taking care of more repetitive and structured problems, where experience plays a large role on how the processes are carried out and what outcomes one should expect. The Non-programed decisions are more unique and non-repeating, and they are unstructured. This requires an innovative approach to the decision problem, and one needs more time to get the information to be sure that the information basis gives a good platform for decision-making. The dynamic world of the decision-makers in the shipbuilding industry makes the decisions even more complex and reduces the capability of predicting the outcomes. Therefore, the theoretical frame of "Decision-making under Uncertainty" is useful in the present setting. Non-programmed decisions are quite common in most industries related to the offshore activities, and made on daily basis. . It is perhaps in the planning and engineering phases these decisions of uncertainty will occur most frequently due to both internally and externally uncertainty such as e.g. supplier uncertainty, changing government regulations, lack of internally communication, and more. So the basis of such decision problems must be to minimize our regrets by highlighting what decisions can be made with the give information, and what decisions is wise to be made, given the same information (Wallace 2005).

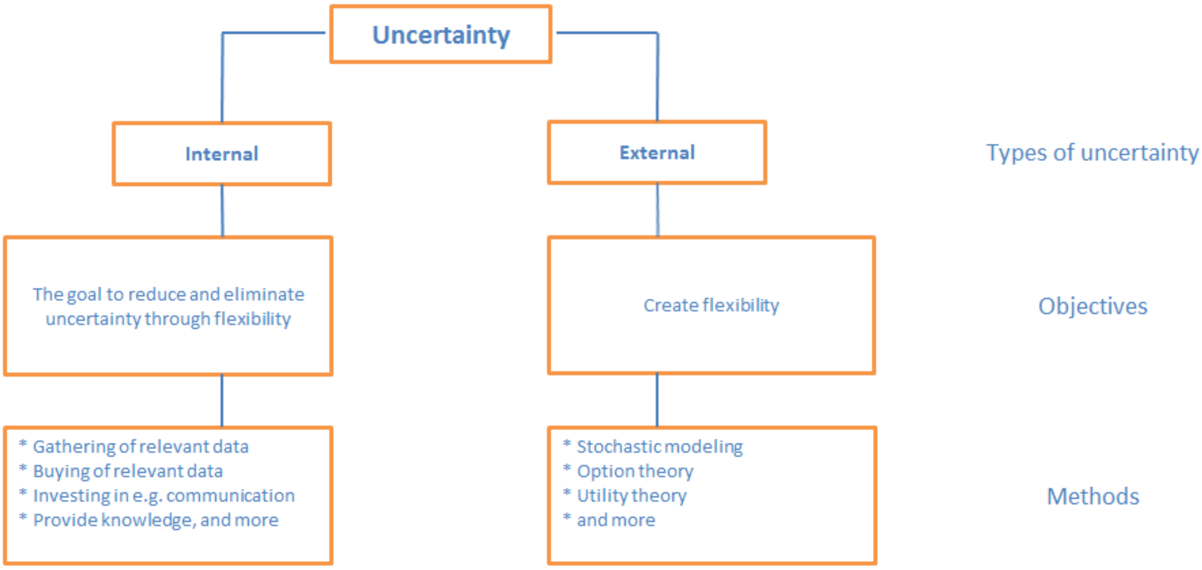


Figure 11 Types of uncertainty and methods

We can define uncertainty as; *a situation where the current state of knowledge is such that 1) the order of nature of things is unknown, 2) the consequences, extent, or magnitude of circumstances, conditions, or events is unpredictable, and 3) credible probabilities to possible outcomes cannot be assigned. Although too much uncertainty is undesirable, manageable uncertainty provides the freedom to make creative decisions(businessdictionary.com 2012)* . I.e. there is a difference between the information required to make a good decision, and the information available at the time of decision-making. The decision-makers need to consider two types of uncertainty, namely internal- and external uncertainty.

- Internal uncertainty refers to lack of knowledge and to ignorance, and these can be controlled. The decision-maker can reduce/ eliminate internal uncertainty by gathering of relevant information within the organisation, or invest in such information (Wallace 2005).

- External uncertainty cannot be controlled by the decision-maker, and the gathering of information is of limited use to overcome such uncertainty. The decision-maker must create flexibility in the process to be able to cope with this type of uncertainty. This can be done with e.g. Utility Theory, Stochastic Modelling, or Option Theory, etc., which all tree helps coping with the external uncertainty (Wallace 2005).

External uncertainty cannot be eliminated; it is out of the decision-makers control, so the goal must be to plan for uncertainty by Flexibility. There are a number of options in the literature on how to cope with such issues, where different theories can be used to manage the aspects of different decision problems. These theories can be Option Theory, Operations Research, Utility Theories, and more, and the literature refers to these concepts as proper tools to cope with decision-making under uncertainty.

In the offshore shipbuilding, uncertainty is a major part of the decision problem; although frequently underestimated. To handle uncertainty, information must be improved and/or flexibility created to handle both internal and external uncertainty. One way to create flexibility in the engineering and production processes is platform based product architecture. Platform Planning is treated within literature of Product Variety. Platform planning means that a 'commonality plan' and 'differentiation plan’ is developed for several ship, defining the common and differentiated components.

The goal of this thesis is to find ways to handle error and variation orders, where variation orders is profit drivers and opportunities for the shipbuilder, and error orders is cost drivers that must be handled in proper ways to minimize costs and lead time. One should also plan for flexibility to avoid error orders, and to handle variation orders more efficiently. The data collection process for this thesis at the shipyards, the analysis and conversations with some of the engineers showed a ratio of 80/20, where cost-related orders stands for 80 percent of all error and variation orders, and profitable variation orders stands for only 20 percent of the total turnover of such orders. So when talking about Platform Planning through Product Variety theories, the use of the data from especially the Tulcea shipyard can give valuable information on how to plan for flexibility. The vessels are designed by dividing the entire vessel into Blocks and Units, where the six blocks are divided into several units (see chapter 4.6.2).

When talking about flexibility in a production, this flexibility can be defined by the ability to quickly adapt to sudden changes (Wallace 2005). There is also the possibility to create flexibility through having the option of an alternative decision like e.g. the option to delay a certain rate of the production to a later stage, this to reduce the risk of uncertainty due to delays in the drawings and the subscription material from Design or Engineering. This latter seems to be one of the main causes of the VO's from Tulcea, according to some engineers at both yards VARD Soeviknes and VARD Brattvaag. If the goal here is the overall optimisation of the production through minimizing the costs of VO's (error-orders) and maximize the profit through VO's created by customer requests, there is a need for the creation of a transparent information system throughout the whole process (the chain) (Wallace 2005).

4.2.2 Theories within Decision-making under Uncertainty

There have been developed several mathematical and qualitative approaches in the relevant literature. This section will briefly review three approaches that are relevant for this thesis and the issues of Variation Orders and such.

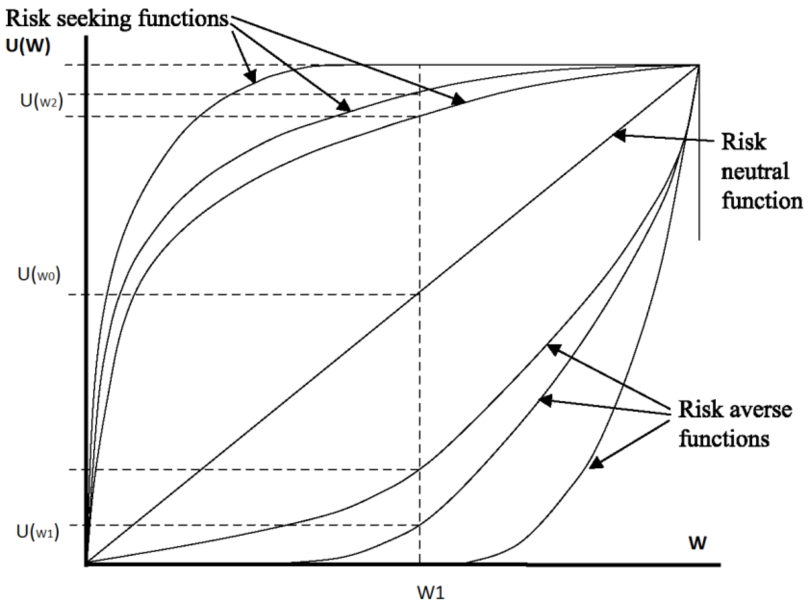
4.2.2.1 Operations Research

Operations Research (OR) is a Decision Science using quantitative methods to support the decision-making. OR is an interdisciplinary science that combines stochastic modelling and Statistical analysis with the intention of finding the optimal, or near optimal solutions to different complex decision problems (Morse, Kimball et al. 2003). Supply Chain Management, Transportation, Production optimization, and more, are areas this issues addresses, and its usability when it comes to project planning and such, helps to detect different critical processes during a ship building process, and what effect this "bottleneck" will have on the overall lead-time and duration of the project from the design-face and throughout to the outfitting, and finally the handover to the end-customer. To get a proper use of Operations Research in the Offshore Shipbuilding industry would most surely be quite valuable. It will create more flexibility around the critical activities, especially in the beginning of the project where there is a possibility to get the right information in time to avoid rework in e.g. the piping outfitting at the yard in Tulcea. Another example is to have the approved drawing from DNV before starting on a task of e.g. hull-outfitting for a door in the after ship, which would keep the lead-time and the additional costs down.

4.2.2.2 Utility Theory

The Utility Theory describes the individual's risk behaviour; e.g. an individual decision-makers consumption behaviour affects his-/here choice by comparing several sets of competing alternatives (businessdictionary.com 2012). It is essential that the individuals are rational and that they want to maximize their utility, by selecting the option that gives highest satisfaction (Wallace 2005). This aspect will be valuable in decision-making, since it gives an understanding on how individuals value uncertainty and risk. The Utility Theory mentions three types of individual behaviours when it comes to risk, as a decision-maker faces uncertainty, namely Risk Aversion, Risk Seeking, and Risk Neutral (Wallace 2005).

Risk Aversion means that an individual seeks the safe alternative where the possibility of loss is present, even if there is a chance of high profit. This is shown in figure 2 where the Risk Aversion function is the curve to the south-east, where the individual's utility must be quite high before taking the chance of e.g. an investment in a certain stock. This means that the individual that are risk averse prefers a secure situation with sure result, rather than a unsecure situation with possible high profit, but with the chance of a loss. The risk-averse individual will get lower satisfaction for each additional gain, meaning that the individual avoids taking risk.



Risk-averce: Increasing welth (W), increase of utility (U) is less poportional than W
Risk-seeking: Increase in W, increase of U is proportional higher than the increase in W
Risk-neutral: Increase in W, increase of U is proportional equal to the increase in W

Figure 12 http://www.emeraldinsight.com/journals.htm?articleid=852198&show=html (Figure 2 is modified)

When it comes to **Risk Neutral**, the individual accepts equally gain or loss of a gamble where the chance for both situations is the same. In figure 29 we can see that there are equal levels of satisfaction of utility proportionally to the gain of wealth in any gamble for this person.

A **Risk-seeking** individual likes to take a gamble or more correctly a chance on a risky situation. This person wants to take a risk of either a gain or a loss, compared to a certain gamble where the wealth stays equal. The risk-seeker seeks risky decisions most of the time, due to the additional gain brings a higher proportional level of satisfaction.

The difference between the Risk Seeking, Aversion, and Neutral, explains the individual decision-makers attitude towards uncertainty and risk in a decision-making situation. For an organization to have control of these issues, can help them to gain advantages in a competitive market, and in improve their market position. But it is extremely important to be aware of the dangers the organization can be exposed to, by to high exposure towards risk.

4.2.2.3 Options Theory

Options Theory is an organizational approach to uncertainty, a technique to value uncertainty in a volatile and changing world. In this setting one can get flexibility through the existence of options, and flexibility reduces uncertainty in the decision process. This means that the options give the opportunity to postpone the decision, and by that reduce the uncertainty before deciding (Wallace 2005). There are always some costs associated with flexibility, and options often come with an initial cost. In shipbuilding one could postpone as long as possible each "milestone", and by that create the flexibility needed to minimize uncertainty. The chance of having all the information needed from e.g. the customer requirements will increase dramatically as days passes by in the project. Such measurements can help the shipbuilder to avoid costly rework and waste in both engineering and production departments. It is important in this aspect to be aware of the cost of flexibility. All flexibility in this context comes with a cost (Wallace 2005). By postponing a "milestone" (one of several other possible options) the decision-maker will get more time to gather necessary information, but as mentioned this comes with cost like e.g. resources in engineering, design, project planning, or project coordination, and more. It is important to hold and respect the schedule for project delivery, and not increase the lead time of the project. The decision-maker needs to make cost-benefit evaluation and find what option is the best in the current state of the project, is the option worth the price or not? The postponement as mentioned above gives the opportunity and advantage of a situation by waiting on information needed to make the right decision. The presence of options gives a hesitance to invest due to lack of information. This lack of information makes it difficult for the decision-maker to evaluate the different options. Options are not valued exactly all the time, and uncertainty makes their value increase. Options Theory are perhaps one of the most common used valuation of strategic investments in an uncertain world today (Wallace 2005).

4.2.3. Heuristics and Behavioural Psychology

There have been several studies on individuals in different processes of decision-making under uncertainty, where there has been implicated that such decisions not always are rational like we see in other traditional economic theories. In the Prospect Theory (Kahneman and Tversky 1979), people are not seen as rational in assessing probabilities of possible alternatives due to limited information on the time of decision. This makes a decision unreliable. Decision-makers will rely on Heuristics when it comes to estimating the different probabilities in the uncertain alternatives and under the pressure of time. Such Heuristics are seen as Rules of Thumb, and generates systematic errors in estimating values and probabilities. The human bias does that there are many predictable mistakes, where Predictability means that one can learn to avoid them by discovering earlier mistakes. Even the most gifted decision-makers can make such mistakes due to the mentioned bias, and this section emphasizes these systematic mistakes. The behavioural aspect seems extremely important in decision-making (Kahneman, Tversky et al. 1987).

These human biases give wrong estimations and evaluations in different planning processes and more, and Wallace (Wallace 2005) mentions three mistakes based on Kahneman and Tversky (1987). Wallace shows that it is easy to come to the wrong and false conclusions in Cognitive Heuristics, and those heuristics are; Representativeness, Availability, and Adjustment.

4.2.3.1 Representativeness

People often overlook prior probabilities in given additional information, even if there is no significance, and it is misleading.

Law of small numbers or Incentive to sample tells us about the way people tend to see a sample is representative in a population. Here we can see how people tend to react to sample size when they don’t do any calculations, but just rely on their heuristics (Wallace 2005). Wallace (2005) shows that people tend to oversee the size of a sample and see any sample as a good representative of a population. An example here can be if we see to the in Wallace’s compendium where there are two hospitals, in one hospital there are 15 childbirths per day, and while in the other there are 45 childbirths. As we know there are about 50 % boys born, but one year they had 60 % boy children! In this example it is most likely to reach 60 % in the small hospital than on the larger one. We can see that in the smaller sample we can get further away from the mean than in the larger sample, which is the core of the law of small numbers, and the fact that we all tend to overlook the sample size and think that any samples represents the populations equally (Wallace 2005).

Predictability is about the behaviour of a group according to a probability distribution, and that this distribution gives no help in individual evaluations among the group members. As an example to explain Predictability, one can see to the football where a population of young talents which scores are normally distributed. The core of the theory of Predictability says that you can't evaluate if one individual football player in five years' time will be good enough to play on Manchester United derived from the mentioned distribution.

Regression of the mean refers to the phenomena that a situation tends to go back to a mean state after an extremely good period of e.g. sales. People often overestimate such good periods by over evaluate their own actions and decisions in the pick period (Wallace 2005).

4.2.3.2 Availability

Availability is about to predict the probability of something happening based on easy examples. This heuristic mentions Retrievability and Imaginability as ways to estimate probability from associative connections.

The bias of Retrievability also called Ease of Recollection is about that often happened events will be overestimated in the estimation of the probability of an event to occur (Kahneman, Tversky et al. 1987). If we see to the example of Wallace (2005) where people were given a list of 50/50 male and female names, the list of males contained several famous actors, and where asked to estimate how many of each sex. The fact that the list of males contained famous names does that the male population where overestimated. It was easier to retrieve the list of famous people from their memory.

Imaginability is where over- or underestimating are depended on how a decision-maker valuate a problem (Wallace 2005). If it is difficult to see what may go wrong in a future situation, the probability of it to actually happen could easily be underestimated. Similarly if you are extremely afraid for something to happen, the probability of this to happen would easily be overestimated.

4.2.3.3. Adjustment and Anchoring

Everything has a beginning; this also applies the estimation of a number, since we cannot come up with a number from "nothing". Adjustment and Anchoring is a heuristics where individuals make estimations from starting point. This starting point is called an Anchor, than people tend to lean through wards this anchor when making an assessment (even if this point is irrelevant for the case). Than the individual adjust to give their final answer, which is called adjustment (Kahneman, Tversky et al. 1987).

Wallace (2005) uses an example by Kahneman et al. (1987), where two groups of students were given a multiplication problem. Group 1 was asked to estimate

8 * 7 * 6 * 5 * 4 * 3 * 2 * 1 =

And the other group was asked to estimate

1 * 2 * 3 * 4 * 5 * 6 * 7 * 8 =

The first groups' median was 2250, while the second group had a median of 512. This difference can be explained by the assumption of that the first group have a higher numbers in the start of their estimation, 8 * 7 = 56, and the second group starts with low numbers in their estimation, 1 * 2 * 3 * 4 = 24, hence the first group will start at the "anchor" = 56, and adjust to that. The second group will start at their "anchor" = 24, and adjust to this value.

The actual value of the task is 40 320, which mentioned estimations are not close to. This shows us that we do estimations from a starting point, and we tend never adjust enough. The first group that started with a higher numbers often comes up with a higher estimation than the group that started with a lower numbers (Wallace 2005).

Conjunctive and disjunctive events are usual deviations of judgement when it comes to the estimation of probabilities. This effect gives an overestimation of probabilities in conjunctive situations, situations where events must occur with connection to each other. It also leads to the underestimation of probabilities in disjunctive events, situations where events occur independently of each other. As an example we can take a project with a proper project scheduling of five different activities that needs to be done to be able to deliver the product to a customer. Activity 1 must be finished before activity 2 can start, and so on up to the finishing activity 5. There is likelihood for a delay of 10 % per activity, so people involved tend to underestimate the chance of a delay of the project. But the probability of a delay overall is 41 %, and the probability for the project being on time is $0.9^5 = 0.59 \approx 59\%$.

When basing our modelling on subjective probabilities, we must be aware of the low variance of the data obtained from people, and this must be a warning according to Wallace (2005).

Even for decision-makers fully aware of these errors, it will be difficult to avoid falling in the mentioned pitfalls. Lovello and Sibony (2010) mentions five categories to classify the most common cognitive biases in both individual and organizational decision-making (Lovallo and Sibony 2010).

- **Action- oriented biases** which is where people takes actions less thoughtfully

- **Interest biases** comes when we have the presence of conflicting interests
- **Pattern- recognition biases** is where people are lead to recognise patterns even if there are none
- **Stability biases** creates inertia where there are uncertainty present
- **Social biases** can arise where there are harmony of conflicts present

This is one of the reasons why one should use a mathematical approach when dealing with uncertainty in decision-making, these mathematical models in section 1.2 are not exposed to the mentioned biases and heuristics. “We can force a model to be “logical” according to the rules we choose ourselves, since we may not be able to do that in our minds” (Wallace 2005).

4.3 Supply Chain Management and the flow of information

In the data gathering phase of this thesis, there were major indications on problems in the information sharing process, internally within the individual yards and especially between the involved yards, the hull construction VARD Tulcea, Romania, and the outfitting yard VARD Søviknes. There was, therefore, a need to adapt the thesis work to the arising challenges by including some theory regarding information sharing within the organization and its supply chain.

This chapter will focus on the “internal” flow of information, within the different organization at VARD, and will not take into account the external environment of suppliers, and more.

There are strong indications on problems in information sharing within the organization and between the involved yards is a reason why VO’s occur. Also the planning process can be affected by deficiencies in the information sharing, all the way form the Master Plan and down to the Week Plan. As mentioned in the chapter of Lean Thinking, also the sharing of information is important in the Lean Concept, the Lean Thinking is about the knowledge on how and why different activities occur to be able to have simpler methods, eliminate waste, and highlight continuous improvements through better information sharing and decision-making at each level of the production. A success here, in both the sharing of information and Lean Concept, will give a better result in the Error and Variation Order handling.

The flow of information in an organization or a supply chain is important to be able to eliminate waste, and highlight continuous improvements through better information sharing and decision-making at each level of a production. It is also obvious that a construction benefits of information flow with high reliability. Improvements in information flow have greater influence on the construction phase than the design phase. The project will run more smoothly when construction can take actions in advance before receiving the design information. This will coordinate the follow of resources, materials, and the completion of prerequisite assignment, giving more efficiency to the project as a whole. *We have numerous instances from construction processes showing the benefits of increasing material and information flow reliability even within the job site itself (Ballard and Howell 1998, Ballard 2000).* This shows that it is important to have the right conditions to achieve an efficient flow of goods, but perhaps even more important is the efficiency on the flow of reliable information.

Information must be reliable due to the uncertainty factor in asymmetric information. Information asymmetry between participating units leads to uncertainty, and as mentioned above uncertainty leads to inefficiency in the organization as a whole (Premkumar 2000). One have to be aware of the danger of organizations in the supply chain, or departments within an organization, that wants to reduce their uncertainty, their reduction may be on the expense of others within the Supply Chain-/ Organization. In this context uncertainty can be defined as *the difference in the amount of information required to perform the task and the information already possessed by the organization(Premkumar 2000).* An example here can be in the engineering process at a shipbuilding site where a recipient of information sits waiting for a "bulk" of information before executing a task, rather than giving information to the sender on what information is required to perform the task. The organization has a need to match the uncertainty, the right level of coordination and information sharing, even with the external environment, an acceptable level of deviations or variations from the required performance and the cost of immediate measures are needed to meet critical performance measures.

Inter-Organization relationships (IOR) are the relationship between two organizations, e.g. relation between the yards in Norway and in Tulcea (Golicic and Mentzer 2005). The reason why this approach was selected in the thesis is the findings in the data-gathering process at the yards here in Norway, and conversations with different employees (there are four methods of data collection for qualitative research: Interviews, Observations, Focus Groups, Other, where the method used here is; other). The daily communication between Tulcea and Norway, sharing of information, and the execution of the different projects, gives high indications on two different cultures not working together as one group. It is here, after all, talking about one company, namely VARD. As mentioned in the Decision-making chapter, internal uncertainty can be eliminated, and be handled through flexibility. But since we here are talking about the communication and execution of assignments between two different cultures within the same Group, there is a need for a different approach to find possible solutions in the literature on how to handle the problems the data-gathering found.

In the context of information sharing in the Inter-Organization relationship, the information is the key ingredient between organization and in any SCM system. The information sharing refers to the information communicated to the supply chain partners, and the reliability in the relationship. Since the aim must be to improve the sharing of information to be able to avoid Error Orders, the information distortion must be reduces, and the quality of shared information must be improved. This means information shared has to be as accurate as possible and organizations must make sure that the information flows with minimum delay and distortion (Li and Lin 2006). The sharing of information within the supply chain creates flexibility, which reduces the uncertainty and can prevent potential VO's, but this requires accurate and timely information. The study done by Li and Lin (2006) shows that there are three dimensions to consider in a IOR, namely **trust** between the parties, **commitment** of trading parties, and **shared vision** between partners. Such dimensions should be incorporated into the relationship between Tulcea and the yards in Norway. The trust in a trading partner is defined as the willingness to rely on the partner you have confidence in, and trust also prevent opportunistic behaviour (Li and Lin 2006). *Opportunistic behaviour (Buvik and Reve 2002),* which is when one party has superior knowledge and takes advantage of it to leverage its own utilization at the expense of partners. Disclosure of information is a key word in this setting, and was one of the findings from the VO-meeting at VARD Brattvaag, and the subsequent conversation with the participating engineers and Project Manager. It seems important to prevent such opportunistic behaviour to be able to have the flow of required and accurate information in the different projects (Maurer 2010). This is in order to be able to eliminate waste, and highlight continuous improvements through better information sharing and decision-making at each level of a production. There should be a common goal for all organizations involved to maximize the utility of shareholders and customers, and to minimize waste and have continuous improvements.

To be able to implement a good information sharing strategy, it is important to have a strong support from the Top Management. The importance of such information sharing must be understood by the Top Management, and they should provide guidance, vision, and support for the implementation measures needed, and perhaps the most important is to have a strategy for this issue in the overall business strategy and to allocate resources required. It is found that information sharing is impacted positively by top management support, and trust in supply chain partners and shared vision between supply chain partners. (Li and Lin 2006).

A tool in the information sharing between participants in different organizations is the use of IT-software solutions. VARD is today using the Share Point as a common platform of information in their on-going projects, providing access to the actual participants in each project. To have a system that ensures the flow of reliable information, both within an organization and in an IOR, seems crucial for the success in these types of projects. The high uncertainty and volatile demand of changes orders, has a need for actions that can cope with such issues. IT can be used to link supply chains and organizational processes together, but it does not help alone on a not fully functional IOR. There is a need for a foundation to have an effective IOR, if not, *any effort to manage the flow of the information or materials across the supply chain is likely to be unsuccessful* (Li and Lin 2006). Li and Lin (2006) made some findings, as mentioned above, in their study that highlighted the importance of Inter-Organizational relationships, where relations were built on trust, commitment, and shared vision, in facilitation of information sharing and the quality of shared information. They demonstrated that to achieve a high level of information sharing and information quality, there must be an effective IOR. Therefore, it will be valuable for participating organizations like e.g. VARD in Norway and Tulcea that wishes to improve their level of information sharing and information quality, to spend more time and resources in building good relationships with their partners in hand, namely the Group, VARD. An advantageous IT-solution with a common information platform between the yards in Norway and Tulcea should be developed to increase the sharing of reliable information throughout the project periods. This will give some flexibility in the information sharing and reduce the uncertainty for error in the planning processes (the uncertainty of errors due to information sharing in this context cannot be eliminated due to e.g. the cultural differences). This will result in less Error Orders and give the opportunity profitable Variation Orders. For an Inter-Organizational relationship to work there is a need good communication, coordination, and corporation. In this setting communication is the flow of information between partners, coordination is in terms of delivery scheduling, production planning, logistical coordination, and more, and the last, namely cooperation which is where e.g. two business partners share their common goal and uses comparable performance measures of their inter-organizational activities. Such cooperation can be seen over a wide range of levels and throughout many functional areas within the organization (Premkumar 2000). Premkumar (2000) says that, *there is a need to be* *an alignment of business strategies and commitment among the organizations for long-term business corporation, if the system is to succeed.*

To summarize the chapter on information sharing, reliable and timely information is the key words. It is the lack of accurate and timely information that creates uncertainty. Reliable and timely information minimizes the uncertainty of errors and misunderstandings, and increases the chance of a successful Lean production through the elimination of waste and have continuous improvements. In this setting we have both internal and external uncertainty as mentioned in the preamble to this chapter.

Basically the way to handle the uncertainty in the internal information flow is by doing measures to improve the flow of accurate and timely information. It is here important to have the support from the top management to be able to improve the flow of information due to the resources needed. The top management should provide the organization with provide guidance, vision, and support for the implementation measures needed, and perhaps the most important is to have a strategy for this issue in the overall business strategy and to allocate resources required. The support from the top management has a positive impact on the information sharing processes, and gives trust in the relationship between participating partners.

Asymmetric information between participants gives as mentioned uncertainty, and prevents VARD from their goal to be Lean. Accurate and timely information is perhaps one of the most important issues in Lean Thinking, since we want to eliminate waste and have continuous improvements in all production. This can be done through better information sharing and decision-making at all levels in the organization, an information flow of great reliability reduces the uncertainty of Error Orders to occur. By having access to timely and reliable information flow, gives the opportunity to coordinate the flow of resources, materials, and the completion of prerequisite assignment, giving more efficiency to the project as a whole, and construction can take action in advance of fully information from the design-teams. It is clearly a need for the organization to meet the uncertainty by e.g. the right level of coordination and sharing of relevant information with an acceptable level of variation and deviation. The cost of due to the mentioned deviation must be taken into account, due to immediate measures needed to meet performance measures like Lead Time, quality, and more. Uncertainty leads to inefficiency in the organization as a whole, and will inhibit the implementation of Lean.

As mentioned earlier, VARD has a problem due to the cultural differences between the yards in Norway and Romania. To find proper measures to reduce the uncertainty of error in the information flow between these participants, one can not only find solutions due to Internal Uncertainty. Findings as mentioned, indicates a slightly different approach to this problem, namely to create a better relation between two different organizations with different cultural approach to finding solutions to common problems. This must also be handled as an External Uncertainty, where the creation of flexibility will minimize the risk of error in the sharing of information. By creation of a good and effective Inter-Organizational relationship (IOR), with a high degree of reliability through trust between the parties, commitment of trading parties, and shared vision, the information distortion will be reduced and the quality of shared information will be improved. There were also indications of a strong opportunistic behaviour between the parties at the data-gathering process in Brattvaag and Søviknes, which also is a strong indication on the need for a stronger and better IOR. Involvement and support from the top management is important since this has a positively impact on the trust aspect and on the desire to improve the sharing of information. By having a good IOR, you create the needed flexibility to minimize the risk of error, through e.g. having access to timely and reliable information flow so you can prevent any delays or costly rework. All this will be discussed later on in the thesis.

VARD has today a common data-base for information sharing on on-going project through “SharePoint”, but this does not include the yard in Tulcea. All participates in the different project has access to required information, giving a common platform for the sharing of reliable and timely information, which seems to be a successful approach. Such a common platform should also have been established through wards the yard in Tulcea, a common IT-solution seems curtails for the success of these shipbuilding projects. An IT-solution can link together organizational processes, and give the required flow of accurate and timely information needed to avoid Error Orders. To end this summary, there is a need for a foundation for IOR to function, if not, the sharing of information will not succeed.

4.4 Product Platform Planning

Many industries are struggling with uncertainty and dynamic changes in their environments, like rapidly changing customer specifications. These new trends challenges the producers ability to rapidly deliver products that are innovative and highly customized(Alblas 2011). In many industries, the costs of increased variety are higher than the revenues. How firms choose to create variety, and how the firms’ functions and its supply chain are managed to implement variety, are key for success. To enable rapid adaptations to new customer requirements and deliver high level of product and component variety, while also controlling the costs, companies in most industries are now considering a platform-based product development. Platform based product development means developing a family, or *platform* of products, and producing them in a flexible process, tailored customer needs. A Platforms is a collection of assets (i.e. components, processes, knowledge, people and relationships) shared across several products (Robertson and Ulrich 1998). Taken together Components, Processes, Knowledge, People and Relationships, these shared assets constitute the Product Platform (PP). PP can also be defined as a set of common components, modules or parts from which a stream of derivative products can be efficiently developed and launched (Alblas 2011), with the underlying core technology implemented across several products. In offshore shipbuilding this can be used in this context by seeing to their strategy of standardization of vessels, and outfitting these vessels covering customers' needs. The balance of the market value of differentiated product and the achieved profit of commonality, is what effective platform planning is all about.

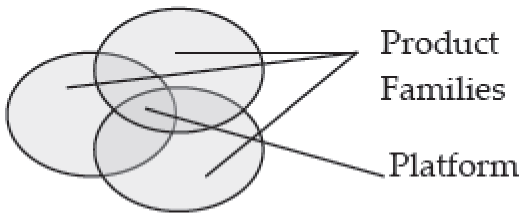


Figure 13:Graphical view PP (Alblas 2011)

Platform Planning can be quite challenging, meaning that there is a risk of achieving high commonality at the expense of the differentiation of the products. Also that the production of differentiated products comes with excessive cost, or to create sustainable platform plans that never are to be realized (Robertson and Ulrich 1998). It is important to be aware of a standardization of different product groups could lead to the sharing of a moderately amount of components, but such shared components are not considered as a Product Platform (Fisher, Ramdas et al. 1999).

There are tree tools to support platform planning and to contribute to understanding of the trade-off between commonality and variety (Robertson and Ulrich. 1998) these are as follows:

1. The Product Plan
2. The Differentiation Plan
3. The Commonality Plan

These tools will help to facilitate the planning processes in the projects by having a common language between Marketing, Design, and Engineering and Production Functions. Such PP processes is best carried out by a core-team made up of representatives from each of these functions (Robertson and Ulrich 1998). The goal of the platform planning process is to achieve coherence across these three plans (Alblas 2011). This will give the company good conditions to create platform that allows an efficient and quickly development of a set of differentiated products covering the customers' expectations. Perhaps one of the most important things here for offshore shipbuilding, is that such a platform approach will increase the flexibility and responsiveness in the construction processes by the sharing of production processes and components, which in the end will give increasing product development at lower costs and less use of resources. Alblas (2011) summarizes the benefits of using a PP approach, and the most important is *flexibility, responsiveness, reduced development time, less production costs, improved ability to upgrade products, test reduction and promotion of better learning across products*. All these mentioned benefits are in accordance with the strategy of VARD to be a Lean company.

The effort to provide customers with a variety in products in the market is valuable and gives the company a competitive edge through wards their competitors. But to provide such variety often comes with a substantial cost (Lancaster 1990).

By using the PP approach one can balance Commonality and Distinctiveness of the products offered. When it comes to Commonality and Distinctiveness, there are three ideas to consider:

1. Customers care about distinctiveness; costs are driven by commonality
2. Given a particular product architecture, there is a trade-off between distinctiveness and commonality
3. Product architecture dictates the nature of the trade-off between distinctiveness and commonality

By the sharing of a significant number of assets across the products, PP is balancing the need for Distinctiveness with the need for Commonality (Robertson and Ulrich 1998). As an example from the shipbuilding industry, this can be done by the development of a physical section of crew cabins that are produced in such a way that it will fit in any

Offshore Specialized Vessel offered by a specific yard. The crew cabin must be as a whole section that can be lifted in to the vessel when the hull is being built, and should contain all intentional facilities planned in the PP process. As a subordinate clause, such sections can be out-sourced. The example above will give flexibility, responsiveness, reduced development time, less production costs, improved ability to upgrade products, test reduction and promotion of better learning across products, as Alex Alblas (2011) summarized. And the example above is quite similar to the example of the automobile industry used in the paper, Platform Product Development (Robertson and Ulrich 1998).

It is important that the Top Management is involved in the platform development process, since a decision on a possible platform is a strategic one, influencing all the subsequent planning and production processes. Platform decisions may cut across divisional boundaries or several product lines, and often requires the resolution of cross-functional conflicts (Robertson and Ulrich 1998). This shows that the top management must participate because a good PP decision requires the involvement of several disciplines within the shipbuilding, such as piping, hull, machinery, and more. This will be discussed in more detail under the shipbuilding company VARD description.

Platform management was from the start mainly used in industries with high volumes of products and large product ranges (Randall 2012). The case study provided by Alex Alblas (2011) shows that PP also can be used in producing low volume of complex products such as Offshore Specialized Vessels.

The case company VARD is subject to a large number of error and variation orders during the production processes. Platform planning in the company would potentially simplify the implementation of changes during the production processes. This shows that PP is not a static activity, but a continuous process since changes must be handled consecutively due to their impact on the platform as a whole (Alblas 2011). The more complex a platform is, the more it affects the platform management. The definition of a platform change (EC) is change in the platform after it is released from design and into production (Alblas 2011).

An EC almost always have a negative impact on the flow production which we often see in Lean Production. Such negative impacts could be on the production costs, routing, rework, and more, but perhaps the largest impact can be seen in the supply chain as a whole (Alblas 2011). This shows that already in the design phase of a vessel, there is a need for having at hand all the customer requirements, so that the chance of an EC can be minimized. In figure 31 we can see some examples on some types of EC’s and what disturbance these give to the platform.

	Platform change	Disturbance
Procurement with kitting	New part version of a common part.	Increased variety in locations in both the warehouse and on the conveyance kanban.
Flow production	New product variant that changes common parts of the platform.	Impacts on CODP and more variety introduced in production steps.
Maintenance of installed base configurations	New versions or variants of common parts.	More spare parts which makes qualification of products more difficult and learning more complex.

Figure 14: The effects of EC (Alblas 2011)

The example above shows from the Engineers point of view, that all products and their platform must be stable, especially when using the Lean Thinking in the production.

To conclude this chapter, a Product Platform approach potentially provides a substantial effort to the Lean Construction that would benefit the complex and highly specialised production in offshore shipbuilding. However, setting up a product platform during the development of a project and to stick to the chosen platform is not sufficient. The development and managing of a Product Platform is a continuous process, and if the environment is such that products are often changing, management of such platforms will be difficult (Alblas 2011). The importance of maintaining the platform is also highlighted by several essential requirements. A Product Platform must be planned, designed, maintained, changed, and archived like other artefacts. In the issue of Error and Variation Orders Handling such Platform Planning will provide flexibility in the production processes, and thereby reduce the risk of costly orders, but also give the opportunity of profit through customer required change orders.

Table 32 summarizes the benefits and disadvantages of modular versus integral design architecture.

	Modular design	Integrated Design
Benefits	• Increase variety • Increase speed of change • Improve re-configurability • Improve maintainability and service • Decoupling of developing tasks	• Hard to copy • Tight coupling of design teams • May increase system performance • May reduce system costs
Disadvantages	• Make imitations easier by competitors • May reduce performance • May be more expansive	• Hinder design changes • Hinder customization • Reduce variety

Figure 15: Benefits and Disadvantages of PP

5 VARD – the case company

VARD a Fincantieri company, is a major global shipbuilder, constructing offshore and specialized vessels (OSV) used in the offshore oil and gas exploration & production and oil services industries (VARD 2013).

VARD constructs highly advanced OSV's, and in addition to that other types of specialized vessels like LNG-powered ferries, naval and coast guard vessels, and more. Their expertise and track record have earned us worldwide recognition.

They have developed strong relationships with their customers over the years, and have gained a reputation for constructing reliable, high quality vessels. VARD believes that the depth of their relationships with, and geographical proximity to, a large number of industry-leading customers and suppliers provide them with a strategic advantage (VARD 2013).

With their engineering teams and their innovative design, they are able to provide through their highly skilled workers in outfitting, some of the most advanced vessels, solutions, and service to customers worldwide.

VARD has nine shipbuilding facilities around the world, five in Norway, two in Romania, one in Brazil, and one in Vietnam. These shipyards are strategically located to provide the right capacity, capabilities, cost- efficiency, to be able to meet the needs of a diverse and sophisticated global customer.

The data-gathering effort was conducted at two Norwegian shipyards;

VARD Søviknes is one of their five Norwegian shipyards located in Søvik, Haram municipality, 52 km from Ålesund, and has 181 employees (VARD 2013).

VARD Brattvaag is one of their five Norwegian shipyards located in Brattvaag, Haram municipality, 27.8 km from Ålesund, and has 150 employees (VARD 2013).

As mentioned, VARD, is a major global shipbuilder, constructing OSV, and more, used in the offshore oil and gas exploration & production and oil services industries, and other shipping areas. At the same time they deliver other products and services like:

- Ship design
- Ship repair and conversion
- Accommodation, through their company VARD Accommodation AS specialized in interior-outfitting
- Electrical engineering, Power and Automation, through VARD Electro AS
- Piping systems and installations, through subsidiaries

- Trading, through VARD Trading

Four projects where followed through this thesis, and data was gathered on Variation Orders at the facilities in Søviknes and Brattvaag. I would like to thank all those who contributed to the thesis work at the two shipyards, employees in engineering, Coordinators, Foremen, and others.

6 Case Study Analysis, Findings

In this sub-chapter the different findings through the data-gathering process will be presented. All findings are done with the use of the data collection methods above, and written successively starting with the primary data. The secondary data was the most time-consuming part of the data-gathering process, due to internal communication challenges in gaining access to needed material. The data collection process started early in January 2013 at the shipyards, VARD Søviknes and Brattvaag. One was given access to the internal data-base of VARD, SharePoint, and an office space in Søvik. One was also shown around on the sites, and introduced to different key-personnel to be asked. Major findings are listed below through sections 1.5.1 – 1.5.6

6.1 Communication and Information Sharing

The study of "Communication and Information Sharing" was not an initial aim in this thesis. That said, during the data collection process there were clear indications on that VARD an internal communication challenge. Inefficient information sharing between different staff members and, especially with the hull-constructor yard in Tulcea, leads to inefficiency, longer Lead Time, and higher cost than needed. This seems to be a major driver of error and variation orders in the organisation. Even if there are Project Organizations defined for each project in VARD on SharePoint, it seems to be indications that the *allocation of responsibility* is unclear in these organizations. Planners and Coordinators do not always know who is responsible for which task at the different stages of the project. This indication was found consistently through all four projects this thesis underwent. As an example to inefficiency in communication one refers to the effort of getting data from project accountings. One had to use up to 8 weeks before getting the required data. One was sent form one person to another, as there was no clear understanding who could help in getting the needed data for analysis.. This situation was repeating throughout the thesis-process at the yards, throughout the observations and interviews-/ conversation.

Another finding is that not all information attempted to be communicated from the top management and down to the “factory floor”, reached the receiver of the information. Conversations with different Foremen and employees indicated that this is more common than not. An example on this is the attempt of implementing Lean principles by the top management at the different yards, while the workers on the ground seem to be reluctant to Lean due to lack of knowledge, which comes from misconceptions through miscommunication. They feel that the concept is “pressed down on their heads”, as we say in Norway, and that they in fact opposes the implementation. This indicates an incomplete communication- and information sharing strategy. Also the sharing of needed information between the different layers of the organization may seem somewhat lacking. All these findings are contributing to the occurrence of Error Orders in the different project, and a possible solution to these problems can save time and money.

Also the communication and sharing of information between different disciplines within the engineering departments can be a problem when it comes to the aspect of Error Orders. In the engineering department time is the key word. When drawings and other required technical documentation are delayed, a subproject or process potentially starts before all needed information is available. This can give basis for Error Orders in the project as a whole and an extension of the Lead Time. It is one's opinion here that planning to e.g. “Milestones” (Milestone, see Literature Review) is important to prevent delays in the processes.

The sharing of information and other communication between the collaborating yards in Norway and Romania should ideally be viewed as internal communication. The uncertainty arising on the interface between these yards should be seen as internal uncertainty (that can be controlled by improving information sharing processes and communication). However, there are some fairly strong indications that this is not the case. It was mentioned in the date-gathering process that there is a great difference when it comes to the cultural aspect of doing business between the two organizations in Norway and Romania. Too much time is spent on such culture driven internal company issues. It was confirmed by several sources that Tulcea is too overly focused on 'earning' money, and less concerned by problem solving. One was participating in several meetings regarding this issue. For a concrete example, consider a VO Meeting (variation order) in Brattvaag with a subsequent conversation with the Engineers and Project Manager. The engineering department in Brattvaag have got a list of VO’s suggestions from Tulcea. A relatively large number of VO suggestions from Romania were rejected by the engineers at the meeting. Large scale rejection of VO's was sad to be “rather a rule, than an exception". It was sad early in the meeting that Tulcea attempted to get more VO’s than they were entitled to, perhaps to maximize their own profits and utility. In Tulcea there is one department only working on handling Alteration Sheets (a dwg-drawing of changes). The engineers at the meeting suspected that the dwg-drawings from the mentioned department are deliberately holding back the drawings from production, by the creation of VO. Quoting a Project Manager at VARD Norway: ”if we all have worked together as a team with common goal as one company, then we could have dropt the most of this meetings”. This is confirmed by the employees working with this kind of issues every day. As a good example on this subject, Hildre mentioned that if Tulcea has to make a hole in the hull to lift in some required equipment, and the cause of this is poor communication between Hull and Outfitting in Tulcea, the yard in Tulcea sends a VO to Brattvaag in Norway on additional work on the hull. The meeting referred to here is an example information sharing and communicative problems, from most of the sources in the data collection at the two shipyards. It became rather obvious that the organization in Brattvaag and Tulcea did not work together as a team with the common goal of maximizing the utility of the shareholder of VARD and their common customers.

There are several indications of poor communication between the different responsibilities in Tulcea being a major cause for a large number of VO’s sent to Norway, and the reason why the number of rejections is relatively high.

There are also indications on the cultural differences between VARD in Norway and Romania influencing the number of VO’s, and that communications and information-sharing is not as it should be. There is also inefficiency created by a rather cumbersome system of e-mailing. The company in Romania should, instead, use a common data-base for the whole project like in Norway (SharePoint or similar). Several engineers one has interviewed requested a new system for communication between the departments in Norway and Tulcea in Romania. It seems to the author that the system used in Norway (Non-Conformance), would be a good system across the collaborating yards as well. Non-Conformance is a system where deficiencies are registered, for the intention of learning from past mistakes. This system is not completely incorporated today, and an effort of implementing this system fully should have been prioritised. This is perhaps the easiest method of several needed, and at a low cost, for reducing variation orders and errors in the organisation

One other obvious finding is the opportunistic behaviour of the hull constructor Tulcea . The aim should be to deliver a product to the end customer within the defined time-frame and quality, but it seems the goal in Tulcea is more to maximize their own profit and utility. This was shown in numerous ways as also indicated above; the delay of dwg-drawings from engineering to production, the effort of getting more VO's than entitled, and more. This can be evidence on how a potential internal uncertainty in information sharing is transformed to external uncertainty.

When it comes to the internal delays of drawings in the Norwegian departments as mentioned earlier, which creates VO's, it is obvious that this is a complex issue. The causes can be:

- DNV, long processing times (External uncertainty)
- Technical documentation, not in hand at due time (Internal and external uncertainty)
- Sub-Contractors, delivery or other (External uncertainty)
- Lack of resources (Internal uncertainty)
- Information distortion (Internal uncertainty)
- And more

This line-up of issues is only to illustrate how complex the task of reducing the occurrence of VO's in each project is, when it comes to the delays of dwg-drawings. Measures which could be taken will be discussed later on.

6.2 Variation Orders

Error and Variation Orders or VO (Variation Orders) as they are named in the VARD system, are orders that occurs after the agreed specified contract on a project is signed by both parties, shipbuilder and customer. VO's that are requested by the customer gives profit, and VO's caused by any kind of error, both internal and external, comes with a costs. Both types of VO give a possible extension of the Lead Time in the projects. It is important to mention that it was almost impossible for the author to distinguish which VO in the data-set from Tulcea was caused by error or customer request. There was given some help from the staff at VARD Søviknes, but due to the time consuming work, this separation is somewhat limited. What is what will be further explained under the specific data presentation in the Variation Orders chapter.

Gathering secondary data on VO's was a complex and time-consuming task. The author was given access to the database SharePoint, which is an internal project data-base for VARD in Norway, with copies of project accountings of all VO's, both in Norway and in Tulcea, Romania. It was given permission to gather data from six projects at VARD Søviknes and Brattvaag, but due to the time limitations of this thesis and due to that two of the projects have not been launched in the building process, only data from four projects (Projects 771, 776, 793, and 794) is collected. Project number 771 was finished and delivered to customer when this thesis work started, while the three other projects are on-going projects in different stages in the building process. The VO data was given in the format of Microsoft excel, and in the SharePoint as in dwg-drawings-/ Alteration sheets. The author did not have access to data-programs that is compatible with dwg, but with good help from several engineers in Søviknes the needed data was acquired.

Within this thesis, each vessel is divided into Blocks and units, since VARD is using this approach in their shipbuilding processes. This will give several advantages when we want to analyse the VO's, such as:;

- A more manageable representation of the VO's
- Understanding on which Blocks or Units are most vulnerable to VO
- Can give helpful information for possible future platform planning processes
- Gives an indication of allocation of resources, where one needs to strengthen
- And more

Regarding the location of each VO in the different parts of the vessels, a small section of the unit numberings is shown in the figure below.

Figure 3 gives an overview of how each vessel has been divided into Blocks and Units to easily handle the large amount of data a vessel like this possesses.

Sectia Nr.	Numele sectiei		Buc.	G(t)	Obs.
48SB	FR.23+150..FR.35-150		1	1.00	
48PS	FR.23+150..FR.35-150		1	1.00	
47SB	FR.11-150..FR.23+150		1	1.75	
47PS	FR.11-150..FR.23+150		1	1.75	
46SB	AFT..FR.11-150		1	8.20	
46PS	AFT..FR.11-150		1	8.20	
08SB	FR.23+150..FR.35-150		1	47.36	
08PS	FR.23+150..FR.35-150		1	47.36	
07	FR.23+150..FR.35-150		1	35.00	
06SB	FR.11-150..FR.23+150		1	38.75	
06PS	FR.11-150..FR.23+150		1	38.75	
05SB	FR.11-150..FR.23+150		1	26.5	
05PS	FR.11-150..FR.23+150		1	26.5	
04SB	FR.0+150..FR.11-150		1	27.5	
04PS	FR.0+150..FR.11-150		1	27.5	
03SB	AFT..FR.11-150		1	24.61	
03PS	AFT..FR.11-150		1	24.61	
02	FR.4..FR.23+150		1	15.02	
01	Aft..FR.0+150		1	60.00	

BLOC 01—461.11 tone

51SB	FR.56-150..FR.70		1	2.00	
51PS	FR.56-150..FR.70		1	2.00	
50SB	FR.46-150..FR.56-150		1	2.00	
50PS	FR.46-150..FR.56-150		1	2.00	
49SB	FR.35-150..FR.46-150		1	2.00	
49PS	FR.35-150..FR.46-150		1	2.00	
17SB	FR.70..FR.76-150		1	11.80	
17PS	FR.70..FR.76-150		1	11.80	
16	FR.59-150..FR.76-150		1	50.00	+ U HATCH
15	FR.59-150..FR.76-150		1	52.00	
14	FR.59-150..FR.76-150		1	50.00	+ L HATCH
13SB	FR.63-150..FR.76-150		1	33.97	
13PS	FR.63-150..FR.76-150		1	33.97	
12sup	FR.46+150..FR.59-150		1		
12inf	FR.46+150..FR.59-150		1		
11SB	FR.51+150..FR.63-150		1	49.82	
11C	FR.46+150..FR.59-150		1		
11PS	FR.51+150..FR.63-150		1	49.82	
10inf	FR.35-150..FR.46+150		1		
10sup	FR.35-150..FR.46+150		1		
09SBinf	FR.35-150..FR.51+150		1		
09PSinf	FR.35-150..FR.51+150		1		
09C	FR.35-150..FR.47-150		1		
09SBinf	FR.35-150..FR.51+150		1		
09PSinf	FR.35-150..FR.51+150		1		

BLOC 02— tone

OSCV 11

Figure 16: Section of unit numberings (VARD 2013)

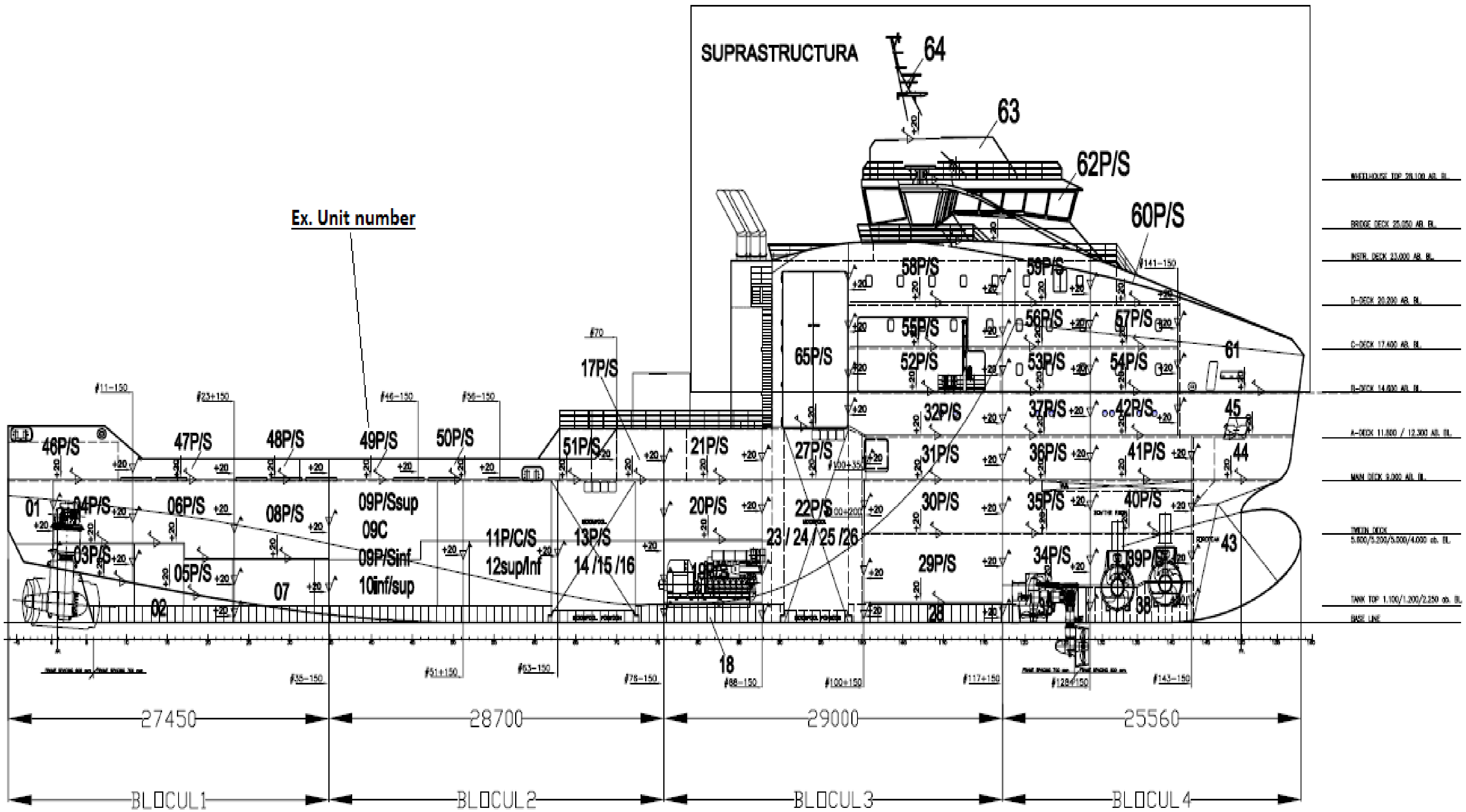


Figure 17: Block and Unit overview (VARD 2013)

As shown in figures 4 the vessel is divided into e.g. 4- 6 blocks + Suprastructura ++ (called block 7), where each block is divided into different units. Figures 4 are just a small section of several layers of dwg-drawings containing the entire vessel divided in blocks and units.

6.3 Variation Orders per Block

First to be presented is the number of VO's from the yard Tulcea, divided into projects and blocks on each projects. Underneath all four projects compared by the number of units in each project that have VO in it, and in which block they occurs. If we look at project 771, there are 237 VO's, which came from Tulcea. 61 units were subject to VO, and the table below shows a ratio of exposed blocks. All data contained needed information on costs and more, but due to the sensitivity of information, only selected data have been used in the thesis.

VO Tulcea.

Number of VO per Block, 771			Number of VO per Block, 776		
Block	Number of VO	Ratio	Block	Number of VO	Ratio
1	11	18,03 %	1	4	6,67 %
2	12	19,67 %	2	8	13,33 %
3	14	22,95 %	3	16	26,67 %
4	9	14,75 %	4	14	23,33 %
5	14	22,95 %	5	5	8,33 %
6	1	1,64 %	6	12	20,00 %
			7	1	1,67 %
Sum units with VO	61	100,00 %	Sum of units with VO	60	100,00 %

Number of VO per Block, 793			Number of VO per Block, 794		
Block	Number of VO	Ratio	Block	Number of VO	Ratio
1	9	14,29 %	1	7	14,29 %
2	10	15,87 %	2	9	18,37 %
3	15	23,81 %	3	11	22,45 %
4	11	17,46 %	4	14	28,57 %
5	5	7,94 %	5	3	6,12 %
6	12	19,05 %	6	5	10,20 %
7	1	1,59 %			
Sum	63	100,00 %	Sum of units with VO	49	100,00 %

Figure 18: VO Tulcea per block

No detailed numbers will be given in this thesis due to the sensitivity of the data material provided by VARD, only the trends of VO will be highlighted. We can see the trends of VO's in these tables that specially block 3 and 4 are exposed, as shown in figure 6.

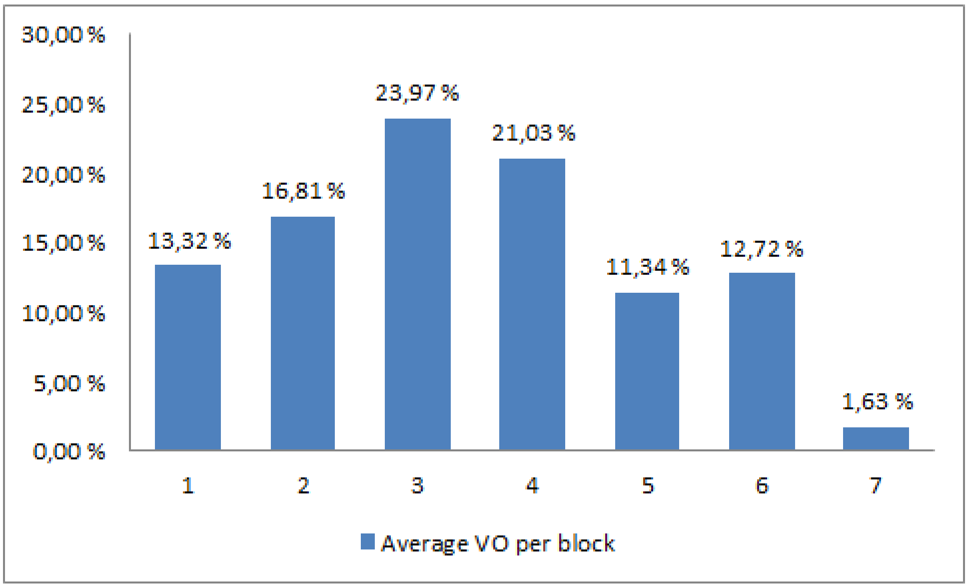


Figure 19: Average VO per Block

Figure 4 can give an indication of what and where to concentrate the effort on minimizing the number of VO's in the different projects. This will be discussed later on in this paper, than up against the highlighted literature in the review section.

6.4 Variation Orders per Unit

As mentioned, each block is divided into units. A unit can be anything from a small section of the engine room, a section on the mid-ship, or e.g. a section in the cabin department of the ship. The aim of analysing VO's per Units, is to see units have largest exposure to VO, and if any trend, propose measures to handle these variation orders. As an example here can be the sections of cabins, which perhaps is where standardization and platform planning can be a proper way of handling increased amount of VO's.

Figures below is divided into projects as shown earlier, and where only the units with the largest ratio of VO's is highlighted due to the constrain of space (large number of VO). The tables refers to the Block where the different units placed, with the ratio of how many occurrences of VO in each unit, divided on the total Sum of units with VO.

771

Block	Unit	VO per unit	Ratio
2	13	13	21,31 %
2	9	13	21,31 %
2	11	10	16,39 %
3	32	9	14,75 %
5	61	8	13,11 %
4	45	8	13,11 %
3	22	8	13,11 %

Figure 20: Ratio number of VO per unit

776

Block	Unit	VO per unit	Ratio
5	93	12	20,00 %
6	55	12	20,00 %
6	52	8	13,33 %
5	94	7	11,67 %
3	65	7	11,67 %
6	62	6	10,00 %
6	58	6	10,00 %

Figure 21: Ratio number of VO per unit

793

Block	Unit	VO per unit	Ratio
5	93	9	14,29 %
3	29	9	14,29 %
3	32	8	12,70 %
3	28	8	12,70 %
3	26	7	11,11 %
3	31	6	9,52 %
3	30	6	9,52 %

Figure 22: Ratio number of VO per unit

794			
Block	Unit	VO per unit	Ratio
4	55	4	8,16 %
6	62	3	6,12 %
6	63	2	4,08 %
6	57	2	4,08 %
6	52	2	4,08 %
4	45	2	4,08 %
4	42	2	4,08 %

Figure 23: Ratio number of VO per unit

Unit	VO per Unit
93	21
32	17
55	16
45	10
52	10
62	9

Figure 24: Comparison all four projects VO per unit

When comparing all four projects in table 11, we see which units that are most exposed to variation orders through several projects, and one can possible see a trend in which one can propose measures to handle these variation orders.

6.5 Variation Orders divided on SFI

SFI is a coding and classification system used by the maritime and offshore industry worldwide. This is used to classify all systems e.g. on board an Offshore Specialized Vessel like at VARD, and it is an international standard that provides a functional subdivision of technical information. SFI consists of a technical account structure covering all aspects of ship/rig specification, and it can be used as a basic data indexing standard for all systems in the shipping/offshore industry. SFI is used by shipping and offshore companies, shipyards, consultancies, software suppliers, authorities and classification societies (Wikipedia, references checked).

The use of SFI in the data-gathering makes it possible to evaluate efforts that are pointed down in a system detailed level. If you can point out that there tend to be higher uncertainty of VO occurrences in e.g. Ship Common Systems or in Equipment for Crew and Passenger, which is some of the main groups of the SFI System, it would be easier reallocate resources in the engineering to plan for measures to handle Error and Variation Orders.

MAIN GROUPS

0 HOURLY COSTS

1 SHIP GENERAL

2 HULL

3 EQUIPMENT FOR CARGO

4 SHIP EQUIPMENT

5 EQUIPMENT FOR CREW AND PASSENGER

6 MACHINETY MAIN COMPONENTS

7 SYSTEM FOR MACHINERY MAIN COMPONENTS

8 SHIP COMMON SYSTEM

9 SPECIAL EQUIPMENT / PACKAGE PRICES

Figure 25: SFI Main Groups (VARD 2013)

As shown in the figure 12, the vessel is divided into ten main groups, where each group is divided into subgroups for more details. This is a good and functional system that has been tested, in one way or another, by several industries. When it comes to the use of SFI by VARD, it seems to be somewhat deficient. The yard in Tulcea uses main groups 2 and 7 as two main groupings instead of using the specified SFI classifications spread all over the ten groups. This gives a distorted picture of where the actual time consumption and costs is spent. The author, with some help of a Project Coordinator at VARD Søviknes, tried to recapture some of the VO-list from Tulcea and implement the categorization of SFI in each order.

2			HULL
	20		HULL MATERIALS, GENERAL HULL WORK
		201	Hull materials (steel and aluminium)
		202	Transportation, sorting and storage of hull materials / units (incl. sandblasting, shoppriming)
		204	Pressure testing of tanks
		205	X-ray and ultrasonic testing of hull parts
		206	NC-data, templates, and moulding work
		207	Joining of hull parts in dock
		208	Purchasing of hull
		208 001	Hull weight:
			Price EURO / ton:
			Exchange rate EURO / NOK:
			Total price standard scope of work:
		208 002	**Building inspection of STX-NO people**
		208 003	Towing of hull incl. all taxes (insurance incl. in gr.no 111)
		208 004	Materials sent from **STX-NO** to the hull builder incl. freight
		208 005	Travel expences **STX-NO** people to / from hull builder
		208 006	Various aligning of hull after arrived at outfitting yard
		208 007	Extended outfitting at hull builder
		208 008	Mounting of Steering Gear
		208 009	Mounting of Rudder
		208 010	Mounting of Main Engines

Figure 26: A section of SFI Subgroups (VARD 2013)

Figure 13 is a small example of a subgroup in the SFI, just to show how the groups are divided.

In the VO lists from Tulcea, which we can see that there is still main groups of 2 and 7 that has the largest amount of VO's. This means that there is in the Hull-process and the System for Machinery and Main Components, the uncertainty of VO's is highest.

VO Tulcea, SFI

	771	776
SFI-group	Ratio of tot vo cost-TP	Ratio of tot vo cost-TP
0	0,00 %	0,00 %
1	0,15 %	0,00 %
2	64,43 %	39,77 %
3	5,69 %	3,11 %
4	7,50 %	6,03 %
5	3,74 %	1,98 %
6	0,00 %	4,03 %
7	14,47 %	43,16 %
8	4,02 %	1,93 %
9	0,00 %	0,00 %
	100,00 %	100,00 %

Figure 27: VO due to SFI, projects 771 & 776 (VARD 2013)

	793	794
SFI	Ratio of tot vo cost-TP	Ratio of tot vo cost
210	33,10 %	41,97 %
263	7,93 %	7,78 %
701	58,98 %	50,25 %
	100,00 %	100,00 %

Figure 28: VO due to SFI projects 793 & 794 (VARD 2013)

As shown in the figures above, Tulcea uses main groups 2 and 7 as a collection post, and does not use the SFI system in full. This is a weakness for VARD in their effort to be Lean and not at least due to the aspect of VO. The use of the SFI system could help pinpoint measures in systems that have higher uncertainty for a VO to occur. To be able to get the full overview of the VO's from Tulcea and to place them in the SFI group after the engineers in Romania has sent their VO-lists, is a heavy and extremely time consuming job, so the goal should be to implement it from the origin, namely by the engineers in Tulcea.

Item	Ratio of total VO-cost	Percentages
A	Modification based on updated Soviknes drawings	30 %
B	Additionally contractual works (VO) or requested by Soviknes during building of the vessel	26 %
C	MISCELLANEOUS-/ Other costs	44 %
D	VO without SFI	70 %
	Sum	100 %

Figure 29: Ratio of total VO cost, 771, Tulcea

The causes explained from Tulcea on why VO occurs are shown in table 16. The item A and B are self-explanatory, but item C is things like; Materials bought by VARD Tulcea on behalf of Søviknes, Modelling and redesign, Hotel costs for Søviknes representatives, and more. In this overview only project 771 is used since this is the only project that is completed. We can see that the largest costs comes with the "other costs", and sum is a summarization of A,B, and C. Item D is only highlighted to show the proportion of how many VO's comes without SFI marking of the total amount of VO.

The VO data from Norway was collected after the data from Tulcea, Romania is collected.. These data was given in excel format containing, as assumed, Customer Requested Variation Orders (potential profits). This is in some extend quite natural, since it is mostly outfitting work at the Norwegian yards. Of course there can be Error Orders occurring in the Norwegian yards as well, but the author got no such data materials. The aim of the

Norwegian organizations is to use and implement the mentioned Non-Conformance system, where specifications and costs of such errors are to be stored. This Non-conformance system is not working after its intentions as of today, and the information was of no use in this thesis project. The VO lists from the Norwegian yards where delivered up to data when it comes to the use of SFI.

Figure 17 illustrates VO-data from Norway where three projects are compared with the ratio in each SFI group of the total VO cost. Project 794 is omitted, because it has not come so far in the process, and by that the number of Norwegian VO is therefore too low to give any picture of any trends. As mentioned earlier, project 771 is completed and handed over to the end customer. One has to take into account how far they have come in each project. There is a trend in the finished project 771 that VO occurs in group 1 and 3, which perhaps are additional equipment etc. that naturally comes in the end of projects after a learning period and where the customer sees what more is needed to fulfil a future contract.

		771	776	793
SFI-group	Denomination	Ratio	Ratio	Ratio
0	HOURLY COSTS	0,00 %	0,00 %	0,00 %
1	SHIP GENERAL	51,97 %	1,27 %	4,78 %
2	HULL	0,28 %	17,51 %	0,61 %
3	EQUIPMENT FOR CARGO	33,24 %	2,44 %	14,78 %
4	SHIP EQUIPMENT	2,14 %	10,25 %	62,69 %
5	EQUIPMENT FOR CREW AND PASSENGER	3,65 %	22,69 %	8,54 %
6	MACHINETY MAIN COMPONENTS	-0,39 %	25,59 %	3,94 %
7	SYSTEM FOR MACHINERY MAIN COMPONENTS	1,30 %	6,88 %	0,00 %
8	SHIP COMMON SYSTEM	7,82 %	13,37 %	4,65 %
9	SPECIAL EQUIPMENT / PACKAGE PRICES	0,00 %	0,00 %	0,00 %
Sum		100,00 %	100,00 %	100,00 %

Figure 30: VO per SFI, Norway

Projects 776 and 793, which are in the outfitting process at VARD Søviknes and Brattvaag as of today, is shown in the figure above with their ratio of VO per SFI group. A discussion regarding the mentioned above are conducted further down in the thesis.

To count the number of VO per projects do not give a right or fully picture when it comes to Lead Time or costs in general. A VO can hold a material cost of e.g. 90 % and technical man-hour cost of 10 % or vice versa. In the oil industry in special, the delivery within agreed timeframe is essential, due to relatively extreme costs involved. This means that the **technical man-hours** are important in this picture. An example is show in figure 18 by the project 793, where the cost-numbers are gathered at a random point in time during the project to avoid any sensitive data displayed. Here we see the same ratio per SFI group towards the total VO costs, but at the same time there is a ratio and cost overview of how big a part of the VO cost is regarded to technical man-hours, and by that VARD can have a usable tool in their planning processes if one takes this into consideration. Technical price is man-hours * a number based on experience.

VO Brattvåg 793, Customer requested

SFI-group	Denomination	Total VO cost	Technical man-hours	Technical price	Ratio TP/TC $_{per\ VO}$	Ratio VO cost/Tot VO
0	HOURLY COSTS	kr 0	0	kr 0		0,00 %
1	SHIP GENERAL	kr 2 314 240	0	kr 0	0,00 %	4,78 %
2	HULL	kr 297 249	310	kr 201 500	67,79 %	0,61 %
3	EQUIPMENT FOR CARGO	kr 7 151 500	4850	kr 3 152 500	44,08 %	14,78 %
4	SHIP EQUIPMENT	kr 30 338 250	265	kr 172 250	0,57 %	62,69 %
5	EQUIPMENT FOR CREW AND PASSENGER	kr 4 135 177	2650	kr 1 722 500	41,65 %	8,54 %
6	MACHINETY MAIN COMPONENTS	kr 1 908 500	330	kr 214 500	11,24 %	3,94 %
7	SYSTEM FOR MACHINERY MAIN COMPONENTS	kr 0	0	kr 0		0,00 %
8	SHIP COMMON SYSTEM	kr 2 250 890	175	kr 113 750	5,05 %	4,65 %
9	SPECIAL EQUIPMENT / PACKAGE PRICES	kr 0	0	kr 0		0,00 %
	Sum	kr 48 395 806	8 580	kr 5 577 000	11,52 %	100,00 %

Figure 31: VO per SFI, Norway, cost example

So far into the project 793 we can see that in group 2 the cost of man-hours is 68 % of the total VO's in the group and 32 % is material cost or similar. While in group 8 the material costs are 95 % and just 5 % man-hours cost. This must be taken into consideration in the planning processes, also when planning for VO.

There were indications of the occurrence of VO due to DNV (Det Norske Veritas) during the data-gathering process at the yards. Therefore an effort was done to highlight both the number and cost of these VO's regarding DNV.

VO Tulcea

Project	Tot numbers of VO	Numbers of VO due to DNV	Ratio	Cost of DNV VO's
771	265	51	19,25 %	EUR 170 806
776	276	13	4,71 %	EUR 49 198
793	401	3	0,75 %	EUR 6 424
794	157	0	0,00 %	EUR 0
Tot	1099	67		EUR 226 429

Figure 32: VO due to DNV, Tulcea

Project 771 gives perhaps the best picture on the size of VO due to DNV. Almost 20 % of all VO's in project 771 was regarded to DNV, and here, there must be potential for improvement. The author had some interviews-/ conversations during the data-gathering process with both Project Managers and Engineers, and it seems to be crucial to be early with the planning for drawings and similar that DNV is to approve, so that work on the project are not started before having in hand the approval from DNV. It is continuously repeated that the technical basis for DNV is sent out from VARD to late, regarding the occurrence of VO, and that one must take into consideration that DNV is bureaucratic with less Time focus than VARD. This will be discussed later on in the thesis.

The above given findings during the data-gathering process will be further discussed in light of the theoretical framework and methodology of this thesis.

7 Analysis and discussion

In this chapter the results of the data-gathering processes will be analysed up against the Theoretical Approach and the Literature Review, and successively be discussed to give answers to the research question. At the end of the chapter, all analysis and discussions will be put together in one closing discussion.

7.1 Communication and Information Sharing

There were indications of allocation of responsibility is unclear in project organizations, and these indication was shown throughout all four project in this thesis. Planners and Coordinators e.g. do not always know who is responsible for which task at the different stages of the project. This will be discussed in this chapter.

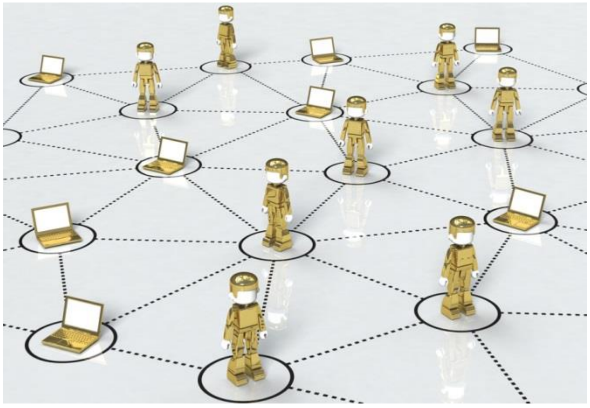


Figure 33: Communication & Information Sharing (www.userinsight.com)

A communication and information sharing (CIS) that does not work as good as it should, increases the internal uncertainty, which affects the occurrence of cost-driven error, in the context of Decision Making under Uncertainty (DMU). With increased uncertainty, you get a higher risk of Error Orders to occur. The goal should be to eliminate internal uncertainty or at least minimize it through the creation of flexibility. The theories in DMU use several approaches for this purpose; Gathering relevant data, Investing in e.g. Communication technology, Buying of relevant data, and more, to reduce uncertainty.

When it comes to the communication and sharing of information within an organization, it is difficult to totally eliminate any sources of error. It is after all humans involved in all decision-making. One should take into account the aspect of Human Bias when striving towards flexibility in CIS. This can e.g. be done by preparation of procedures that determines *what to where, at what time, between who.* Such an approach would be quite easier with proper data-base tools, like e.g. the SharePoint or similar. The communication of error in the production would have been communicated throughout the organization if a tool like the Non-Conformance had worked properly. This would have given “Learning” to the organization as a whole, and errors could be avoided in the future. With the right tools, the aspect of Human Bias and its influence on possible Error Orders can be minimized, but as mentioned above, not eliminated. It is also important to know who the people are who sits in the decision-making positions, and by the establishment of procedures and the right data-tools, you can if not eliminate, you can minimize the effect of the individual risk behaviour preferences to the Utility theory.

As mentioned in the data-findings, there were indications of problems in the sharing of information between different organizations within VARD, especially between Tulcea and Norway. Information must be reliable due to the uncertainty factor in asymmetric information. Information asymmetry between participating units leads to uncertainty, and as mentioned above uncertainty leads to inefficiency in the organization as a whole. This means information shared has to be as accurate as possible and organizations must make sure that the information flows with minimum delay and distortion. The information sharing refers to the information communicated to the supply chain partners, and the reliability in the relationship. There is a strong need for a team-building effort between different organizations and departments within VARD, and to implement the understanding of a “Common Goal”, namely to maximize the utility of both the owners of VARD and not at least the customers. To give too much information and learning to the Romanian yards could expose the Norwegian knowledge and technology, and set the organization in a dangerous situation in the future. So to share information between Norway and Tulcea must be about giving the needed information and not all. The access to a common data base would solve many of the issues of CIS between the different organizations, but with restricted access that gives the needed information only.

CIS is also important in the context of Lean, which VARD is striving towards. The sharing of information is one of the three sources of uncertainty in lean, where the focus on eliminating waste in e.g. the planning process, and the two others are reduction on sources of error and wrong sequencing. The Lean Thinking is about the knowledge on how and why different activities occur to be able to have simpler methods, eliminate waste, and highlight continuous improvements through better information sharing and decision-making at each level of the production. This shows how important it is to improve the possibility of sharing information and have proper communication channels in the organization and between different actors in the projects. Another aspect is that in e.g. the engineering processes, all required information is needed before a task supposed to start. Here VARD can use a "Bank of Recourses", which holds on information until all needed information in an engineering task (e.g. calculation and drawing of the foundations of the main engine) is complete, and then releases the specific job for execution. The implementation of good and functional data bases is essential to be able to be successful in CIS within a dynamic world. Even if the decisions of resource planning often are high up in the hierarchy, deviation will occur with a high probability due to e.g. weaknesses in the information flow and coordination of activities. This weakness of information flow can be reduced by a better data base-/ IT solution as mentioned, and probability of reducing waste and having continuous improvements, will help VARD in becoming Lean.

The finding of deficient information flow from the higher level of the organizational hierarchy and down to the "factory floor" was quite clear from the start of this thesis process. These findings are contributing to the occurrence of Error Orders in the different project, and a possible solution to these problems can save time and money. And perhaps one of the most important findings here, which tells the whole story of this finding, is that the information sharing down to the workers on the ground on Lean, and why Lean is so important for VARD, stops somewhere along the way from the top and down. Perhaps one of the most important things in the implementation of Lean Thinking is that Lean is a human based system that requires high involvement from the employees since they are doing the Lean Activities and takes decisions due to Lean every day. It is important that the employee are involved in the Lean Thinking and especially when implementing such a system in a production. To be able to have a success in e.g. a Lean-transformation, it seems important to develop high commitment levels for the employees, experience a strong belief in Lean, and that they get exposed to good communications and cultivate improved work methodology. Involvement and influence is the keywords. There have been several approaches on how to successfully get the "working-man" to strive for Lean. E.g. Toyota organized a "Suggestion Box", where each and one could come with suggestions on how their working-place could get Leaner, and by secure Continuous Improvements. Suggestions which proved to be effective and feasible, was given a reward. This showed to be successful and can be implemented in Lean shipbuilding as well. Another aspect was the actual sharing of information from the top and down. It indicates an incomplete communication- and information sharing strategy. Workers on the ground seem to be a reluctance through wards the Concept of Lean, and it seems that this is due to lack of knowledge, which comes from misconceptions through miscommunication. They feel that the concept is "pressed down on their heads", as we say in Norway, and that they in fact opposes the implementation. Perhaps an approach here could be to implement Lean step-by-step, as the author would have called it, starting with the learning and implementation on the top, and continue stepwise down the organization hierarchy, all the way down to the welder on the vessels. This way it is the immediate supervisor that provides training and measure the effects as the processes goes along. The human race is quite weird that way, that they do have problems with the top managers and their efforts to override the "Working-Man", and change their familiar everyday working life into something unfamiliar. Key to success is participating employees striving towards Lean in Full Corporation with the Top Management. An improved CIS reduces the internal uncertainty of the occurrence of Error Orders.

Also the communication and sharing of information between different disciplines within the engineering departments in the Norwegian yards, have indications on issues that affect the occurrence of Error and Variation Orders. Here time is the key word, drawings and other required technical documentation may be delayed so that a subproject or process starts before all needed information is available. Since information are missing when the construction of a task begins, and needed information are delayed, changes tends to occur after the task has been started, which leads to VO's and extension of the Lead Time. The internal uncertainty affecting this issue is; Technical documentation not in hand at due time, Lack of resources, Information distortion, and more. It is important to have a well-functioning teams working together in projects that know each other and communicates through a known project organization. The mentioned use of proper IT-solutions-/ data bases, with the use of "Information-Banks", and the postponement of "Milestones" in production, is steps that can be taken in order to minimize the internal uncertainty through the creation of flexibility.

7.2 Analysis, Variation Orders

In this section the different findings within VO will be analysed and discussed successively from the Case Study Analysis chapter.

7.2.1 Analysis of VO, Tulcea

The data findings show a trend of occurrence of VO in Block 2, 3, and 4, where Block 2 is the after mid-ship containing e.g. the cargo area, different tanks, and more. Block 3 is the forward mid-ship containing e.g. the main engine, as in project 771, the moonpool, and more. In Block 4 we have the thruster room, and more. Figure 34 shows the ratio of the number of VO occurrences in each block, divided on the total number of VO.

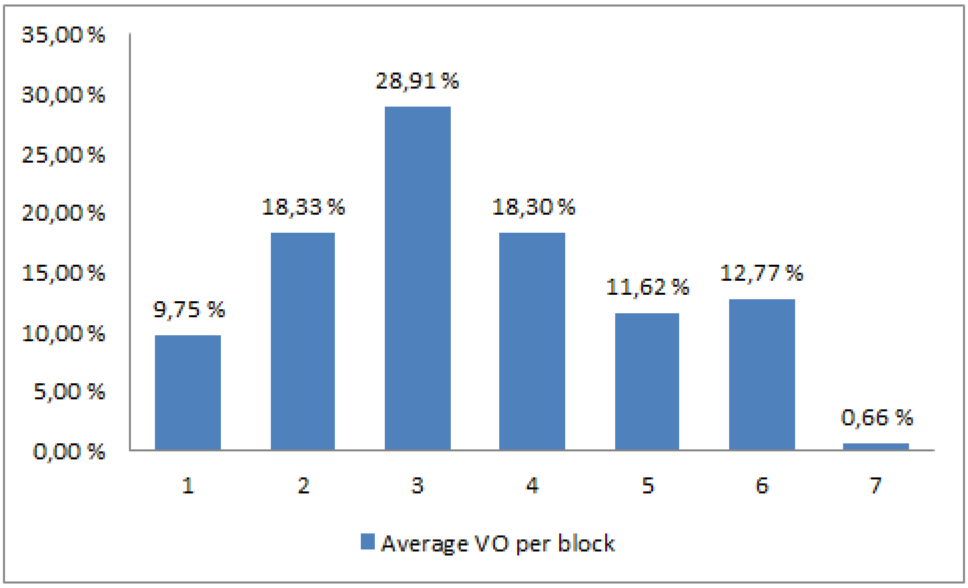


Figure 34: Average VO per block, all four projects

It is Block 2, 3 and 4 (overview of blocks is shown in Case Study Analysis) that stands out as the blocks with highest percent of VO occurrence, especially block 3. Block 3 is as mentioned Forward mid-ship containing among others the main engine and all systems regarded to this. A deeper analysis ought to be done on what systems and units, and more, within this block that causes this amount of VO's since the author do possess neither the underlying data, nor the skills to define the engineering details of such an analysis. The numbers in the figure above says much about the extent of where on the different vessels Variation Orders appears during the project lifecycle. A discussion on these finding comes in the end of this chapter.

When it comes to dividing VO on Units, this will give opportunities to pinpoint potential measures to handle the relatively large number of VO's in the different projects.

Figure 35 shows the Units with the largest number of VO in an average through all four projects. Due to constrain of space in the thesis, the entire list of VO per Unit will be in the section of Appendix.

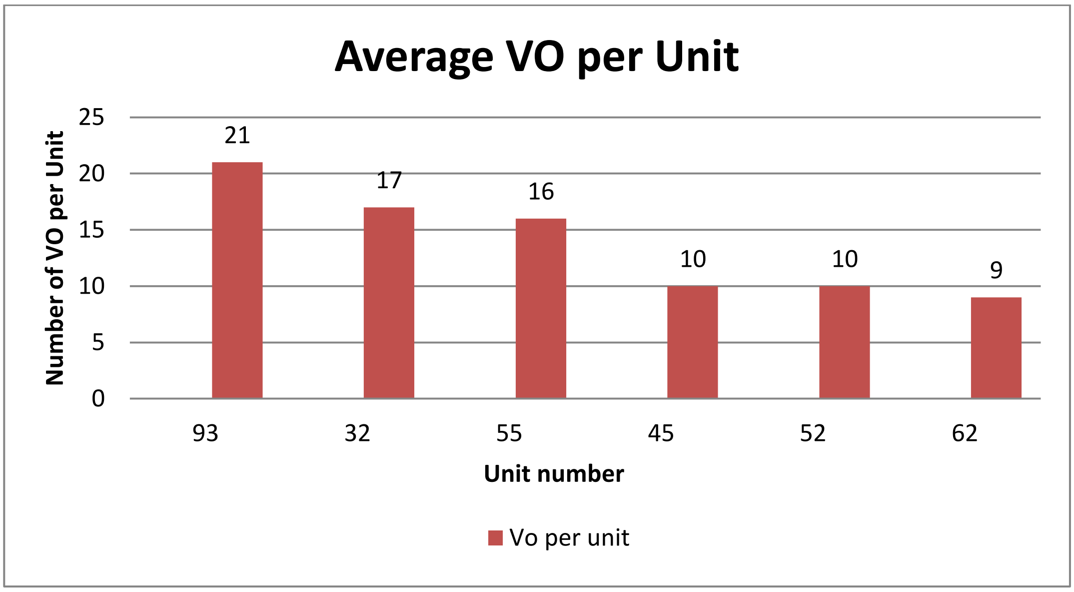


Figure 35: Example of Average VO per Unit, six largest over four projects

We can see the same trends with the occurrence of VO per Unit, where the units with most VO's are placed in Block 2, 3 and 4. The author has as mentioned earlier no data material provided to name the units, and what each unit contains, so this must be a future team-work with engineers, Project Managers, and more. The aim of the approach of seeing VO's up against Units, is to find if there is a trend in which units has largest exposure towards VO, and if any trend, propose measures to handle these variation orders. As an example here can be the sections of cabins, which perhaps is where standardization and platform planning can be a proper way of handling increased amount of VO's.

SFI is a coding and classification system, which is explained in the chapter; Theoretical Approach; Research Methodology and Data Collection Methods and Findings. This approach provides an even greater level of pinpointed findings of where VO occurs throughout the lifecycle of the different projects. Since the majority of the VO's is a part of a larger system like e.g. the propelled Thruster in Block 4, where electrical powering is provided from Block 3- Main Engine Room, it is can be beneficial to divide VO into which system on the vessel they belong. One can pinpoint resources due to the SFI-VO analysis, and see what system that has the higher risk of exposure to VO, and a VO can affect through several blocks and units.

The findings in SFI analysis of VO is presented underneath without project 794 due to the progress of the project has not come has not come so far, so that the underlying data is too small to give any ideas of trends. For project 771, which is delivered to the customer, the numbers show a high ratio for SFI group 1. This group contains General Costs, General Work and Models, rigging etc. This gives indicates perhaps a relatively large amount of redesigning in the engineering work of the vessel or other issues regarding SFI group 1. SFI group 3 is also relatively high, and this could indicate changes in things like; Special Cargo Handling Equipment, Loading/Discharging System for Liquid Cargo, or others. Perhaps by e.g. moving the mentioned Milestones ahead some weeks, VARD could have in hand all needed technical documentation required to execute the subprojects, and by doing so, minimize the occurrence of error orders. In project 776 it is SFI group 2, 5, and 6 which stand out with the highest amount of VO. The cause could e.g. be in the group of the Hull, that DNV classifications are in hand to late, in relation to the planned progress of the project.

VO Tulcea, SFI

	771	776
SFI-group	Ratio of tot vo cost-TP	Ratio of tot vo cost-TP
0	0,00 %	0,00 %
1	0,15 %	0,00 %
2	64,43 %	39,77 %
3	5,69 %	3,11 %
4	7,50 %	6,03 %
5	3,74 %	1,98 %
6	0,00 %	4,03 %
7	14,47 %	43,16 %
8	4,02 %	1,93 %
9	0,00 %	0,00 %
	100,00 %	100,00 %

Figure 36: VO due to SFI, projects 771 & 776 (VARD 2013)

Project 793 shows a large numbers of VO in SFI group 4, Ship Equipment. This could be; Manoeuvring Machinery and Equipment, Anchoring, Mooring and Towing Equipment, and more. This amount of VO can be caused by e.g. changes in customer requirements, which would give VARD a possible profit, but since as mentioned the author do not have neither the data material nor the engineering skills, this paper must assume the ratio of 80/ 20, where 80 % is cost and 20 % is profit in the data material obtained from Tulcea (Jan Emblemsvåg 2013).

	793	794
SFI	Ratio of tot vo cost-TP	Ratio of tot vo cost
210	33,10 %	41,97 %
263	7,93 %	7,78 %
701	58,98 %	50,25 %
	100,00 %	100,00 %

Figure 37: VO due to SFI projects 793 & 794 (VARD 2013)

As mentioned in the analysis above, a relatively large amount of VO is due to DNV (Det Norske Veritas). As shown in the figure below, the cost of Error Orders due to DNV for project 771 (which is delivered to customer) is proximity NOK 1.360.000,- and this is only for one project.

VO Tulcea

Project	Tot numbers of VO	Numbers of VO due to DNV	Ratio	Cost of DNV VO's
771	252	51	20,24 %	EUR 170 806
776	262	13	4,96 %	EUR 49 198
793	429	3	0,70 %	EUR 6 424
794	153	0	0,00 %	EUR 0
Tot	1096	67		EUR 226 429

Figure 38: VO due to DNV

Here, there must be savings for a company like VARD, by minimize the external uncertainty that DNV constitute, by the creation of flexibility and reallocation of resources to be sure of the delivery å drawings and such, is in time to ensure the progress of the projects. Perhaps planning for changes in Milestones can be an approach, by moving a bit farther into the project lifecycle, giving flexibility in the aspect uncertainty of occurrence of VO. The relatively large amount of VO in 771 may have several explanations and not only the possible delays in documentations and drawings and such. The project may have major challenges due to new design, new building technology, new technological solutions in outfitting, or other new features. But the findings indicate the first mentioned in this analysis, namely the issue of Time.

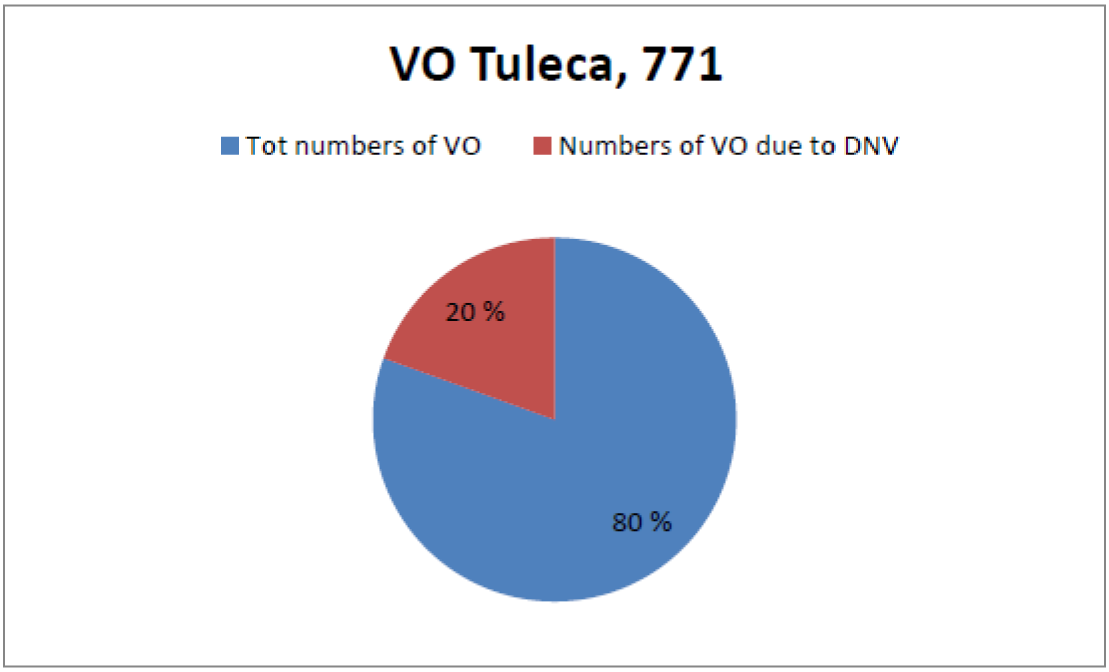


Figure 39: VO due to DNV, 771

The use of Project 771 as an example is because this project is finished and by that gives the most correct picture of the ratio of VO due to DNV. Causes that is mentioned in the Data Collection Findings, is e.g. too late delivered technical documentation in to DNV, and that DNV is bureaucratically organization where things take time, they are known for their bureaucracy.

Figure 40 is an example of what seems to be the causes of VO occurrences in the VARD Tulcea VO-list. It appears that 56 % of the VO's comes from has its origin in VARD Søviknes, which will be discussed further down.

Item	Ratio of total VO-cost	Percentages
A	Modification based on updated Soviknes drawings	30 %
B	Additionally contractual works (VO) or requested by Soviknes during building of the vessel	26 %
C	MISCELLANEOUS-/ Other costs	44 %
D	VO without SFI	70 %
Sum		100 %

Figure 40: Ratio of total VO cost, 771, Tulcea

The tablet also show that 70 % of all VO's from Tulcea is without any reference to the SFI System, which could be at great help in the future planning and handling of Variation Orders.

7.2.2. Discussion on VO, Tulcea

The second part of the cost driven error orders will be discussed with the analysis of findings, up against the Theoretical Approach and relevant literature.

The second part is as mentioned earlier, affected by external uncertainty in the context of Error Orders. The aim must be to create production flexibility in both the engineering and design phase, and throughout the whole project lifecycle.

The indications in the findings show that the occurrence of VO is caused by several aspects in the project lifecycle, all the way from the Marketing and Design and down to the Production itself. Most decisions taken, especially in the earlier phases of the project life cycles, are made under uncertainty, which requires the creation of flexibility in all affected processes. In these setting it is important to have the right people in the positions where decisions ought to be made due to the fact that the reduction of human bias, reduces the risk of decisions made are unfavourable. It is also important to have options, to have alternative ways to perform work, through seeing to previous phases of project lifecycles on earlier projects. To have several options on how to attack different issues, creates flexibility and by that reduces the uncertainty of VO occurrences. There are always some costs associated with flexibility, and options often come with an initial cost. In shipbuilding one could postpone as long as possible each "milestone", and by that create the flexibility needed to minimize uncertainty, by having in hand needed information on both technical documentation and customer requirements. Such measurements will help to avoid costly rework and waste in Planning, Engineering, and Production. The lack of needed information in the decision making process makes it difficult to make decisions and options are not valued exactly all the time and uncertainty makes their value increase. This can also be seen up against Platform Planning (PP), where Platform Planning helps in the creation of flexibility in the uncertain elements affecting Error and Variation Orders, and the flexibility will also help VARD in their pursuit of Lean Shipbuilding by the elimination of waste.

Such a platform approach will increase the flexibility and responsiveness in the construction processes by the sharing of production processes and components, which in the end will give increasing product development at lower costs and less use of resources. The example used in the Literature Review on the development of Platform Planning in the physical section of crew cabins, where the crew cabin must be as a whole section that can be lifted in to the vessel when the hull is being built, and should contain all intentional facilities planned in the PP process. To be able to execute something like this, there will be a need for team-work between different departments and activities. A development of a so called Core Team which consists of members from Marketing, Design, and Engineering and Production Functions, since the issue of PP and decisions made under uncertainty, is necessary for a successful outcome of the process. The Core Team should use available tools to be sure of good qualitative PP through elaboration of The Product Plan, The Differentiation Plan, and The Commonality Plan. This will give the company good conditions to create platform that allows an efficient and quickly development of a set of differentiated products covering the customers' expectations. A Product Platform must be planned, designed, maintained, changed, and archived like other artefacts. PP will provide flexibility throughout the project lifecycle, and by that, reduce the risk of costly orders, but also give the opportunity of profit through customer required change orders.

The three areas of theories, namely Decision-Making under Uncertainty, Platform Planning, and Lean Thinking goes together hand-in-hand in the issue of Error and Variation Orders, with the necessary and additional chapter of Communication and Information Sharing. The need for planning all through the shipbuilding process, from Design and to the production itself, is consistence in the theories. The mentioned Core Team would also be a part of the Lean planning teams, which divides the planning into four different plans, namely:

5 Milestone Plans, that uses the reference point of different milestones made for periods of 12-18 months, which shows the completion of different work packages and-/ or larger phases of the project.

6 Discipline Plans, where more detailed information are highlighted than in the Milestone Plans, planning period of 6-9 month

7 Period Plans, where details of the Discipline Plans is set into sound activities, deviations reports back to the Discipline Plan, Planning period of 5-8 weeks

8 Weekly Plans, which contains executable sound activities, reports deviations back to Period Plans, and 1-2 weeks planning period

The most important in these planning is Sound Activities, which counteracts waste throughout the project lifecycle. By having the Platform Planning in the context of Lean, where both emphasizes standardization and effective use of resources, would create flexibility in the aspect of uncertainty for error order to occur. By managing the VO issue in the Block and Unit sections through the use of PP, will give reduced costs, organizational learning, and flexibility in the project lifecycle. Continuous improvements and Platform Management Maintenance belongs together, and helps organizational learning. In the same way, SFI can be used to handle VO's through the planning process and focusing on which system is most vulnerable to VO. The planning must decide where to use resources, e.g. to prevent error orders due to DNV. The aspect of DNV can also be taken into consideration in planning of Blocks and Units, and not at least by the right Platform Planning.

For a company to manage all these mentioned, they must have the ability to communicate and share the required information. No planning or production can be executed effectively without this, especially towards the yard in Tulcea. The data base in use in Norway today, SharePoint, is perhaps a useable tool in sharing information within each project, but there is a need for Tulcea to have access to a similar data base system since the findings indicated a lack of Communication and Information Sharing between the departments in Norway and Romania. The right communication and information sharing will if not eliminate, it will minimize the uncertainty in the issue of VO and more. As mentioned earlier, it is important to only give "needed" information, and not more due to the danger of losing technological advantage.

Also so the findings of differences in organizational culture must be taken into consideration in the aspect of handling VO's. Here a new data base approach would create favourable conditions to reduce opportunistic behaviour from the organization in Tulcea. Other measures must also be implemented. As it is today, one cannot handle the uncertainty aspect as internal, but it must be handled as external with the measures that requires. This means there is a need to think Inter Organizational Relationship (IOR), and the strengthening of such. A IT-solution can link together organizational processes, and give the required flow of accurate and timely information needed to avoid Error Orders, and there is a need for a IOR to function, if not, the sharing of information will not succeed, and the amount we see today on VO's, will continue in the future.

7.2.3 Analysis of VO, Norwegian yards

As mentioned in the Data Collection Findings, the project 794 is omitted due to the small number of relevant data on the Norwegian variation orders. We are now talking about the Profit Driven VO, creating opportunities for the industry.

SFI-group	Denomination	771 Ratio	776 Ratio	793 Ratio
0	HOURLY COSTS	0,00 %	0,00 %	0,00 %
1	SHIP GENERAL	51,97 %	1,27 %	4,78 %
2	HULL	0,28 %	17,51 %	0,61 %
3	EQUIPMENT FOR CARGO	33,24 %	2,44 %	14,78 %
4	SHIP EQUIPMENT	2,14 %	10,25 %	62,69 %
5	EQUIPMENT FOR CREW AND PASSENGER	3,65 %	22,69 %	8,54 %
6	MACHINETY MAIN COMPONENTS	-0,39 %	25,59 %	3,94 %
7	SYSTEM FOR MACHINERY MAIN COMPONENTS	1,30 %	6,88 %	0,00 %
8	SHIP COMMON SYSTEM	7,82 %	13,37 %	4,65 %
9	SPECIAL EQUIPMENT / PACKAGE PRICES	0,00 %	0,00 %	0,00 %
Sum		100,00 %	100,00 %	100,00 %

Figure 41: VO per SFI, Norway

Project is completed and delivered the customer, so this project will give the most complete picture of VO's in the Norwegian yards. The two other projects is showing trends of VO. 771 has a relatively large number of VO in SFI group 1, which is a group of general costs, technical documentation, projecting, and more. This might suggest a large amount of engineering changes due to modifications in SFI group 3, compared to signed contract. Changes in group 3 might suggest changes in end-customer requirements, meaning the oil companies have a need for new technology in e.g. freight of drilling equipment out to the offshore facilities. The changes in 776 and 793 are shown in the table above, and which groups that is affected by these changes. Changes in the Hull of 776 can indicate changes in preferences from the end-customer, likewise the changes in group 5 and 6. 794 have a huge amount of VO in group 4, which can indicate changes due to new preferences in e.g. the Anchoring, Mooring and Towing Equipment. What the causes of the actual changes are is not provided by the gathered data material.

7.2.4 Discussion on VO, Norwegian yards

In the setting of the profit driven variation orders, it is important to be able to both see and to seize the opportunities when they arise. This can be done by the use of the Option Theoretical approach, where you want to identify alternative ways of performing the work, meaning the all activities from Marketing, Design, Engineering, and to the Production. This must be a continuous process where all levels in the project lifecycle are participating in seizing possible opportunities. The Option Theory suggests an approach where you want to postpone different decisions in the production process, so that one gets closer to the choice of the customer, and by that reduces the uncertainty of a VO to occur. This is also in the Lean Thinking spirit, where the aim is to e.g. eliminate waste. The postponement as mentioned above gives the opportunity and advantage of a situation by waiting on information needed to make the right decision. In this setting one can get flexibility through the existence of options, and flexibility reduces uncertainty in the decision process. In shipbuilding one could postpone as long as possible each "milestone", and by that create the flexibility needed to minimize uncertainty. The chance of having all the information needed from e.g. the customer requirements will increase dramatically as days passes by in the project. All flexibility comes with a cost, so the decision-maker needs to make cost-benefit evaluation and find what option is the best in the current state of the project, is the option worth the price or not?

The mentioned flexibility can also be created through the Platform Planning approach. By having platforms of shared product groups, units, blocks, SFI's, and so on, one can have a standardization that can give profitable changes if the customer has other preferences on the end product than the standardized option. All this mentioned are in need of the right planning through e.g. the Core Team. This planning must be according to Lean Planning, Last Planner, and the needed Sound Activities to minimize waste and ensure efficiency.

Also by having the right conditions for Communication and Information Sharing, would help the organization in their effort to seize opportunities for profitable VO's, and it will help in the context of creating flexibility due to the uncertain environment. By having a common data base, which is mentioned several times, you also will be able to communicate opportunities throughout the entire projects lifecycle, and between all actors involved. This is specially for the Norwegian part of the projects, since the indications is highest amount of profitable VO's in the outfitting stages of the vessels, but we see, by experiential numbers, that 20 % of all VO's in Tulcea also are profit driven. So the sharing of information on opportunity must include the organizations in Romania. If such communication and information sharing is established, you can build greater trust between different parties within VARD, and by that reduce the opportunistic behaviour, which will reduce the uncertainty of Vo occurrence. A proper and log-lasting Inter Organizational Relationship must be established.

7.2.5 Discussion on the Research Questions

This thesis has elaborated and searched through relevant literature and seen this up against a theoretical approach, to highlight issues in the Error and Variation Order Handling in the shipbuilding industry. Two research questions was drawn up though the research methodology, and tried answered through data collection, analysis and discussions. These research questions are:

1. What is the impact of Error & Variation Orders on Lead Time and Costs, and how can these be handled without extending the Lead Time?
2. What are the main causes of why Error and Variation Orders occur?

These issues have been discussed through the Case Study Analysis, Analysis and Discussions, and potential causes and possible approaches are highlighted to answer the research questions.

Perhaps the most important in this setting is to find ways to handle the Variation Orders (VO) that does not extend the lead time due to the high costs involved in the offshore industry. If a vessel is not ready at an agreed time, someone must pay for the lost revenues and such. The responsibility on delivery on time rests on the shipbuilder most of the time. The findings and analysis has shown how VO affects costs and lead time in the different projects. If we see to the VO's caused by DNV as an example, these stands for up to 20 % of the VO-costs alone. It is obvious that the relatively large amount of VO affects the lead time, and that resources are being used inappropriate and could have been used elsewhere. The effect VO's has on the cost on each project was also highlighted, and the effect was relatively significant. With the right effort to handle VO, you will increase profits and improve the uncertainty regarding lead time. How to handle VO in the shipbuilding industry has been shown throughout this paper, and what measures seems to be needed to improve these orders. Communication and Information Sharing should be improved internally, since there are indications of reduced quality of information sharing and communication. A proper use of a communication tool, such as SharePoint, should be reintroduced for more effective use. Likewise should the Non-Conformance tool be highlighted for future learning and perhaps used as Key Performance Indicator for measurements in the context of VO. Also the communication between and throughout organizations should be improved to e.g. help the implementation of lean as shown in the findings, where workers down at the factory floor are reluctance to this thought. There is a need to see the communication towards Tulcea in another light; not internal but external uncertainty is what affects the decisions made due to e.g. the cultural differences, opportunistic behaviour, etc. A strong and predictable Inter Organizational Relationship must be established to minimize the occurrence of VO in Tulcea. There has also be highlighted the importance of coordination of different disciplines, departments and organizations in the planning to give reduced amount of VO in the projects, by the use of Platform Planning, Lean Thinking, Communication and Information Sharing, up against decisions made under uncertainty. Creation of flexibility to minimize the uncertainty of VO occurrence seems to be the key to success, with the help of improved information throughout the organizations and to-wards Romania. The highest amount of VO originates from the issue of communication of needed and required information, and the issue of time in engineering. The right measures will help VARD in becoming more Lean, and to enhance their bottom line.

8 Conclusions

There were early indications during the thesis work on *inefficiency in communication and information sharing* process in the VARD organisation. This inefficiency was identified on different levels: from top level management down to the factory floor, between the different disciplines involved in the shipbuilding , between different departments and, last but not least, between the design and outfitting yards in Norway and hull constructor yard in Romania. This latter is perhaps the main cause of the relative large number of variation orders in the different projects.

Delivery lead-time was also identified to be a major factor driving variation orders. Delays in technical documentation and drawings from engineering were causing unnecessary delays in information sharing between engineering and production. One major source of technical changes during the production process is the DNV (Den Norske Veritas). VO's generated by DNV stands for 20 % of all VO’s, and holds a relatively large cost for VARD.

Different theories were highlighted in this thesis to find possible ways to handle VO. The necessity to improve the quality of Communication and Information Sharing is highlighted, since there were indications of problems in getting the needed and required information to an acceptable time. Efforts to improve communication and information sharing between the hull-constructor in Romania and the outfitting yard in Norway will potentially help reducing the opportunistic behaviour from the Romanian yard, and increase the utility of both the owner and customer.

It was indicated that Platform Planning and Lean theories are potentially useful to improve VARD's decision making processes and ability to handle late variation orders and unexpected errors. Planning processes based on the 'Sound activitiy' concept (from the Last Planner/Lean theory) potentially helps reducing waste (variation orders not generated by the customer are seen as waste) and improves the outcomes throughout the project lifecycles. Having the right key-personnel, in the right places in an organization, is the key to success.

9 Further research

The focus of this thesis was on identifying a theoretical framework for further analysis of the subject "variation order handling", and on data collection to identify challenges and patterns that drive variation orders. It is to be pointed out that the data collected from the hull constructor in Romania doesn't separates between customer driven changes (profit drivers) and other changes requested by the outfitting yard in Norway (cost drivers). Presently, there is no separation between these data. It is suggested as further analysis to separate between these changes, as they require potentially different actions. Furthermore, variation order handling is a potentially large subject that requires more time and resources than it was available for this thesis. As further research, it is suggested to explore more deeply how the identified theories are to be applied concretely to reduce errors and to handle late customer preferences without disturbing the processes and increasing costs considerably.

References

VARD. (2013). "VARD a fincantieri company." from http://www.vard.com/Pages/default.aspx.

ArtofLean. (2013). "Art of Lean." 2013, from http://artoflean.com/.

Ballard, H. G. (2000). THE LAST PLANNER SYSTEM OF PRODUCTION CONTROL. Phd, The University of Birmingham.

Emblemsvåg, J. (2010). IMPLEMENTING LEAN PLANNING AT

STX NORWAY OFFSHORE AS SØVIKNES (STX-NOS). 19.04.2010, STX-NOS.

Lacksonen, T., B. Rathinam, F. Pakdil and D. Gülel (2010). Cultural Issues in Implementing Lean Production. Industrial Engineering Research Conference. Cancun, Mexico.
, University of Wisconsin-Stout.
Losonci, D., K. Demeter and I. Jenei (2011). "Factors influencing employee perceptions in lean transformations." International Journal of Production Economics **131**(1): 30-43.

Steve, L. H. (2003). "An introduction to Lean Production System." FDM **75**(13): 58.

Toyota. (2012). "Toyota Production System." from http://www.toyota-global.com/company/vision_philosophy/toyota_production_system/.

businessdictionary.com. (2012). "businessdictionary.com." from http://www.businessdictionary.com/.

Gordon, J. R. (2002). Organizational behavior: a diagnostic approach. Upper Saddle River, N.J., Prentice Hall.

Kahneman, D. and A. Tversky (1979). "Prospect theory: An analysis of decision under risk. Econometrica (pre-1986) 47, (2): 263, http://search.proquest.com/docview/214665840?accountid=40814 (accessed March 31, 2013)." Econometrica **47, (2): 263**.

Kahneman, D., A. Tversky and P. Slovic (1987). Judgment under uncertainty: heuristics and biases. Cambridge, Cambridge University Press.

Lovallo, D. and O. Sibony (2010). "The case for Behavioral Strategy " McKinsey Quarterly.

Morse, P. M., G. E. Kimball and S. I. Gass (2003). Methods of operations research. Mineola, New York, Dover.

Wallace, S. W. (2005). Decision making under uncertainty. [Molde], [S.W. Wallace].

Ballard, G. and G. Howell (1998). "WHAT KIND OF PRODUCTION IS CONSTRUCTION?" leanconstruction.org.

Buvik, A. and T. Reve (2002). Inter-firm governance and structural power in industrial relationships: the moderating effect of bargaining power on the contractual safeguarding of specific assets. Sandvika, Handelshøyskolen BI.

Golicic, S. L. and J. T. Mentzer (2005). "EXPLORING THE DRIVERS OF INTERORGANIZATIONAL RELATIONSHIP MAGNITUDE." Journal of Business Logistics **26**(2): 47-71.

Li, S. and B. Lin (2006). "Accessing information sharing and information quality in supply chain management." Decision Support Systems **42**(3): 1641-1656.

Maurer, I. (2010). "How to build trust in inter-organizational projects: The impact of project staffing and project rewards on the formation of trust, knowledge acquisition and product innovation." International Journal of Project Management **28**(7): 629-637.

Premkumar, G. P. (2000). "Interorganization Systems and Supply Chain Management: An Information Processing Perspective." Information Systems Management **17**(3): 1-14.
Alblas, A. (2011). PLATFORM STRATEGY FOR COMPLEX PRODUCTS AND SYSTEMS. PhD, University of Groningen.

Fisher, M., K. Ramdas and K. Ulrich (1999). "Component sharing in the management of product variety: A study of automotive braking systems." Management Science **45**(3): 297-315.

Lancaster, K. (1990). "THE ECONOMICS OF PRODUCT VARIETY: A SURVEY." Marketing Science (1986-1998) **9**(3): 189-189.

Randall, D. T. (2012). Log 904- Seminar Product Variety. Molde.

Robertson, D. and K. Ulrich (1998). "PLATFORM PRODUCT DEVELOPMENT."

Gratton, C. and I. Jones (2010). Research methods for sports studies. London, Routledge.

Gripsrud, G., U. H. Olsson, et al. (2004). Metode og dataanalyse: med fokus på beslutninger i bedrifter. Kristiansand, Høyskoleforl.

Hox, J. J. and H. R. Boeije (2005). Data Collection, Primary vs. Secondary. Encyclopedia of Social Measurement. K.-L. Editor-in-Chief: Kimberly. New York, Elsevier**:** 593-599.

Kristoffersen, S. (2012). Nextship - lean shipbuilding: state of the art and potential to be "lean" in multifariously distributed maritime design, engineering and construction. Molde, Møreforsking Molde AS.

Meredith, J. (1998). "Building operations management theory through case and field research." Journal of Operations Management **16**(4): 441-454.

Thomas, J., K. Nelson and S. J. Silverman. (2011). "Research Methods in Physical Activity." Retrieved 02.05, 2013, from http://www.humankinetics.com/excerpts/excerpts/explore-four-methods-for-collecting-qualitative-research.

Yin, R. K. (2009). Case study research: design and methods. Thousand Oaks, Calif., Sage.