Master’s degree thesis

LOG950 Logistics

The Human Bias in Shipbuilding Decision-making
Case study STX-OSV Søviknes

Youssouf Traore and Yuliya Rymarava

Number of pages including this page: 114

Molde, 2011.05.24

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Preface

This master thesis was made to evaluate the effect of human bias in shipbuilding decision-making. It was written in cooperation with STX-OSV Søviknes shipyard. The aim was to identify the main sources of uncertainty in the engineering activities and the main human bias affecting the decisions. We tried to determine ways, which create flexibility to cope with the uncertainty and reduce as much as possible the effect of human bias on the decisions. This thesis is submitted for the completion of our Master's degree in Logistics and Supply Chain Management. It contains the work done from January to May 2011 both in Molde and at STX-OSV shipyard in Søvik and it is the continuation of our proposal presented in January 2011.

We would like to take this opportunity to thank sincerely the persons who helped us to achieve this work. We thank our advisor and supervisor Hajnalka Vaagen for all her guidance, ideas, patience and recommendations during this period. The discussions we had with her were invaluable. Our sincere thanks go as well to Kristina Kjersem from Møreforsking AS, who has shown a large and consistent interest in our project during the whole period. Our numerous scientific discussions and her constructive comments have greatly helped to improve this work.

The research part of the thesis was done while we were living at STX OSV Søviknes shipyard. It was a great pleasure working there. Our sincere gratitude goes to Jan Emblemsvåg, Director of the shipyard, for his time, inspiration, guidance and support. Jan, thanks for your advices and for acting as a mentor to us. It was an honor working with you. We also thank Tore Huse, HR director, Per Gunnar Søvik and all the workers of the engineering department for being so kind, understanding and supportive during the research.

We would also like to address some special thanks:

From Youssouf Traore,

To my beloved parents, my father Nouhoun Traore, my mother Mariam Traore and my sister Nakany I will like to express my profound gratitude for sending me permanently their guidance, moral support and affection.

I am also grateful to Pr Aka Joseph E., vice-president of the University of Abidjan Cocody in Ivory Coast, for being the one at the beginning of this journey.
Last but not least, I thank all my friends and fellow students who made my stay in Molde so pleasant.

From Yuliya Rymarava

I would like to thank my father, Vladimir Rymarav, for his invaluable support, love and patience and for all the lessons I've learned from him. I send my thanking and devotion to my wonderful mother, Galina Tikhomirova, whose persistence and love gave me strengths and ideas for writing this thesis. I want also to thank my brother, Dmitry Rymarav, for all our meaningful chats and for his wonderful advices.

I want to express my deep gratitude to my friends, Pavel Shchalkunou, Andrey Shelepko and Alesya Tcharnikhovich for being there for me and for all your love, support and help.
It is very important for me to acknowledge my teachers, Irina Gribkovskaya, Irina Mamonova, who gave me this wonderful opportunity to study in Molde University College and Alexander Voronin, who showed me what true logistics is

Youssouf Traore and *Yuliya Rymarava*

Summary

The field of decision-making in lean environment was not studied enough, and that inspired us to run more precise investigation in that area. Nowadays, with the implementation of lean in numerous companies all over the world, it is important to understand not only the truisms of lean, but also what impact does it have on sub-processes of activities of the organization. One of those sub-processes is decision-making. As it is known, decisions are made by human and that means those decisions are influenced by many human factors. One of those factors is biases and framing effects, that had been closely studied by Noble prize winner Daniel Kahneman and his co-author Amos Tversky. They studied those effects from a point of view of economical psychology, yet not going into details. We took their work as a basis for our study of human biases and decision-making under uncertainty in shipbuilding.

In this thesis, we try to take a closer look into three theories (lean planning, lean information flows and information in supply chain and decision-making under uncertainty). We connect them in order to achieve an understanding of how those aspects of organization's activities are connected and how they influence on each other.

This study was performed with two main goals in mind. The first goal was on one hand to understand and identify the main sources of uncertainty in the engineering process; and on the other hand to identify the main human biases that affect the decisions made in the engineering process. The second goal was to see the theoretical aspects of decision-making through the process of lean planning and lean information flows implementation and to identify ways to reduce the impact of the human bias on the decisions made.

In the first part of the thesis, we describe the theoretical aspects of named problems, giving a great attention to aspects of contemporary ways of lean implementation and current areas of study of decision-making under uncertainty. In the second part, we describe our research, which was performed in the engineering department of STX OSV Søviknes shipyard. From the analysis of the results we obtained, we identified potential methods of solving arisen problems.

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CHAPTER 1 - INTRODUCTION

In shipbuilding industry, the different actors in the value chain make different kind of decisions concerning their functions. On one hand, offshore shipbuilding has an engineer-to-order production system where the level of specification and detailed decisions required is high and each construction project is different from the other ones. On the other hand, lean thinking is a hot topic in most of the shipbuilding companies in order to improve their value chains performance. It helps to improve the financial results through waste elimination in the planning and the production process. The objective of lean implementation is to reduce the lead-time and the work in progress, to have frequent and complete deliveries from suppliers in small lot sizes and to synchronize the planning, development and production activities. The coordination of these actions requires all the actors and partners to make decisions in the design, planning, engineering and production processes in order to achieve these goals. In organizations, before designing and implementing a particular planning or production system, it is important for the management to understand what kind of information is required through the value chain, who analyses and decides and where does this occurs.

These assessments permit to guarantee the reliability and the quality of the organizational decision-making.

1.1 – Motivation

We have been motivated by our topic because it induces a subject not so much discussed in supply chain literature: the behavioral effect in decision-making under uncertainty in shipbuilding. The idea is to determine how human behavior affects strategic and operational decisions made in companies. Studying this subject enables us to see how human biases and perceptions affect the quality of the information and the related decisions made in light of uncertainty. This is important because people located at different stages in a supply chain processes information in different manners. The problem is likely to occur in offshore shipbuilding industry, characterized by a high level of uncertainty, variability and system disturbance as well as a large number of people involved in the decision process. STX Norway is one of the leading companies in offshore and supply vessel's market. Hence, to maintain its position, it is important for it to reduce the level of uncertainty and create more flexibility on its activities. Uncertainty in offshore shipbuilding can be classified under three main categories as in Figure 1:

- suppliers' uncertainty,
- production uncertainty
- ship-owners' uncertainty.

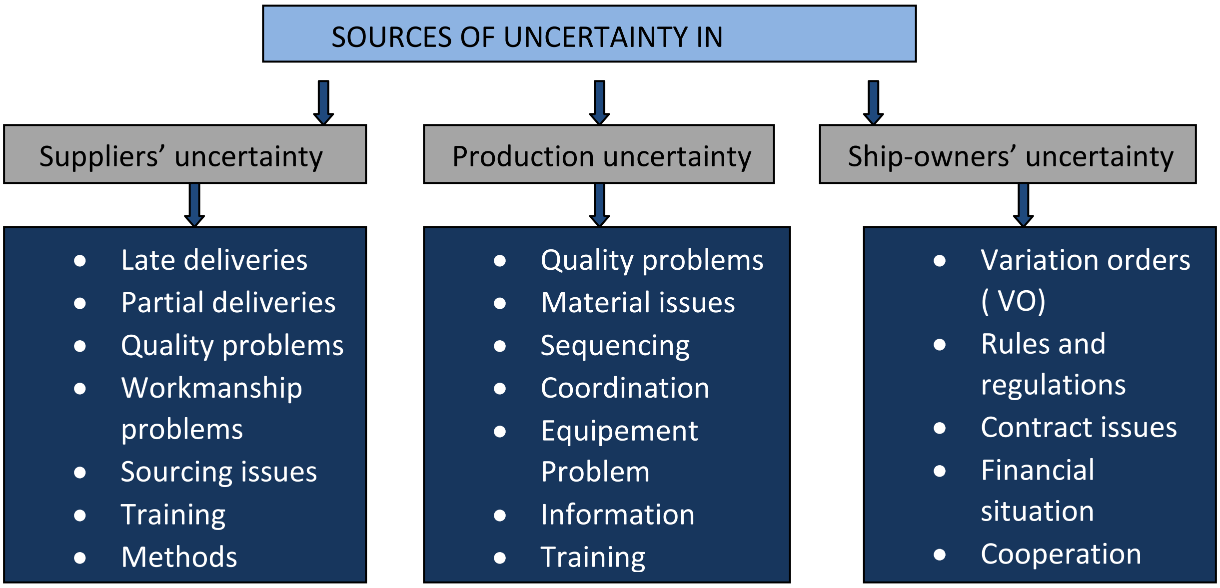


FIGURE 1: SOURCES OF UNCERTAINTY IN SHIPBUILDING

In addition to uncertainty, the introduction of time pressure through deadlines, as it appears in shipbuilding project scheduling, induces some affective and emotional states that may change the quality and the nature of the decisions made by the different actors along the organizational chain (Maule et al. 2000). The presence of time pressure, uncertainty and a limited capacity to process the information and perform complex computations leads to the use of simple heuristics for decision-making. They serve to estimate probabilities and values but they are often misleading (Wallace, 2005). Wallace (2005) discusses these heuristics and rules of thumbs based on the work of Kahneman et al. (1987). Kahneman and Tversky (1984) describe three major groups of heuristics: representativeness, availability and anchoring and adjustment, which will be thoroughly discuss later in this thesis. Another important factor affecting the decisions is framing effect. With framing effect, depending on how questions are formulated people attitude toward risk varies. They become risk averse when the problem is put in a positive frame or gain aspect and risk seeking when the problem is presented in a negative frame or loss aspect (Kahneman and Tversky, 1979). Therefore, asking the incorrect question can affect considerably the outcome (Wallace, 2005). Pieters (2004) who studied framing effect in petroleum industry shows how the errors in probability estimates can be high because the decision-makers are subject to biases and framing effect and use heuristics to make decisions under uncertainty. The error margin can vary between 30% and 98%, which is quasi-complete inaccuracy. To counteract the fact that it is impossible to have all the information required to make a decision; there should be a tailored decision-making process, which allows to reduce as much as possible the impact of the above mentioned systematic errors (ibid).

1.2 - Research question

In this regard, our thesis is an interdisciplinary work combining supply chain management through lean planning, decision-making under uncertainty and behavioral psychology. The aim is to discuss the effects of human bias in decision making under uncertainty in the engineering process. We focus on two aspects:

1- The identification of some of the potentially major uncertainties and human bias in shipbuilding decision-making.

2- The relation between the defined uncertainties and lean planning, to find ways to reduce the impact of human bias on the decisions made.

1.3 - Research approach

Our research was done through three questionnaires in cooperation with the management of the case company STX-OSV Søviknes. Questionnaires were addressed to the engineers of the engineering department. They were sent by email to the respondents who gave it back on paper form. These questionnaires addressed different aspect of our study. Questionnaire 1 was related to uncertainty and lean planning. Questionnaire 2 was made to identify the main human biases and reveal the existence of framing effect. The third questionnaire permitted to evaluate professional maladjustment. The results of these questionnaires served as basis for our analysis and we did not have any interview for data collection. During our research period, we stayed most of the time on site at STX-OSV Søviknes and had different meetings with the management to reframe the research and questionnaires. Meetings were arranged with the engineers as well to give them an idea of the purpose of our research. Data obtained from these meetings and questionnaires were direct qualitative data. Most of the indirect data were collected from internet, from articles and books related to decision-making, human bias, lean planning, lean thinking and supply chain.

1.4 - Case study

The thesis is written in collaboration with STX-OSV's shipyard located in Søvik (STX-OSV Søviknes). Currently the company upgrades its Enterprise Resources Planning (ERP) system. It is trying to integrate its old Industrial and Financial System (IFS) with its ERP system by using an appropriate referencing and codification structure. This will help to manage the information flow internally, with its external locations and through its supply chain more effectively. Simultaneously, the company implements a lean planning system on the yard.

At STX-OSV Søviknes, the aim is to move in the long run from the current sequential Engineering Procurement and Construction (EPC) process towards a concurrent EPC process as shown in figure 2. This move towards concurrent processes will reduce the project delivery time and simultaneously give some flexibility at the beginning of the process to improve quality and permit to adjust the project according to ship-owners' requirements. So, to maintain its leading position in the offshore shipbuilding market, the company needs also to be aware of human bias and framing effect that may affect decisions made during planning meetings or individually by the engineers. It should implement techniques, which will permit to reduce as much as possible the risk of errors and take advantage of the improvement brought by lean planning. One way to achieve this is to secure an effective and accurate information flow inside the company and between the company and its supply chain partners.

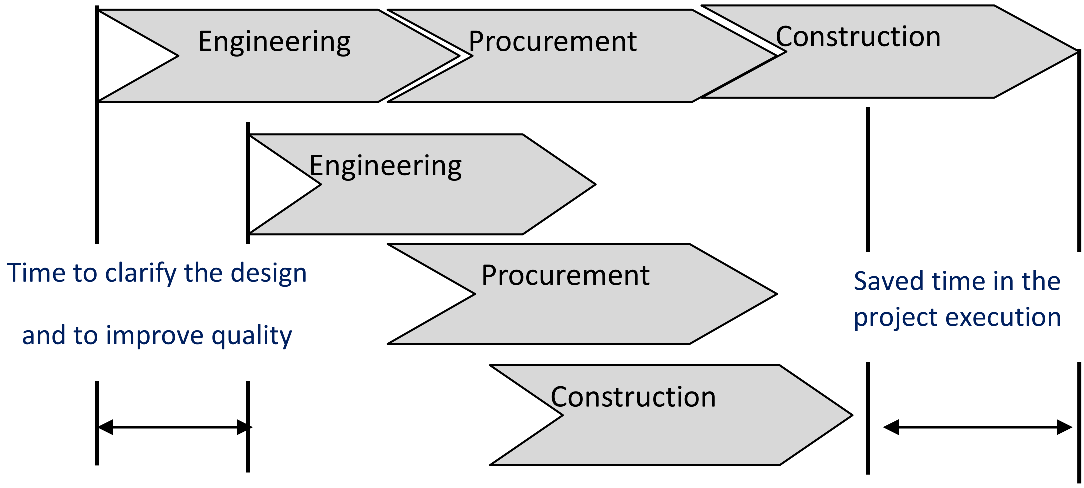


FIGURE 2: FROM SEQUENTIAL TO CONCURRENT EPC (STX-OSV PRESENTATION, J EMBLEMSVÅG 2010)

This information flow helps to visualize variations and uncertainty in a consistent way. The occurrence of phenomena such as the bullwhip effect, characterized by large order variations from manufacturers to retailer due to a lack of information (Riezebos et al. 2009b), can be effectively handled by the different partners of the supply chain. The bullwhip effect can appears in decision-making where one wrong first decision in a process can go amplifying and affect negatively the planning and the whole project. Information is also needed to support the change process and adapt to the different requirements through the execution of a project because efficiency in information flow reduces uncertainty. Therefore, uncertainty in offshore shipbuilding and the impact of human bias on the decisions made under uncertainty will be the subject of this thesis.

Our research permits to identify the main sources of uncertainty and the main biases existing in the engineering department. From the results, we notice that the difficulty in the coordination of the engineering work and the third party activities is due mainly to ineffective information flow and lack of capacity. The delays in the execution of the different steps of the work come principally from imprecise and unavailable technical documentation. These delays are caused also by late customers' requests and rework.

The most important biases in the engineering department are representativeness, availability, reliability and anchoring. The effect of these biases on the decisions made by the engineers can be reduced with the use of some decision-making techniques. We identified four techniques, which can be relevant for the company. There are the six thinking hats (de Bono, 1985), the premortem technique, the checklists (Kahneman and Klein, 2010) and the memos (Sibony, 2011). These techniques can permit to the engineers to keep the schedule and reduce the effect of individual biases on the decisions made. Moreover, it will permit to take advantage of the improvement brought by lean planning on the engineering process.

1.5 - Thesis layout

A literature review is provided in Chapter 2. We discuss lean planning, information in supply chain management and decision-making under uncertainty. The synthesis of these theories is given in Chapter 3; the chapter presents the link between the theories and their implication for STX-OSV Søviknes. Chapter 4 introduces the case company STX-OSV Søviknes. In this chapter, we present the company and discuss the behavioral challenges for lean implementation inside the company. Chapter 5 presents the research: the research purposes, the methodology, the settings and the limitations. Chapter 6 discusses the results and their implications. In this chapter, the potential solutions to reduce the effect of human bias on the decision in the department are presented. The conclusion is given Chapter 7.

CHAPTER 2 - LITERATURE REVIEW

An interdisciplinary theoretical framework is developed in this thesis. The theories we apply are:

1) Lean planning system,

2) Information in supply chain management and

3) Decision making under uncertainty including heuristics and behavioral psychology.

2.1- Lean Planning System

2.1.1. Lean system

Lean history is related to the Toyota Production System (TPS), which started with the establishment of Toyota Motor Corporation in 1937. Simultaneously with the development of the company, Toyota worked toward the improvement of all the lean tools such as Just-In-Time (JIT), kanban, kaizen (continuous improvement) and takt time (www.artoflean.com). However, it is important to notice that TPS is laying on the PDCA (Plan-Do-Check-Act) cycle for continuous improvement. In their new plants, the managers of Toyota started implementing some techniques using PDCA cycle to convert all the operations in a flow production system in order to "everyday make the necessary items in the necessary quantities". This was resumed as JIT, meaning, "do not over-produce or make things too early" (www.artoflean.com). The TPS is based on two pillars JIT and Jidoka as shown in figure 3 below where it illustrates principally the job-shop level.

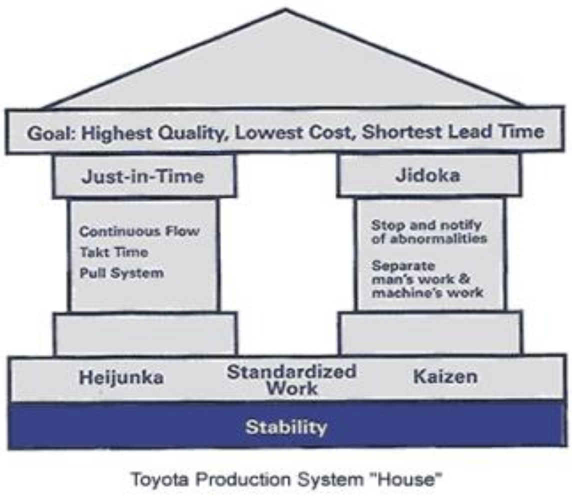


FIGURE 3: TOYOTA PRODUCTION SYSTEM "HOUSE" (WWW.ARTOFLEAN.COM)

The JIT part refers to the notion of flows, takt time and pull-system for production and inventory control. The Jidoka part focuses on building in quality and on the separation between men and machine for more efficient work. The whole TPS and lean thinking insist on the importance and the role of employees in the system. Without people involvement, the whole improvement effort is deemed to fail and is pointless as well (www.artoflean.com). Lean system is about knowing how and knowing why each action occurs to simplify the methods, eliminate wastes and focus on continuous improvement through information sharing and decision-making at each step. This production system focuses on three main operating goals: achieve the highest possible quality, at the lowest possible cost, in the shortest possible lead-time (ibid).

As mentioned above, lean thinking was first developed and refined in the automotive production through the TPS. It evolved afterwards and now the concept of lean is used as best practice and applied across different fields (Hobbs, 2003). Among others, we have lean planning and lean construction used in project-based construction industry, lean laboratory used in beverage and pharmaceutical companies, lean accounting used as business strategy in lean companies. There is also lean engineering, which applies lean thinking to eliminate wastes and improve cycle time and quality in the engineering process (McManus *et al*. 2005). In other fields, we have lean logistics to improve supply chains performances and lean software development using lean principles in software development. All those lean concepts have objective to meet customers' value expectations for quality, schedule, performance and price (ibid). Lean planning and lean construction are applied principally in construction industry. They represent a project management approach for project delivery; they are a new way to plan, design and build capital facilities by using some lean production techniques (McManus *et al.* 2005). Shipbuilding as part of the construction industry requires a coordinated and consistent planning approach to achieve the above-mentioned objectives. This is effectively done through lean planning that we discuss in the next section.

2.1.2. Lean Planning

The implementation of lean principles in shipbuilding activities enables improvements of the quality of engineering activities (the number of defects will be reduced as well as the project execution time). Due to the uniqueness of each construction project, the activities in shipbuilding industry have a fundamentally different level of complexity compared to traditional areas that produce more or less large quantities of homogeneous products in workshop conditions (Ballard, 2004). This is mainly caused by the rapid development of technological solutions in offshore industry to meet the requirements of the oil companies that are exploring oil field at increasing depth. Therefore, the projects have to respect each time new specifications and requirements. Thus, customers, designers, suppliers, subcontractors and other participants of the construction process form an expanded organization engaged in the project execution. These actors vary considerably from project to project, and in addition to this variability, many other factors influence shipbuilding activities (figure 4). The engineering activities, which are also part of the whole process, are influenced by a certain number of factors (figure 5). These factors create the need to have a good coordination and an effective planning approach to ensure high performance and efficiency of the business processes (Reed, 2008).

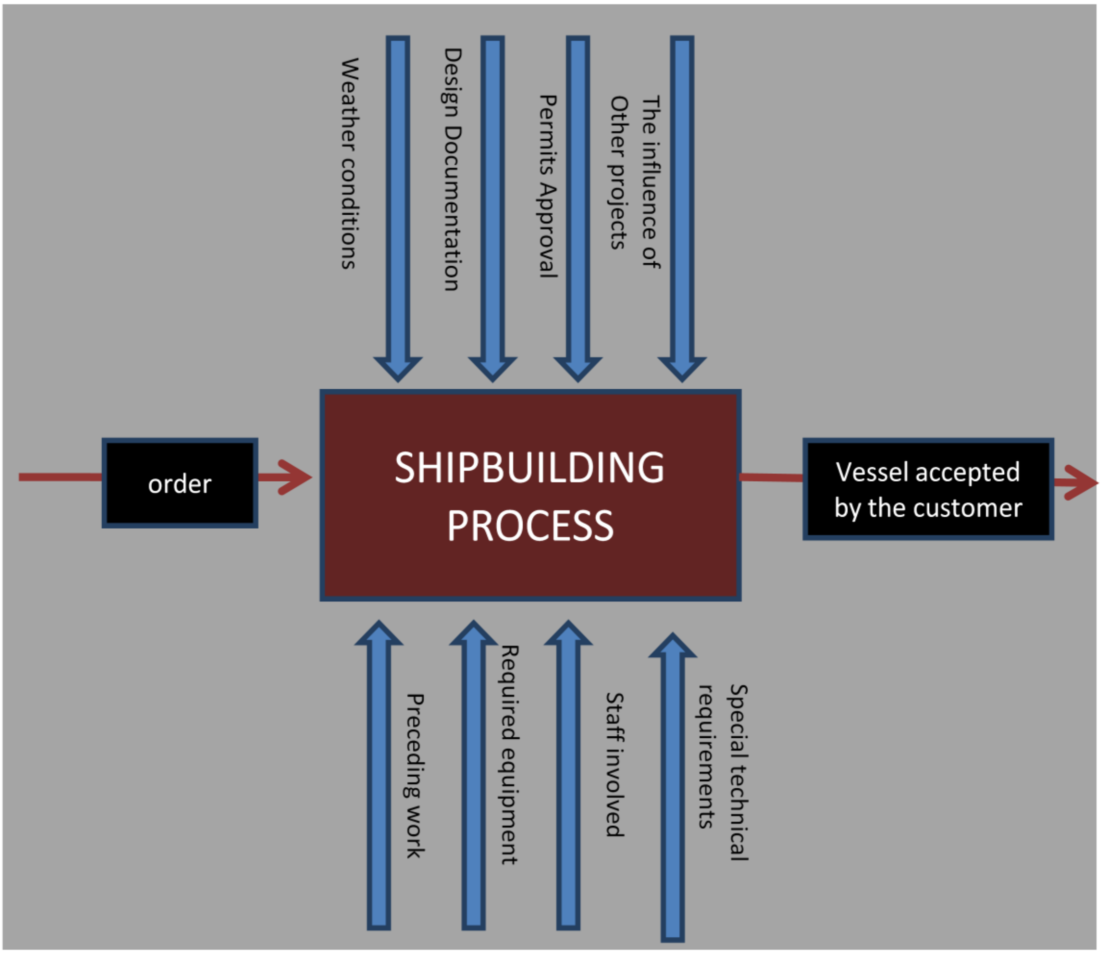


FIGURE 4: FACTORS INFLUENCING SHIPBUILDING ACTIVITIES

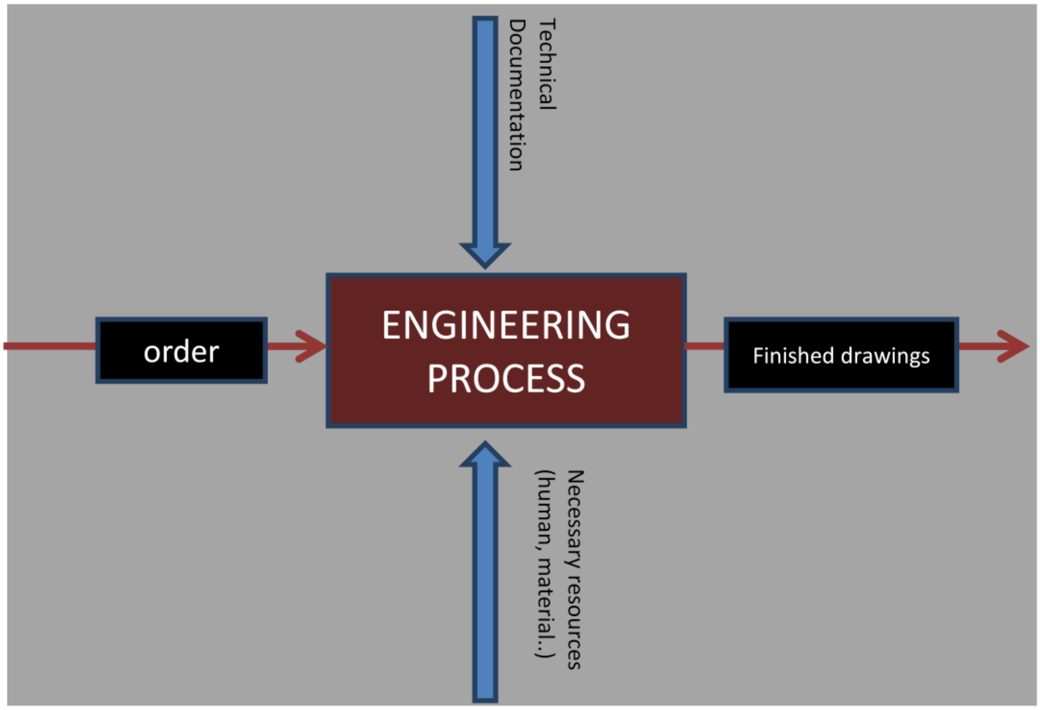


FIGURE 5: FACTORS INFLUENCING ENGINEERING ACTIVITIES

In this regard, focusing on the task level maximizes local performances but jeopardizes the overall performance of the project members. The absence of relevant planning reduces the release of work downstream, increases the overall project's duration, complicates the coordination, and creates conflicts between the parties (Reed 2008). In order to conduct the project in a way that emphasizes on the overall efficiency instead of sub-optimization, lean planning is a relevant tool. It means that by implementing lean principles in planning, we can improve accuracy and efficiency in project delivery.

Table 1 gives an overview of the application of lean principles in planning as defined by Emblemsvåg (2010).

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 1: A BRIEF OVERVIEW OF RELEVANT LEAN PRINCIPLES AND THEIR APPLICATION IN PLANNING (EMBLEMSVÅG, 2010)

Thus, lean planning is a methodological application of these significant distinguishing characteristics of lean production in construction planning. It is divided in 4 different plans based on the Last Planner approach elaborated by Glenn Ballard (1994). The Last Planner is a planning approach used to improve the design and construction scheduling and predictability (Ballard, 2000). The four plans are:

1. Milestone plans, using as reference point different milestones and made for a period of 12 to 18 months, represent the completion period of a work package or a phase of the project.
2. Discipline plans, containing more detail than the milestone plan, are made for a planning period of 6 to 9 months
3. Period plans, which give details of the discipline plan into sound activities and report the deviation to the discipline plan. They use a planning period of 5 to 8 weeks
4. Weekly plans, with a planning period of 1 to 2 weeks, contain sound activities executable in that period and report deviations from the period plan.

Milestone and discipline plans form the master plans. Master plans of the project permit to solve many important problems: from total long-term coordination of project resources to the formulation of contractual payment terms. However, due to lack of precise information on many future events such aggregated plans cannot describe aspects of practical execution of activities in detail (Ballard, 2004). The period and weekly plans inform coordinators and work leaders' about what should happen in respectively 5 to 8 weeks and 1 to 2 weeks period (ibid). These plans give them the opportunity to take early actions to perform the required tasks. The planning periods and their duration are illustrated in figure 6.

The engineering department at STX OSV Søviknes uses period and weekly plans on a regular basis. Due to the high level of uncertainty in offshore shipbuilding, the department focuses on activities that can be monitored on a weekly basic to have a better overview of their execution.

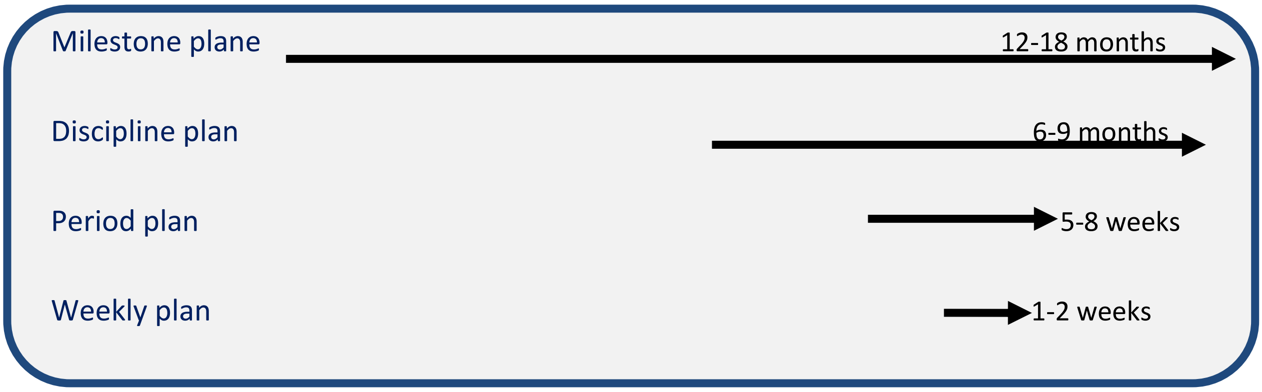


FIGURE 6: PLANNING PERIODS DURATION (SOURCE STX-OSV SØVIKNES)

In the following, we describe the Last Planner and compare the traditional planning approach with lean planning. This will show the relevance of the planning approach based on Last Planner in offshore shipbuilding.

2.1.3. The Last Planner

The Last Planner is based on a mechanism that transforms what should be done to what can be done when required to protect the planning integrity and predictability (Ballard, 2000) because there is a great risk that engineering processes can be carried out with errors. The risk of errors in engineering is fundamental in offshore shipbuilding because of the high level of uncertainty.

Planning of the engineering activities in lean shipbuilding resembles in appearance to traditional approaches. With the traditional planning, plans for a whole year, quarters and months are elaborated and the daily activities are carried out according to them (Tchernikh, 2009). However, despite this apparent similarity, lean planning carries fundamental differences. These important differences may include the following:

- lean shipbuilding recognizes that given the complexity of these activities, errors in the implementation of operational plans are inevitable. In other words, complete fulfillment of weekly and daily schedules will be the expectation rather than the rule.
- the functioning of operational planning needs to be measured by numerical indicators. It creates an information basis to identify root causes of recorded failures and the development of improvement programs in the relevant areas of work;
- to increase the degree of execution of operational plans, timely preparation upfront of works should be regarded as a crucial process of production management. The results of this process should be measured and the process should be continuously improved based on the measurements (ibid).

When running the plans especially period and weekly plans, it is desirable to make them consistent with what should be done within the constraints and what can be done (Ballard, 1994) as shown in figure 7. Thus, a universal index is proposed to evaluate the results of the execution of the plans. This index is the one used at STX-OSV Søviknes to monitor the planning and engineering activities.

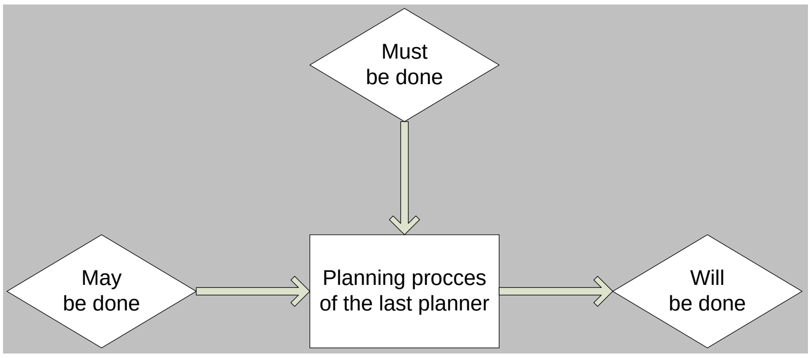


FIGURE 7: PLANNING APPROACH FOR WEEKLY AND PERIOD PLANS (INSPIRED FROM BALLARD 1994)

2.1.4. Measurement of the planning process and its improvement

The index used is the proportion of work according to weekly plans, completed on time: Percent Plan Complete (PPC). The PPC depends on a variety of factors, from which productivity and quality depend. If the PPC value is not equal to 100%, when it should be so, it is necessary to know the reasons (Ballard, 1994). According to empirical studies of the practice of companies applying lean planning, the following inconsistencies are often cited:

- incorrect information or guidelines received by the Last Planner (there is an incorrect information in the information system that the needed resource is available, although in fact it is absent);
- error of planning at the last planner's level (there’s too much job planned for the week);
- errors in the coordination of activities which involve joint use of some resources;
- change in priorities;
- errors of design or technical documentation during an attempt to perform the work (Ballard, 1994).

The use of PPC value during engineering work creates an information base to launch programs for continuous improvement in shipbuilding organization. This permits the use of the PDCA cycle to achieve a 100% completion of the activities at the end of the planning periods. In one hand, in the engineering department, the PPC informs work leaders and discipline owners about the tasks, which require more attention in order to avoid delay in the process. These tasks are the ones discussed during planning meeting. They require attention to avoid decision-making errors in the evaluation process. Moreover, on the other hand, the use of PPC permits to identify the improved activities. It characterizes the system’s performance at the operational level and makes the work of organizations and departments that participate in the planning and construction transparent (Tchernikh, 2009).

This allows building a common understanding of the basic directions of activities' improvement, choosing and implementing a set of practical actions. As a solution to some of the major problems of operational planning, specialists of lean planning consider the establishment of reasonable reserves of ready tasks. Ready tasks are tasks ready to be executed and which do not disturb the planning order. Therefore, these reserves ready for execution ensure the alignment of flows of engineering works and prevent resources to remain idle and provide some additional options to tackle uncertainty (ibid).

In accordance to this planning scheme, at STX OSV Søviknes, the main driver of period and weekly plan are sound activities (ready tasks). A sound activity in the engineering department is an executable activity that satisfies the availability of technical documentation, completion of the previous activity and resources requirements as illustrated on figure 8.

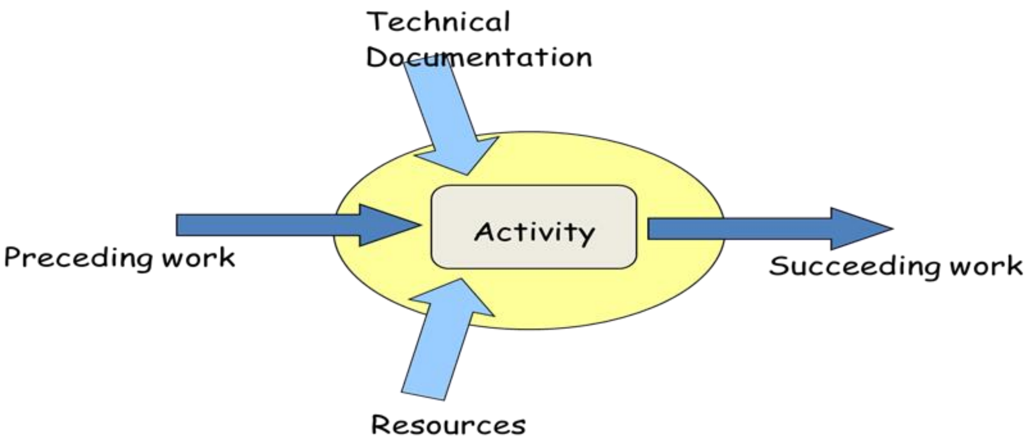


FIGURE 8: SOUND ACTIVITY IN ENGINEERING (EMBLEMSVÅG 2010)

Thus, there should be an appropriate execution of several preceding actions for the continuity and effectiveness of the process:

- complete technical documentation must reach the employee on time, and it should not contain errors;
- Resources here include particularly human resources that are engineers. For accuracy and quality of the engineering process, it is necessary to have enough workers. But, it is also necessary to ensure that they are trained enough for the project (Tchernikh, 2009).

At STX OSV Søviknes, the specialized discipline coordinators run the period plans and divide the plans into sound activities. Before work, there is heavy focus on planning to eliminate sources of error, wrong sequencing and lack of information, which are the main sources of uncertainty. Recall that lean planning is a fact-oriented approach where people have to go on the site of the problem and make their opinion themselves. Those that do the work have to plan it to avoid information distortion and identify the real requirements for sound activities. Therefore, the specialized work leaders run the week plans. The objective is to reduce as much as possible the time frame required to process different activities and continuously improve the process using the PDCA approach to keep solution spaces open as long as possible. This permits to cope with the high level of uncertainty by creating flexibility. Therefore, one of the advantages of lean planning is that it is a better way to communicate information in this dynamic environment (Lacksonen *et al.* 2010). Most of all the lean thinking is a human based system requiring high employee involvement because they are the ones who are going to make lean decisions daily (Steve, 2003). This situation leads to a risk of decision-making error related to human behavior.

However, it is important to notice here that the fundamental principle of lean, lean planning and the use of Last Planner is embodied in the Plan-Do-Check-Act (PDCA) cycle that Dr Edward Deming taught Toyota after World War II (figure 9).

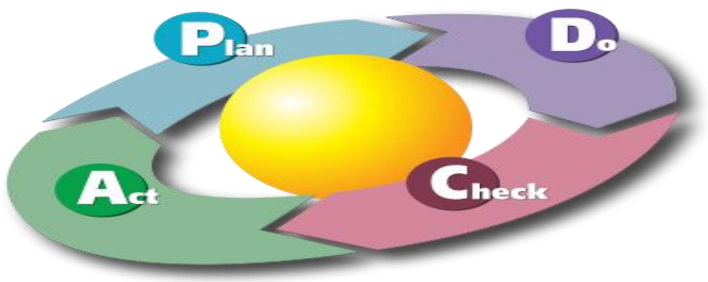


FIGURE 9: PDCA CYCLE (BULSUK, 2009)

In this cycle, every action goes through four different steps in search for continuous improvement:

- ❖ Plan: consists of setting the objectives and processes according to the expected outputs based on facts.
- ❖ Do: is about the implementation of the new processes, on a small scale if possible.
- ❖ Check: consists of the measurement of new processes' results and their comparison with the expectations in order to find out potential differences (deviations). It is the analysis of the results to find the causes of deviations and to find where potential improvement actions have to be taken.

- Act: is the deployment of countermeasures to eliminate or reduce deviations in order to get as closely to the objective as possible. It focuses also in changing standards (best practices) to secure and sustain best practices so that performance does not slide back after some time (Bulsuk, 2009).

Thus, determining the PPC of each activity permits to identify improvements and failures in the engineering activities to go through a continuous improvement process.

2.1.5. Summary

To summarize, lean planning is based on the fact that the first priority in order to improve engineering activities' execution is a quality planning at the grassroots level of the organization (last planner). To measure the quality of planning at this level a universal index (PPC) is used. The value of this index reflects all the imperfections peculiar to the planning, engineering and production processes as a whole (Ballard, 1994). Systematic work on the analysis and improvement of this index runs the entire improvement process of the organization in long-term systematic manner, using the PDCA cycle. In practice, such approach allows achieving real improvements in the level of productivity and quality in shortest possible time (Ballard, 2004).

Nevertheless, application of the Last Planner involves some requirements related primarily to the retraining of staff to use this new working method, but also to the adjustment of information flows within the organization. The last Planner used at STX-OSV Søviknes allows an effective follow-up and monitoring of all the planning, engineering and construction activities in the company. However, to reduce the effect of uncertainty in the processes, the planners need to have accurate information to support the planning, avoid decision-making errors during the planning evaluation and have sound activities ready on time.

Thus, in the next section, we will take a closer look at information flows, their importance in supply chains, their organization, ways of optimization and constraints faced when implementing changes in information flows within enterprise.

2.2 - Information in supply chain management

After the description of the lean concept and its application to planning and shipbuilding, we will now look at information in supply chain management. The rise of international cooperation, vertical disintegration, along with a focus on core activities have led to the notion that firms are links in a networked supply chain (Chen and Paulraj, 2004). In other words, in the current business world, companies are not functioning as isolated entities but rather as networks with upstream and downstream partners. Thus, one of the objectives of supply chain management is the management of this network of suppliers and customers to achieve an accurate and efficient flow of goods between the partners. However, the most important condition to achieve this efficient flow of goods is to have an accurate and efficient information flow inside the company and through the supply chain.

2.2.1 Information flow and information technology in supply chain

Information flow is the information, which is organized to move in specified directions, with fixed points at the beginning, in-between and finish (Anikin, 2001). It links all the departments of the company and provides relevant information when needed. This is illustrated in figure 10.

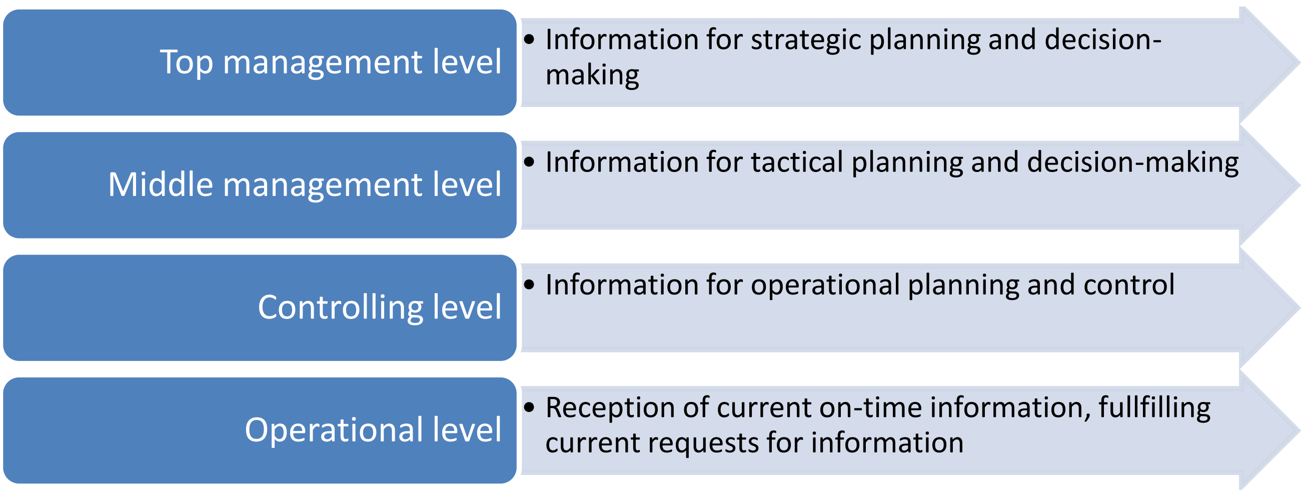


FIGURE 10: INFORMATION UTILIZATION

These flows are described as informational logistics. It reflects the movement of material, financial and other flows, which influence the production processes. The main goal of informational logistics is to supply logistics systems with information in needed time, in needed volume and in the right place (ibid). Most of the time, software are used to ensure an effective information flow inside organizations and to support the physical flow of materials. These software provide management with information on scientific and technical progress, connect the organization with its partners and permit to have a standardize documentation system in the company (Kirshina, 2001). This can be done through Electronic Data Interchange (EDI) and Enterprise Resource Planning system (ERP). Despite the fact that the use of computers and software permits to facilitate and accelerate the process of managerial decision-making, we have to emphasize that at the end of the chain, it is humans making the final decisions. Therefore, when facing uncertainty as in shipbuilding and in case of limited information, the risk of error is still high.

Today, with the fierce competition between companies, the problem of customer satisfaction is on the first place. To evaluate the benefits that logistics brings to clients, logistical procedures must be measured accurately (Tomilova, 2003). Without constant and updated information in the system, the company cannot measure its performance in order to analyze current situation within and outside the company. The PPC index used at STX-OSV Søviknes to monitor engineering activities and the planning process permits to have this overview with accurate information.

Moreover, information systems help to reduce the required time and the cost for integrated control, they permit to realize the ordering, the maintenance of the bill of material, the plant maintenance, the inventory tracking and tracing in an accurate and less time-consuming manner and they provide lead-time information. The implementation of these electronic connections between business partners has objective to enhance the performance of the supply chain and reduce as much as possible the level of uncertainty (Gunasekaran and Ngai, 2004). These systems also present a vast potential to facilitate collaborative planning between supply chain partners by sharing information on forecasts and production schedules. Their ultimate aim is to replace inventory with perfect information (Karoway, 1997). All these advantages show that effective and accurate information has a central role for lean planning. Its main objectives are:

1) Permanent management of the logistic system with reliable, relevant and adequate information;

2) Permanent supply of the company's employees with the necessary operational information;

3) Operative management of an enterprise;

4) Provision of management with visual information on the utilization of resources;

5) Provision of information for the strategic planning;

6) Assistance in finding bottlenecks;

7) Provision of possibilities for reallocating company's resources;

8) Enable the evaluation of terms of execution.

Therefore, in lean organizations as STX-OSV Søviknes, the flow of information provides the necessary crucial elements to control the system and support the decisions made. Thus for a better coordination, there should be a move toward lean information flow.

2.2.2 Lean information flow

As, there are two approaches to the implementation of production processes, there are also two approaches for information flow: the push and the pull system. In the most radical form of push information flow, material flow triggers the information flow. It is pushed strictly on commands coming from the control center to each successive element of the production chain (Voronin 2010) as shown on figure 11 below.

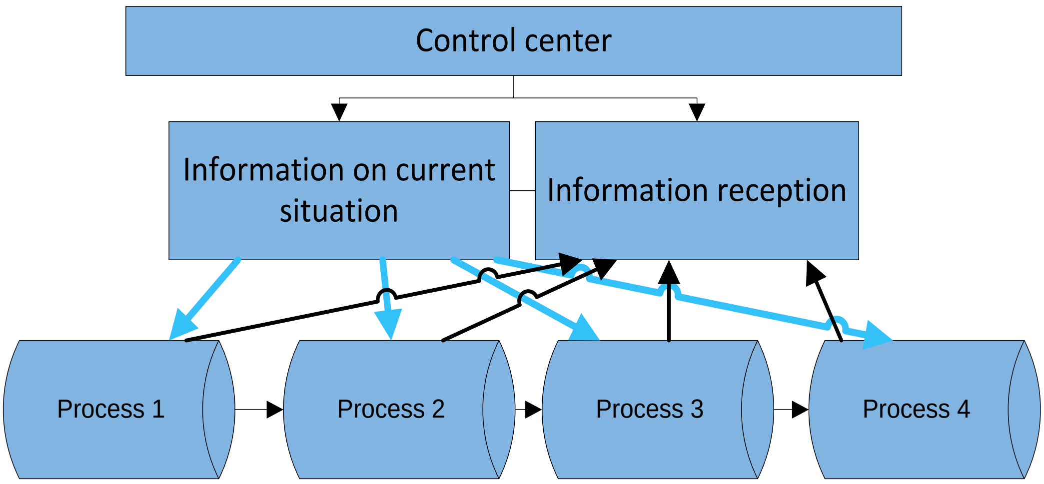


FIGURE 11: PUSH SYSTEM INFORMATION FLOW

According to Voronin (2010), this system has some drawbacks:

1. inability to respond quickly to changing situations as due to internal reasons and because of need for continuous adjustment of the centralized planning of production;
2. the need for excess insurance stocks, which increases total costs (in this case by insurance stocks, we understand the excess number of employees);
3. inability to fully optimize plans due to lack of opportunities to take into consideration all the circumstances that may affect these plans;
4. the need for constant increase of the complexity of information processing systems and personnel qualification considering the growing number of factors that should be taken into account when planning;
5. the need to create large units for planning of situation and a timely response to the changing of situation.

However, these disadvantages are corrected in the pull system. In a pull information system, known as lean information flow, the information flow is pulled by followed element from the previous when it is ready, but not on command from the center (Voronin, 2010). In this case, the main features of the system are the horizontal linkages and delegation of authority to make decisions at the level of teams or small groups of workers (the ones doing the work). The result of the implementation of pull system is a system, which provides "just in time" service, while the value of total costs is reduced significantly.

Another system that can be applied to lean planning processes and highlight the role of information in planning is the method of synchronous processes. It provides the necessary elements to support lean information flow in the organization.

The method of synchronous processes was developed based on the Theory of Constraints of Goldratt. This theory indicates that the effectiveness of any system is determined by its most inefficient parts. To highlight these parts, all system resources are divided into insufficient (bottlenecks), limited and excess capacity. The evaluation of the resources is carried out by applying a system of "drum-buffer-rope" in the following sequence (see figure 12)

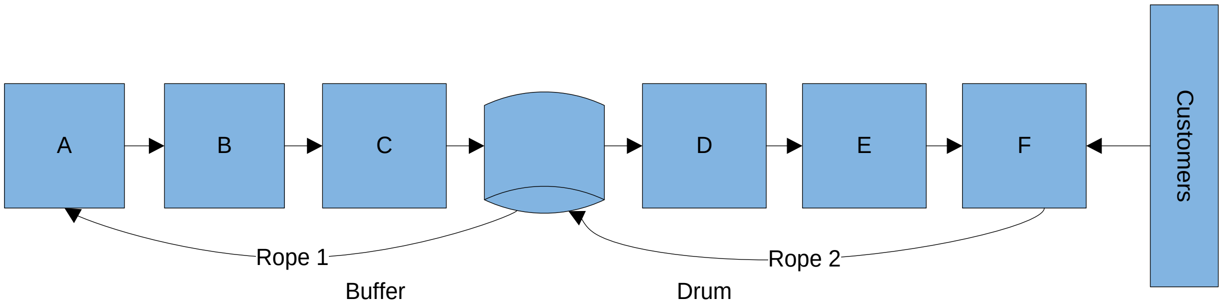


FIGURE 12: DRUM BUFFER ROPE

1. Function of the drum that gives rhythm to the processes to analyze the information is entrusted to the limitations of the system. An option for limiting can be a resource, which capacity is limited because of deficiencies in the organization.

2. Plans to maximize the efficiency of limitations of the system are determined. To maximize the efficiency of "tight" resource, a buffer is created before it, that is, a reserve stock that can provide a constant load of insufficient product.

3. The whole system is set up to implement these plans (even if this reduces the effectiveness of redundant components). To do this the optimal value of amortization stock based on statistical data is determined, to makes sure that the drum will work all the time, not depending on the problems arising in processes before it.

4. Effect of restrictions is successively decreased. For this purpose, there are two ways: either buy another similar resource, or gradually increase the capacity of the existing resource.

5. Defining the following restrictions and repeating steps described above (Voronin, 2010).

This approach permits to have available information on time and submit the whole activities in the organization to the availability of the required information.

From the above we can say that efficient information flows in an organization is one of the keys to effective performance. Thereby lean organization of information flows helps to optimize organization's activities. It happens through detailed analysis of flows passing through departments and the restructuration of these flows. The main problem, which should be eliminated, is the high level of uncertainty in offshore shipbuilding industry.

Thus, a good decision-making requires using and securing high quality and complete information (Gordon, 1993). This to illustrate the fact that shipbuilding professionals are facing a high risk of making key decisions that can become unproductive due to market uncertainty and causes beyond their control. However, an effective information exchange can help to reduce this uncertainty. In shipbuilding, an effective information exchange and processing system will help for a better coordination of all the activities in the engineering disciplines and between engineering, procurement and construction. This coordination can help to achieve concurrent processes and concurrent engineering. Recall that concurrent engineering is a systematic approach that integrates the designs of products and the related processes including engineering, manufacturing, construction and support (Pennell and Winner, 1989). It integrates all the elements in the product life cycle from the beginning. Concurrent processes are one of the possibilities to cope with errors and potential reworks in the engineering activities while taking in account customers' value expectation. It is based on the idea that it is important to face accurately the fast-changing market place and to avoid costly rework in the production stage by focusing on coordination and accurate information exchange between all the departments. Therefore, all the activities should be integrated so that there is constant and accurate overview of the process. The most important condition to achieve this concurrent process is an integrated and effective information exchange system between the different actors (see Figure 2).

Another importance of effective information exchange in organizations is that it is one of the key elements to take in account when implementing new processes. As STX-OSV Søviknes is now implementing lean planning in the yard, a good communication between the management and the employees helps to reduce a lot the resistance to change even if it does not completely take it away. Moreover, when the employees feel a sense of gratification and ownership over their work, they tend to work harder and are more engaged because they have a say in the general process.

2.2.3 Summary

To summarize, we notice that the lack of information creates uncertainty. To secure an effective flow of goods in the supply chain, to tackle more effectively uncertainty in shipbuilding, to establish concurrent processes, to implementing new concepts; it is necessary to have an effective information flow among the different actors in the organizational chain. Moreover, an accurate and effective information exchange and processing is one of the key to reduce uncertainty and simultaneously increase employees' involvement and their sense of ownership. All stated above leads us to discuss what prevents organizations from using lean information flows (inside the company and along the supply chain) and lean planning systems that are proved to be more effective, efficient and optimal. One of the reasons, that we will analyze, is human factor in decision-making under uncertainty. Decision-making is the area of professional activity, which involves mostly people therefore creating a risk of errors. In the next sections, we will analyze how methods of decision-making are implemented in order to optimize the overall process of decision-making and how behavioral psychology can influence this process.

2.3 – Decision-making under uncertainty

Decisions have to be made at different levels in the organization and by different people. We can identify two main types of decisions: programmed decisions and non-programmed decisions (Gordon, 1993).

Programmed decisions are the ones that address relatively structured and repetitive problems. The decision maker's experience in making such decisions facilitates the process and increases the likelihood to have the expected outcome. Non-programmed decisions are unstructured and most of time new and unique. They can be problematic and challenging and require innovative solutions. Non-programmed decisions require time to gather information, expertise to address accurately the problem and creativity to find innovative solutions (ibid). The organizations and decision-makers are performing in a dynamic world. This may increase the complexity of the processes and reduce people's ability to predict the outcome of their decisions. It reduces also their ability to gather all the information required to make their decisions. Therefore, they make decisions under uncertainty. This is the case in offshore shipbuilding where non-programmed decisions are made frequently, especially in planning and engineering. People have to adapt to changing customer requirements, supplier uncertainty and to changing regulations. They have to find innovative solutions and make decisions before gathering all the relevant information.

Uncertainty can be defined as the lack of predictability of outcomes meaning that we do not know for sure what will happen (Wallace, 2005). It is the difference between information required to make a good decision and the information available when the decision is made. This difference is characterized by a lack of required information, lack of control over the problem and lack of knowledge over the problem's characteristics. The decision makers face two types of uncertainty: external uncertainty and internal uncertainty.

- External uncertainty (weather conditions) is the one out of control of the decision makers. It cannot be control and it does not make sense to collect information to try to overcome it. The objective of the decision maker in this case is to create flexibility in the process. That will allow him to cope with the uncertainty. Stochastic modeling, utility theory and options theory are use to provide flexibility in case of external uncertainty (e.g. weather condition).
- Internal uncertainty (e.g. lack of needed technical documentation) can be controlled. It refers to ignorance and lack of knowledge. The decision maker can get rid of internal uncertainty by buying or collecting relevant information. The decision-makers' objective is to reduce or eliminate this uncertainty by investing in the search for information or create flexibility to adapt (Wallace 2005). Figure 13 illustrates the different types of uncertainty and the objective of the decision makers in each case.

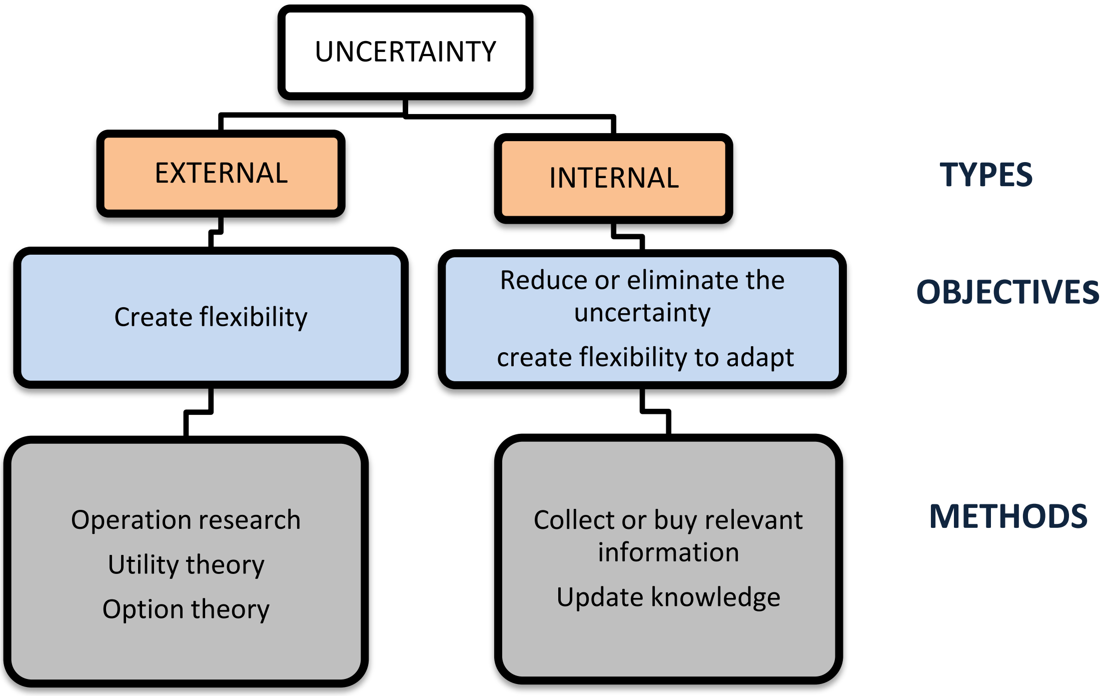


FIGURE 13: DIFFERENT TYPES OF UNCERTAINTY AND METHODS OF CONTROL

Although, external uncertainty cannot be totally controlled, different approaches permit to cope with it. Theories like operation research, options theory and utility theory combined with heuristics and behavioral psychology provide tools to cope with it. In offshore shipbuilding, the introduction of flexibility in design, drawings and 3D modeling can be done by using a common platform for several ships. The use of a common platform at the beginning of the process permit to focus on cost reduction. The late customer requirements are introduced in a later stage during the outfitting. This postponement of the final requirements is a source of flexibility, which can help to reduce the effect of uncertainty in the process and avoid costly reworks. The introduction of flexibility in design illustrated in figure 14 presents how the uncertainty can be handled at this stage.

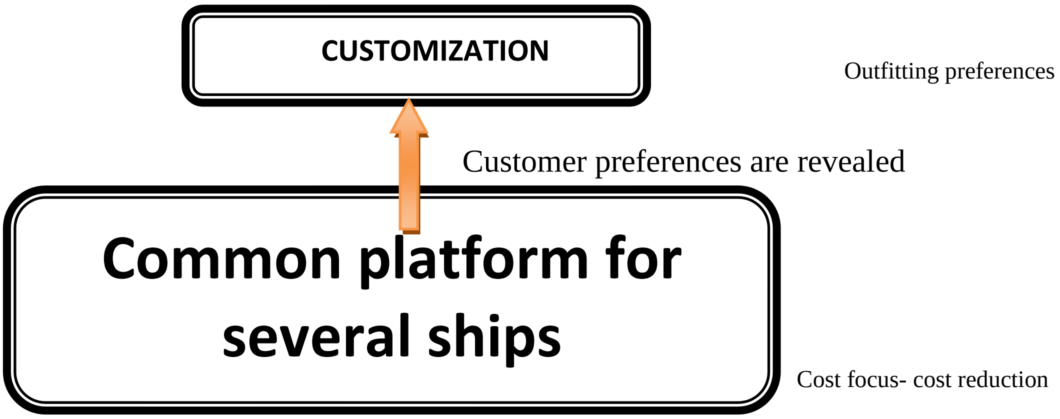


FIGURE 14: FLEXIBILITY IN DESIGN

Operation research, option theory and utility theory are mathematical approaches, which permit to avoid the risk of biases. The next sections will introduce heuristics and behavioral psychology and mathematical decision-making theories.

2.3.1 Heuristics and behavioral psychology

In 2002, the Nobel Prize of economics was received by a professor of Princeton University, D. Kahneman for his studies of individual decision-making under uncertainty and risk (many of those were conducted in collaboration with A. Tversky). It turned out that these decisions are not always rational, as assumed in traditional economic theory. The main thesis of prospect theory of Kahneman-Tversky is that people are not rational in assessing the probabilities of possible alternatives because they make decisions based on limited information, which is largely unreliable. The inability to process accurately the information due to bounded rationality is another factor that prevent also individual to be completely rational when making decisions. Simon (1991) described bounded rationality as the limitation of people rationality due to limited information and the finite amount of time available to make decision. Humans are intended rational but are limited in their actions. Therefore, we tend to satisfy rather than optimize and the decisions are made within the limits of human knowledge and our computational capacity (ibid). It means that we cannot use models and mathematical methods to make decisions under uncertainty when we have to estimate value and probabilities in a short time frame.

Thus, under time pressure and uncertainty and due to bounded rationality decision makers rely on heuristics to estimate probabilities and values. These heuristics are rules of thumb that give rise to systematic decision-making errors caused by human bias. This section describes these systematic mistakes that can be made even by the most intelligent people because of the biases. It shows that the behavioral aspect is extremely important in decision-making (Kahneman *et al.* 1987).

The presence of those biases leads to wrong estimations and wrong evaluation in project planning. Hence the importance for shipbuilding companies to identify them. Wallace (2005) refers to three of the main misleading heuristics based on the work of Kahneman and Tversky (1987). They show how easy it is to come to false conclusions, when we rely too much on cognitive heuristics. These heuristics are representativeness, availability and anchoring and adjustment.

A) REPRESENTATIVENESS:

It is the fact that people tend to overlook prior probabilities when they are given additional information even when those information carry no significance. The additional information is misleading.

An aspect of representativeness is **the law of small numbers** or **insentivity to sample size** showing how well a sample is representative of the population. It illustrates how people react to sample size when they do not perform actual calculation but rather must rely on their own heuristics (Wallace 2005). Thus, there is a tendency to fully overlook the size of a sample and think that any sample is a good representation of the population.

Another aspect is **predictability**. It is the fact that the behavior of a group according to a distribution does not help to evaluate individual among the group. Thus, people make evaluative judgments in accordance with the level of a specific description consistent with the broader category.

Another flaw of representativeness heuristic is the **regression to the mean**. It refers to the fact that a situation tend always to go back to normal after a pick period. When people make estimates, they overlook the effort made in pick period and over evaluate the impact of their actions and decisions made in this period (Wallace 2005).

As we can see, the use of representativeness heuristic results in serious errors when estimating probabilities and values.

B) AVAILABILITY:

It is the fact of estimating the probability of a situation based on how easy it is to come up with examples. The availability heuristic gives rise to retrievability and imaginability biases and to estimated associative connection. Therefore, relying on this heuristic can lead to errors in the estimates.

The bias of **retrievability** or ease of recollection is the systematic misconception about how often certain events occur. Kahneman and Tversky (1984) claimed that when a person is judging the frequency of occurrence of an event, he relies on individual cases. The event for which examples are more easy to recall, will seem more frequent than the event that occurs just as often, but for which examples are recalled not so easily. Usually we also recall probable events much easier than improbable ones.

Imaginability bias is another flaw of availability heuristic, which leads to overestimation or underestimation of probabilities and values depending on how people valuate a problem. It is easy for us to assume that our memoirs characterize most of the real events, but in reality, we have no idea about these events.

Estimated associative connection refers to the fact that when estimating the probability of two events occurring at the same time, people often become victims of fallacies associated with the availability of information. When the probability that two events will occur simultaneously, is estimated by the presence of examples of such simultaneous events in our memory, we usually measure inappropriately high probability that these two events will coincide again.

C) ADJUSTMENT AND ANCHORING:

It is a heuristic characterized by the fact that people make assessments, starting from an initial "anchor", depending on what kind of information they have. Then they adjust it to give a final answer. Kahneman et al. (1987) brought evidence that the rejection of "anchors" is usually not sufficient to negate its effect. In all cases, the answers tend to lean in the direction of the initial "anchor", even if it is irrelevant to the case. At various reference points, different answers are given. The important point is that we tend to be overly optimistic in estimating a probability of success in project scheduling when the probability of completing each activity is high. Alternatively, we tend to underestimate the probability of failure when each failure has a small probability of occurring (Wallace, 2005).

Often, we give a great importance to our first impressions, and then we cannot adjust our point of view to reality. The use of anchoring and adjustment heuristics leads to errors when people estimate conjunctive and disjunctive events.

Conjunctive and disjunctive events estimation shows the usual deviation of value judgments. This bias leads to an overestimation of the probability of conjunctive events or events that must occur in connection with each other. And it leads to an underestimation of probability of disjunctive events or events that occur independently of each other. Thus, when multiple events must all happen, we overestimate the actual probability. While in case when one of many events should happen, we underestimate its probability. Kahneman and Tversky (1984) claim that the probability of any single event gives a natural "anchor" to evaluative judgments of the probabilities of all events that should happen.

Whenever we try to analyze the probability (for example, will the project be completed on time) or evaluate (for example what salary to offer to the employee), we show a tendency to search for an initial "anchor". However, we always place an undue reliance on these "anchors" and we seldom wonder whether they are justified and whether they suit this situation. We often cannot even realize that the heuristics influences our evaluative judgments. Thus, the key to the improvement of value-judgment is to learn to differentiate between proper and improper use of heuristics.

That is the reason why it is better to use mathematical approaches and models in general to deal with uncertainty since they are not subject to these 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, p.24). The next sections will present different modeling and mathematical approaches to cope with external uncertainty in decision-making and provide flexibility.

2.3.2 Ways of controlling and coping with uncertainty

While talking about information flows and their use in lean planning systems, we mentioned that human biases and internal and external uncertainty have a great impact on decision-making processes in shipbuilding. Now we will discuss ways of controlling information flows and decision-making processes in order to make them less dependent on human biases and uncertainty.

There are many mathematical approaches that have been developed and an extensive literature that describes them. This section will review briefly four approaches that we think are relevant for shipbuilding.

A) Operations research

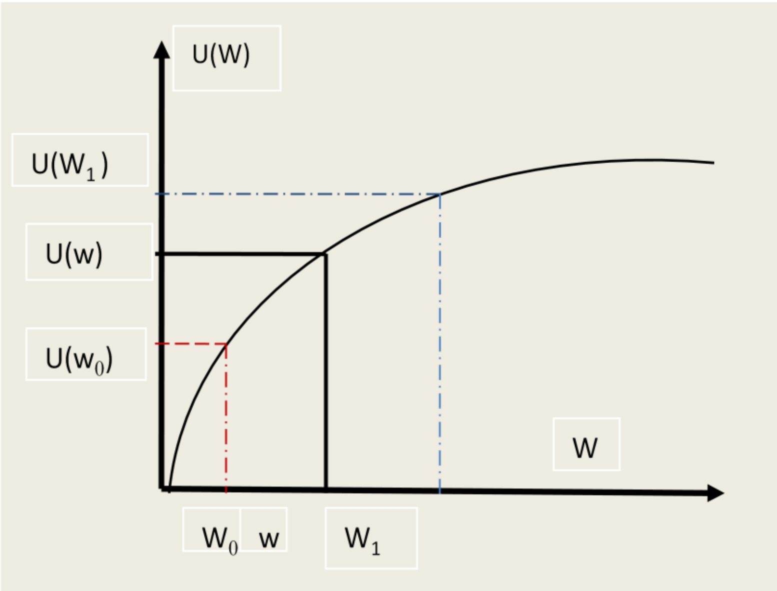
Operations research (OR) also known as decision science is the art of using quantitative methods to support decision-making. It is an interdisciplinary mathematical science combining stochastic modeling and statistical analysis. OR aims to find optimal or near to optimal solutions to complex decision-making problems. It addresses different issues in disciplines such as supply chain management, transportation and optimal search among others. Its application to project planning permits to determine the critical processes in a project that affect the overall duration. This can be valuable in offshore shipbuilding. It will permit to create more flexibility around the critical activities especially during the outfitting to address changes in ship-owners requirement in a timely manner.

It can be used to reduce biases and the level of uncertainty because it uses mathematical approach to decision-making and that actually helps to avoid biases.

B) Utility theory

The purpose of utility function is to describe individual consumption behavior by comparing choices among a set of competing alternatives for the decision makers. Utility theory is an individual approach to organization where the rational individuals are expected to maximize their utility by selecting the options, which provide them with the highest satisfaction. This is useful in decision making because it shows how individuals value risks and utility under uncertainty. Assuming that an individual has to make a gamble, she can increase or decrease her wealth w_0 with α at equal probability of 0.5. Meanwhile she can keep her wealth at the same level if she refuses to gamble. In this situation, utility theory points out three types of behavior, which describes each person's attitude toward risk in presence of uncertainty. Assume that:

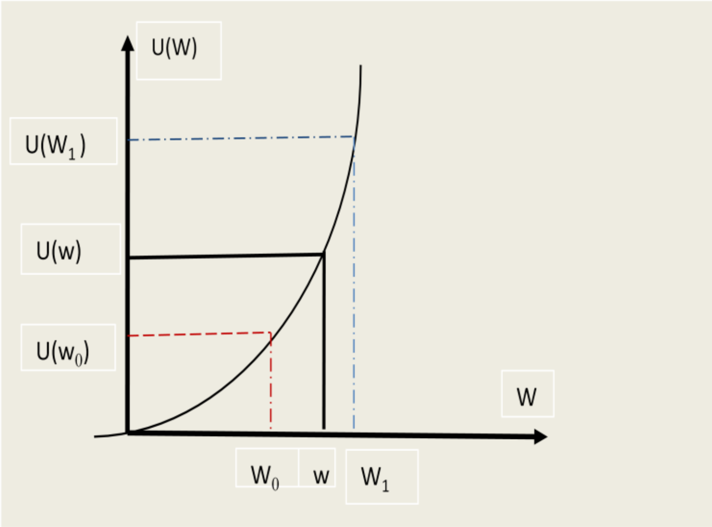
- She prefers the safer option and do not gamble. This is risk aversion meaning that an individual prefers a sure situation with a sure result compared to an uncertain situation with possibly high gain, but with a potential risk of lost. For **risk averse** persons, each additional gain brings a proportionally lower level of satisfaction. So at a moment, they just avoid to take any risk (figure 15).



When the wealth goes increasing, the increase of utility U(w) is less proportional to the increase of wealth W

FIGURE 15: UTILITY FUNCTION OF A RISK AVERSE (RISK AVOIDING) PERSON

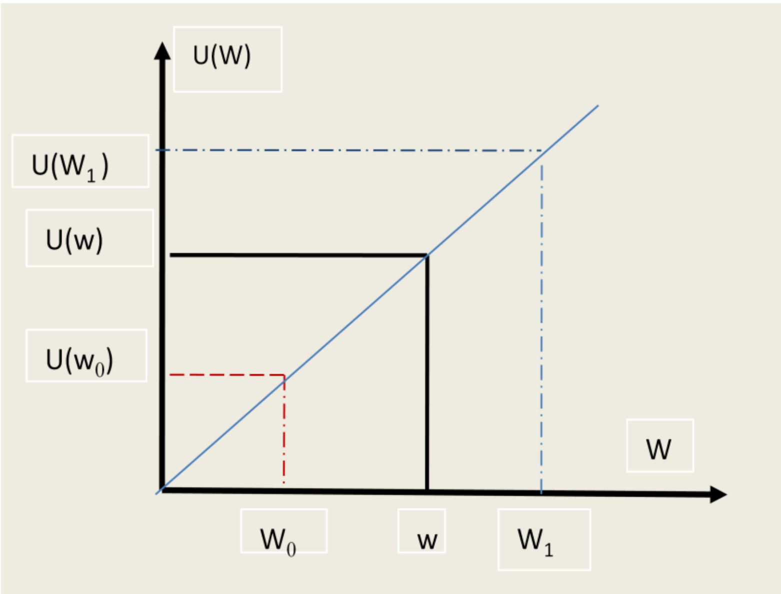
- She takes the gamble. This is risk-seeking attitude, meaning that a person prefers to take a risk of gaining or losing compare to a certain situation where her wealth remains equal. For a **risk seeking** person each additional gain bring a proportionally higher level of satisfaction. So they are willing to take risky decisions most of the time (figure 16).



When the wealth goes increasing, the increase of utility U(W) is proportionally higher than the increase of wealth W

FIGURE 16: UTILITY FUNCTION OF A RISK SEEKING PERSON

- If she estimates that whenever she takes the gamble or not, the two situations are equally good, she is **risk neutral**. Risk neutral behavior means that a person accepts equally a sure situation to a gamble where her wealth can increase or decrease. For an increasing wealth, each gain brings a proportionally equal level of satisfaction as shown in figure 17 below.



When the wealth goes increasing, the increase of utility U(w) is proportionally equal to the increase of wealth W

FIGURE 17: UTILITY FUNCTION OF RISK NEUTRAL PERSON

The distinction between risk aversion, risk seeking and risk neutrality gives an explanation about the individual attitude in uncertain and risky situation. These attitudes can permit to the organization to take advantage of certain situation. However, they can put the company in jeopardy by high exposure to risk.

C) Options theory

Options theory is an organizational approach to uncertainty. It is a technique to value uncertainty in a changing world. The existence of options gives flexibility when people are facing external uncertainty. The options give the flexibility to delay the decision and somehow reduce the level of uncertainty before deciding. Flexibility has always some cost associated and most of the time options require an initial cost. In shipbuilding, flexibility could permit to wait as long as possible and do the final outfitting customization or include the final customer requirements when all the relevant information about ship-owners preferences is known. This can avoid costly reworks and lose of capital in the engineering and production department. However, this flexibility has a cost, which is to pay and secure all the necessary resources and extra-time work that have to be done to respect the project delivery schedule. Thus, the decision maker has to decide whether the option is worth the price or not. The existence of those options creates a hesitancy to invest because due to lack of information the decision maker cannot valuate accurately each of the options available and miss the opportunity to take advantage of the situation by waiting. Options are not valuated accurately all the time and their values increase with uncertainty (Wallace, 2005).

D) TRIZ

Another approach is the TRIZ developed by Altshuller. TRIZ (Russian: Теория решения изобретательских задач (Teoriya Resheniya Izobretatelskikh Zadatch) is "a problem-solving, analysis and forecasting tool derived from the study of patterns of invention in the global patent literature"(Hua *et al*. 2006). It was developed by the Soviet inventor and science fiction author Genrich Altshuller and his colleagues, beginning in 1946. In English, the name is typically rendered as "the Theory of Inventive Problem Solving", and occasionally goes by the English acronym TIPS.

The basic idea is in that decision-making is carried out in strict logical sequence based on the laws of engineering (and other) systems. TRIZ appeared in technical field, because there it could have a powerful patent fund, which served as the foundation of the theory. At the same time, the development of other areas - scientific social, sphere of art - is subordinated to similar laws of evolving. Therefore, many ideas and techniques of TRIZ can be used to solve non-technical creative tasks. The basis of

TRIZ are: a law of materialist dialectics, the general laws of development of systems, laws revealed by examining historical trends in technology evolution, as well as some analogues of the biological laws.

TRIZ knowledge base covers a wide range of fields: geometrical, mechanical, thermal, optical (and electromagnetic wave), electrical, magnetic and electro-magnetic, substances and materials, interaction between substance and "Field", chemical, etc. It also contains application examples in medicine, agriculture, etc. Knowledge in biology and information science are not well included yet.

From the analysis of a large number of good patents, Altshuller (1997) extracted the essence of ideas which achieved breakthroughs of conventional technology, and condensed them into "40 Principles of Invention".

All these principles (together with their sub-principles) are described briefly and have a number of application examples. Some of the principles correspond to the trends of development in technology and systems (Nakagawa, 1999).

1. Segmentation	21. Skipping
2. Taking out	22. 'Blessing in disguise'
3. Local Quality	23. Feedback
4. Asymmetry	24. 'Intermediary'
5. Merging	25. Self-service
6. Universality	26. Copying
7. 'Nested doll'	27. Cheap short-living
8. Anti-weight	28. Mechanics substitution
9. Preliminary anti-action	29. Pneumatics and hydraulics
10. Preliminary action	30. Flexible shells and thin films
11. Beforehand cushioning	31. Porous materials
12. Equipotentiality	32. Color changes
13. 'The other way around'	33. Homogeneity
14. Spheroidality	34. Discarding and recovering
15. Dynamics	35. Parameter changes
16. Partial or excessive actions	36. Phase transitions

17. Another dimension 18. Mechanical vibration 19. Periodic action 20. Continuity of useful action	37. Thermal expansion 38. Strong oxidants 39. Inert atmosphere 40. Composite material

TABLE 2: 40 PRINCIPLES OF INVENTION

TRIZ recognizes the problem as "Technical Contradiction", and tries to find breakthrough solutions by "eliminating" the contradiction. In fact, good patents are historical records of such breakthrough solutions that eliminated contradictions. Thus, learning such solutions must give us many hints for eliminating contradictions in shipbuilding problems.

To describe the essence of TRIZ methods, we will give an example. Let us imagine that during the construction of a cargo ship designed for operation beyond the polar circle, the problem occurred. It is assumed that on the open part of the deck there will be cars and trucks, which quality will be reduced if the snow fall on top of them.

Before using any methods, a problem should be reduced to a task, since one can analytically solve task. The task also includes the initial conditions and the character of the result to be obtained. Therefore, you must first at least in general terms identify possible ways of solving problems to subsequently specify them up to the formulation of objectives. In our case, the following possible ways of solving the problem are possible:

1. improve quality of the coating of the cargo, so falling snow do not worsen its quality;
2. remove or destroy the falling snow;
3. prevent falling of snow on the cargo, sheds are available tools.

To improve this, last, technical system (TS) we will devote the following analysis.

Sheds are used to protect the surface from the fall of snow for a long time, but in conditions of market economy, there is an additional requirement: they must have a low cost. From this, we can formulate a new, narrower issue: when protecting cargo from falling snow by using shed, it has to be as cheap as possible. We have administrative contradiction: the need to reduce the cost of shed, but nobody knows how to do it. This is not the task - there is no baseline data or the nature of the result. In order to lead this conflict to a technical task, we must specify the terms. To do so, it is needed to describe the technical system with which, or based on which solutions will be developed. It should be noted that the obtained solutions do not need necessarily to be similar to the original TS, because the main motivation is the solution of the problem, rather than upgrading the existing TS. We assume that the original TS (a shed) is a roof that is installed on bearings. The essence of the formation of the task is to find the technical contradictions that must be solved. The requirement for low-cost shed is not technical. Therefore, we find technical analogue of this requirement. Cost of shed mainly consists of material costs and cost of works on its construction. Cost of works is not a technical specification, so the contradiction will be formulated regarding the cost of materials. From the technical characteristics we can distinguish: thickness of the roof, the number and location of supports, cross-sectional area of supports.

It should be emphasized that any selected characteristic is a kind of "bait" to catch the ideas. If the ideas that are appropriate for this "bait" are not relevant, the next technical characteristic is chosen to continue the "catching of ideas".

In our case, we choose the thickness of the shed. In order for the cost of materials of the shed was minimal for a certain area, its thickness should be minimal. Thus, we replace the economic criterion of "low cost" on the technical characteristic "minimum thickness of the shed". Now we can formulate the technical contradiction: if thickness of the shed will be big, then the roof will keep the weight of snow, but will turn very expensive; if the thickness of the shed will be little, it will be cheaper, but cannot hold the weight of snow and will collapse.

So, we formed a conflicting pair in the form of the shed and snow. Since the TS is a roof, the main change will be carried with it.Examples will be offered to illustrate the use of certain techniques of TRIZ to solve the task.

Presentation is organized as follows: name of the reception, brief presentation, binding, or adapting the content of the reception to the problem and the solution that follows from this. Names of techniques and their summaries are cited in the work of G. Altshuller (1997).

Admission 1. The principle of fragmentation. a) Divide the object into independent parts; b) Make an object dismountable

c) Increase the degree of fragmentation of the object.

Adaptation: Split the roof into many small roofs, standing on their supports. Then the main load of weight of snow will be borne by the supports and the roof can be made thin.

Solution: make the roof as a set of small roofs on their supports. Represented an intermediate solution, because immediately arises a problem of a large number of supports (Tokarev, 2006).

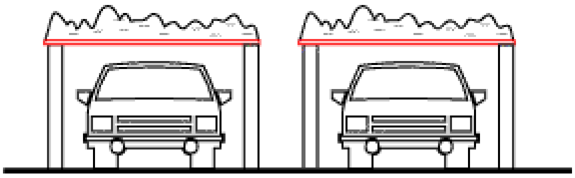


FIGURE 18: ADMISSION 1(TOKAREV, 2006)

Admission 2. The principle of imposing. Separate the hindering part from the object (a "hindering" feature) or, conversely, to highlight only the necessary part (desired feature).

Adaptation: hindering part is the thickness of the roof. It comes mainly because the load on the roof turns to be bending and the tension of the material is very high. Now if it was possible to make just a tensile load, it would significantly reduce tension.

Solution: Hang the roof of the numerous thin ropes, mounted on high poles (Tokarev, 2006).

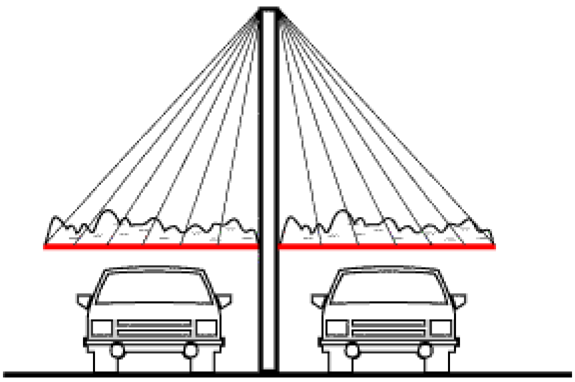


FIGURE 19: ADMISSION 2 (TOKAREV, 2006)

Admission 3. The principle of asymmetry.

a) Go from symmetric shape of the object to asymmetrical.

b) If an object is asymmetrical, increase the degree of asymmetry.

Adaptation: The original TS is represented as a plane lying on poles. It is possible to tilt it to give it an asymmetric shape.

Solution: Make a slant roof, thereby reducing load per unit of area of the roof as well as a sloping roof will provide the snow to slide down and not accumulate on it that also will reduce the load (Tokarev, 2006).

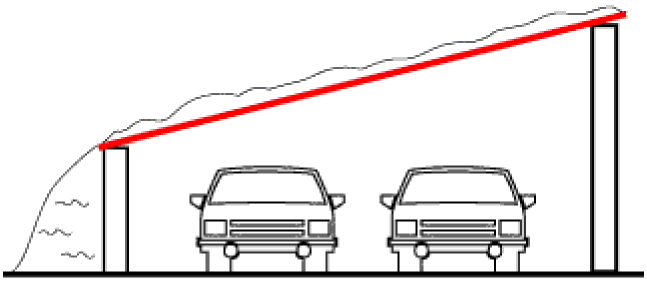


FIGURE 20: ADMISSION 3(TOKAREV, 2006)

Admission 4. The principle of universality. Object performs several different functions, thereby eliminating the need for other facilities.

Adaptation: It is necessary to add a roof other functions, such as to be a floor.

Solution: add a superstructure above the deck - a floor, which is used for residential purposes or a warehouse (Tokarev, 2006).

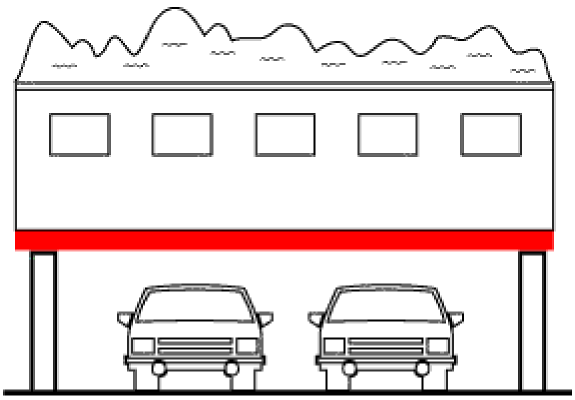


FIGURE 21: ADMISSION 4(TOKAREV, 2006)

Admission 5. The principle of equipotentiality. Change the working conditions so one does not have to raise or lower the object.

Adaptation: The snow should fall on roof, the snow should not leave the cloud.

Solution: Destroy snow clouds or make snow to fall anywhere else (Tokarev, 2006).

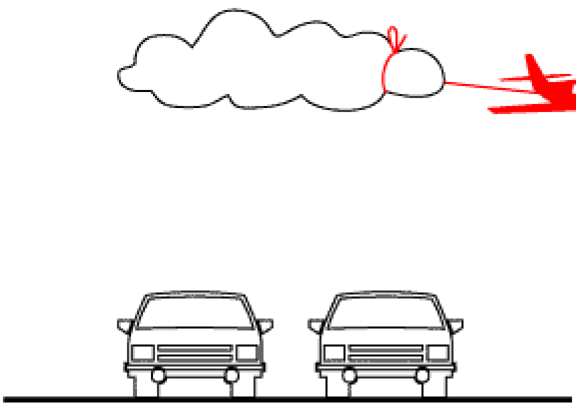


FIGURE 22: ADMISSION 5(TOKAREV, 2006)

Admission 6. The principle of uniformity. Objects that interact with this object should be made of the same material (or close to it in properties).

Adaptation: The roof should be made of snow.

Solution: Make the roof of the ice or from the first fallen snow, or pre-build an ice construction (Tokarev, 2006).

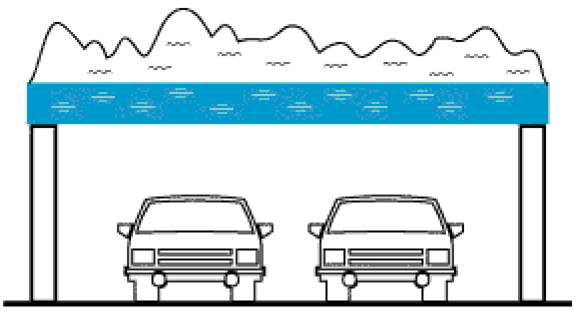


FIGURE 23: ADMISSION 6(TOKAREV, 2006)

Thus, we explored the possibilities of TRIZ for making engineering decisions in shipbuilding. As seen from the example, the application of these methods allows to make engineering decisions based on principles of TRIZ. This, in turn, helps to get a large number of solutions to the problem.

To summarize, the theory of decision-making does not give the final, indisputable recommendations, it can only give you an advice. If the recommendations arising from the different criteria are the same, one can safely choose the recommended solution. The likelihood that it will not fail is high. If the recommendations are controversial, you should think, make an additional evaluation of criteria, and make a choice.

Moreover, human behavior is not always logical. Sometimes it obeys logic, and more often, it obeys feelings. Decisions made by leaders and employees at different level of the organization vary from unexplained, spontaneous to highly logical ones. The lack of information creates uncertainty. When decisions are made under uncertainty, and when people do not use models and mathematical approaches, they tend to use heuristics. The use of those heuristics for the estimation of values and probabilities leads to decision-making errors due to different kind of biases and framing effect.

2.4 Approaches to handle human biases

After discussing decision-making theories in the area of controlling information flow in shipbuilding, we can offer practical approaches of handling arising uncertainty and human biases and create flexibility. Those approaches are:

1) Multi-personal processes
2) Checklists
3) Premortem technique
4) Memos

2.4.1 Multi-person Process

Process matters in decision-making because we do not learn enough from our mistakes (Sibony, 2011). Biases are everywhere and we know that we are subject to them. We are overconfident, subject to anchoring and so on but there is not much we can do to avoid them as individuals. The biases can be control by a multi-person process, where our opinions can constantly be challenged by somebody else's perspective (ibid). The objective with the multi-person process is to ensure that the biases of individuals weight less in the final decisions than the things that should have more attention like facts. This approach can be relevant in meetings where each proposition or estimate can be evaluated on different angles and eliminate individual biases.

It can be done by the six thinking hats technique. The six thinking hats technique developed by Dr Edward De Bono is a thinking tool for group discussion or individual thinking. This technique uses six colored hats, which permit to think in different ways and then combine the results to have a sound and reliable solution (figure 24). Each way of thinking is challenged by the others' opinion. The six hats are white, yellow, green, red, black and blue.

White addresses the rational aspect of the thinking. It allows no interpretations, no opinions and relies only on facts.

Yellow represents the optimistic part of the thinking. It emphasizes on the positive aspects (advantage and gain) of the situation and on the opportunities. The person wearing this hat makes concrete and precise suggestions.

Green emphasizes on creativity. It is about finding new approaches and perceptions and innovative solutions. Under this hat, one has to go beyond what is well known.

Red represents the emotional part of the thinking. It allows the person to raise reaction and concerns with no need to justify or explain.

Black represents the pessimistic and critical part of the thinking. Under this hat, the aim is to criticize the idea or proposition and highlight all its weaknesses. It permits to determine if there is no other possibility.

Blue is the organizational aspect of the thinking. It plans and organizes the thoughts, determine the targets and control the respect of the rules. It permits to do the synthesis at the end of the meeting or the reasoning (De Bono, 1985).

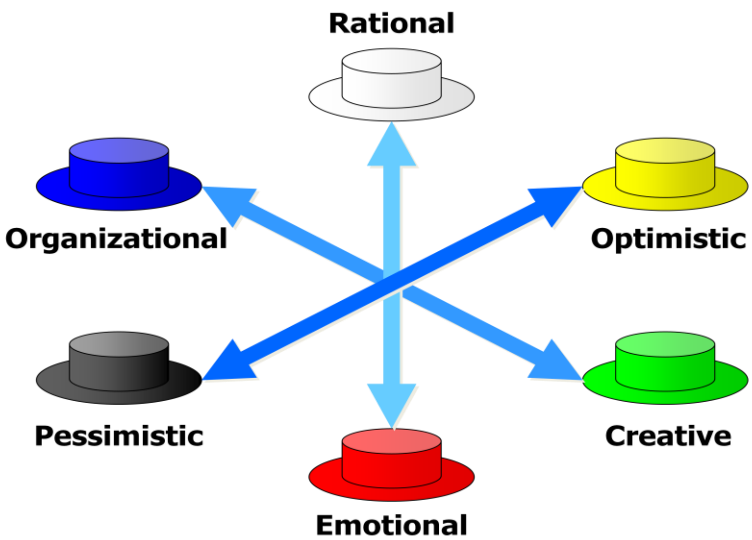


FIGURE 24: SIX THINKING HATS (E. DE BONO 1985/SINTEF)

The rules of the six thinking hats are summarized below in figure25. When using the six thinking hats, the engineers can reduce as much as possible the impact of their individual biases on their decisions. In planning meetings, the technique can permit to eliminate individual biases and reduce the risk of decision-making errors.

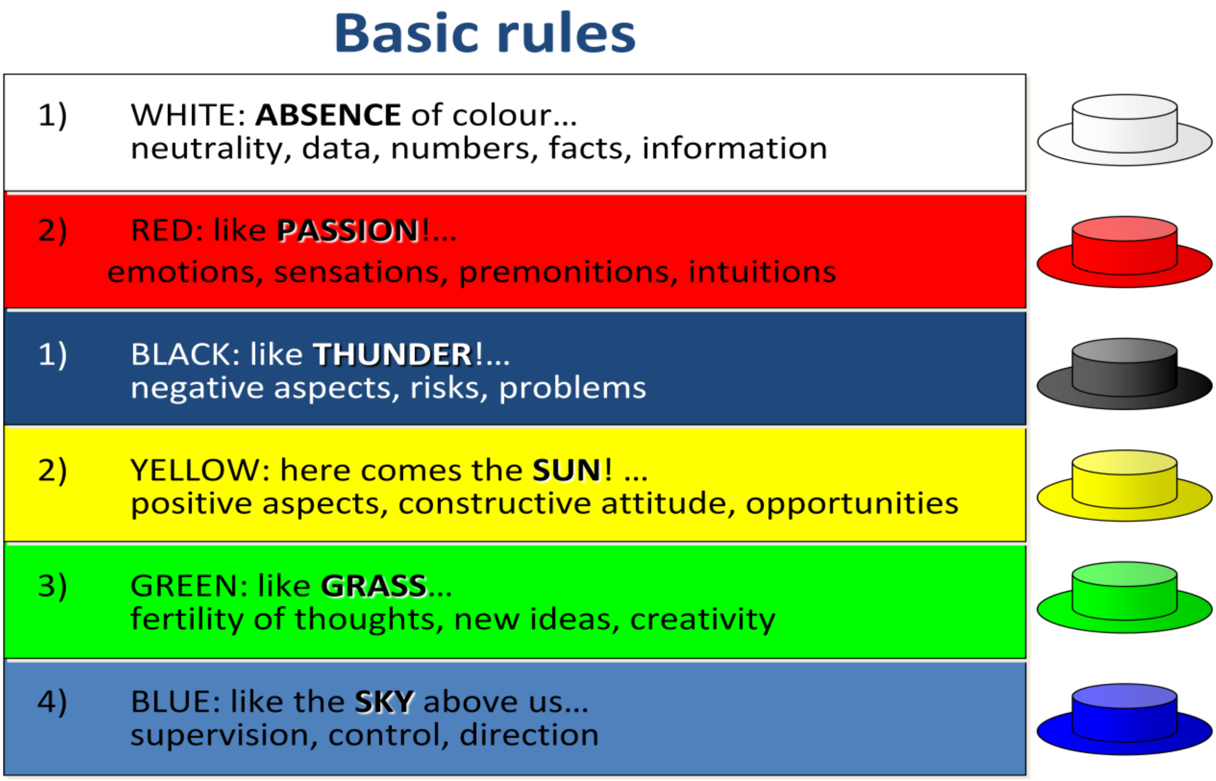


FIGURE 25: BASIC RULES OF SIX THINKING HATS TECHNIQUE (E. DE BONO 1985/SINTEF)

2.4.2 The Premortem Technique

The premortem technique was invented by the psychologist Gary Klein (Sibony, 2011). This technique is a way to present the risk and uncertainty around a task or a project without appearing as a pessimistic person. In the premortem, you ask people to project themselves in the future and assume that the task as not been completed on time, the weekly or period plans have fall behind schedule or that the project has fail. Therefore, they have to identify the reasons of this potential failure beforehand. It allows the different actors to express the risk and uncertainties they kept for themselves (ibid). The whole dynamic changes from trying to avoid anything, which might disrupt the harmony to trying to surface potential problems (Kahneman and Klein, 2010). This identification of potential risks and uncertainty regarding the planning will allows the work leaders or the discipline owners in cooperation with the engineers to make provisions for flexibility. It means that they can have a set of tasks ready to start, which can be use to create flexibility in the process if the potential risk identified earlier occurs. It is about having different options that will be used if necessary to avoid disruption in the task execution and eliminate subsequent delays.

As example, assume that a piping engineer has to start a task next week. He uses the premortem technique. Thus, before starting the task he tries to identify the reasons why he might not be able to complete the task according to the schedule. He notices that there is a discussion about new regulations about the structure of the pipes. Det Norsk Veritas will publish the new standards by the end of next week. In addition, the ship-owner might changes his requirement accordingly or he will just have to redo the whole task by using the new correct technical specification. Therefore, he informs the work leader and together they identify the options to assign him another task and postpone the task including the pipes specifications. Or they can decide to assign this task to a third party partner and allow the local resources (engineers) to focus on executable tasks. This will permit to keep the schedule, focus on executable tasks and avoid delays in the project execution.

The premortem technique can be illustrated as in figure 26 below:

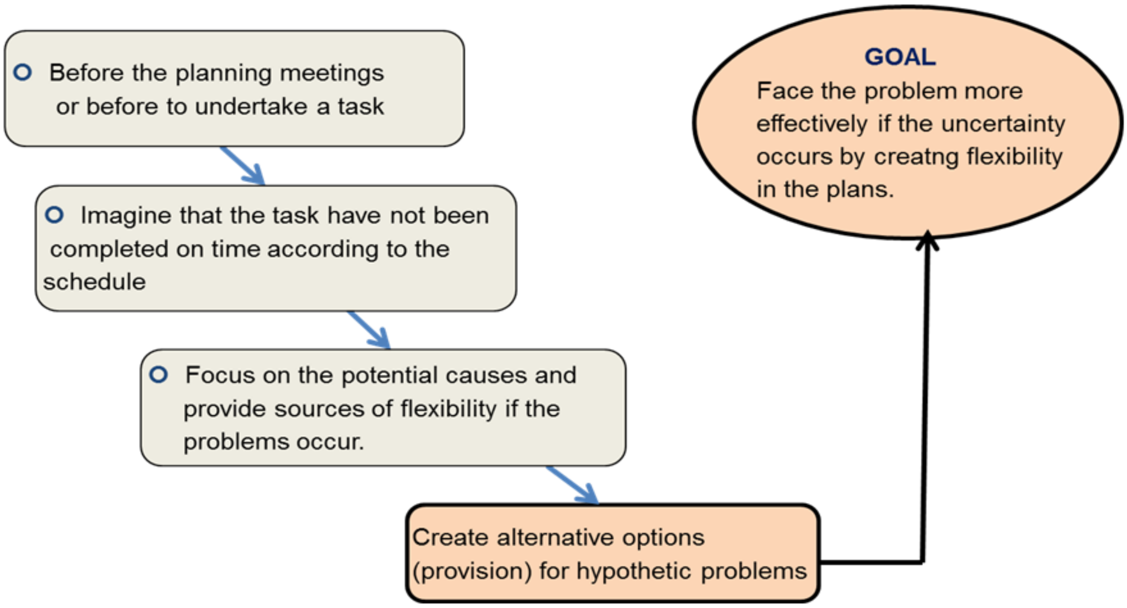


FIGURE 26: ILLUSTRATION OF THE PREMOTEM TECHNIQUE

2.4.3 The Checklists

Checklists can be used individually by engineers to evaluate the likelihood to complete a scheduled task. Checklists permit to verify if the different elements or requirements of a specific task or standard operating procedure are satisfied. This verification permits the engineer to know if he has a ready and executable task when he starts (figure 27). Having checklists does not mean that the engineers will not make errors in case of uncertainty but it will prevent them to be overconfident and identify the real uncertainty behind each action (Kahneman and Klein, 2010). Therefore, before starting a task, one can inform the discipline owner or the work leader about the risk of non-completion and identify the potential causes. Together they can take corrective actions or move to another sound activity, which has all its premises completed and ready for execution.

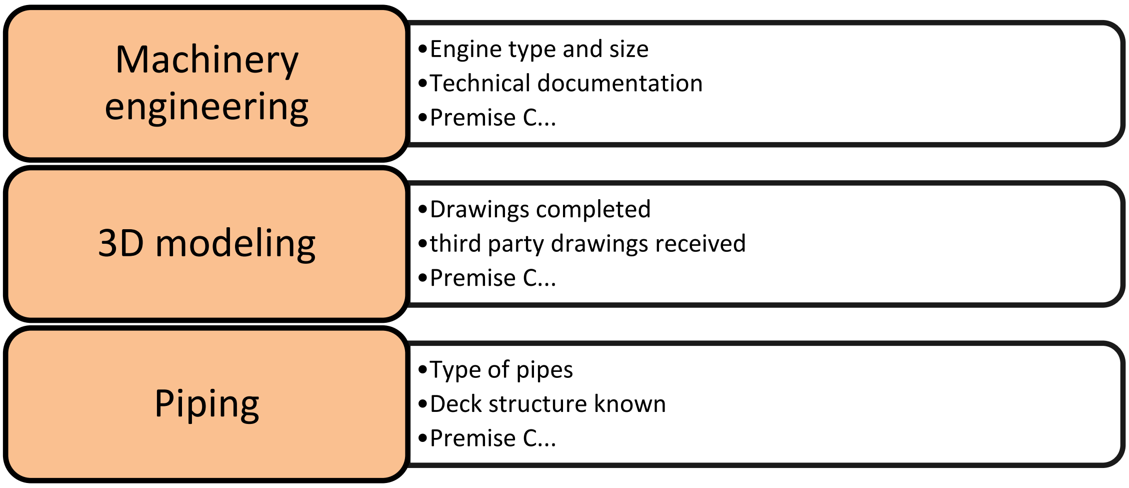


FIGURE 27: EXAMPLE OF CHECKLIST FOR THE ENGINEERS

2.4.4 The Memos

Memos are like checklists but there do not address any specific task or operating procedure. The memo will consist for the engineers to write down the reasons why the tasks or a weekly project will fall behind schedule long prior to the actual evaluation meeting. Because at the time the task has to start or before the weekly meeting, the negative reasons have been forgotten and everybody is framing a positive situation. Unless the possible causes have been recorded, they will not be discussed. Thus, the memo will permit to both the engineers and the discipline owners or work leaders to keep track of the recurrent causes of delays when they do the planning.

2.5 Professional maladjustment and its connection to human biases and uncertainty.

As in this thesis we try to connect lean approach to the area of human methods of making decisions, we consider important to study not only cognitive sphere of decision-making, but also the sphere related to people's emotions and feeling. For this, we use the concept of professional maladjustment. It is important to mention that we do not consider this source of information as a major one, but only as a secondary. It is used in order to understand how emotional sphere of workers is connected to biases that occur in their decision-making process.

So, maladjustment is a concept that describes any violation of adaptation, a violation of adaptation of the organism to the constantly changing conditions of external or internal environment. It can be also described as a state of dynamic mismatch between the living organism and the environment, leading to a violation of physiological functioning, behavior change, the development of pathological processes.

The balance between employees and their professional environment is continuously changing. Therefore, HR managers increasingly face the need to adapt employees to new profession or to readapt people to changing working conditions.

There are different elements that can lead to major changes in man's relation to his profession and even to professional maladjustment. These elements are changes in the professional environment such as changes in technology, the arrival of a new leader, the accession to a new profession or to a new position, changing needs, new opportunities and objectives of the individual. Maladjustment may occur due to short-term and strong environmental influences on the person or due to the influence of less intense but prolonged exposures. Maladjustment appears in various aspects of activities: in decrease of productivity and quality, in violation of work discipline, in the increase of casualties and injuries.

Professional maladjustment is showed in a number of physical and psychological phenomenons:

- emotional shifts - which basically mean deviations of occurring emotions (for example, a person doesn't feel joyful when succeed).
- violations of individual mental processes - can be described as increased level of obliviousness, distractibility, absentmindedness.
- reduction of the total activity - a person feels tired, exhausted.
- fatigue
- Somatovegetative violations - headache, backache, pain in legs\feet, unreasonable anxiety.
- Violation of the cycle "sleep - wakefulness" - it is difficult for a person to wake up, to fall asleep, he or she experiences insomnia and nightmares.
- Features of social interaction - a person is losing interest to interaction with other people, family and friends.
- Reduced motivation to work

Therefore, we use this concept to investigate the influence of self-feeling of a person on the biases he or she experiences.

CHAPTER 3 - SYNTHESIS AND LINK BETWEEN THESE CONCEPTS

In the literature, less emphasis has been put on the impact of human biases in decision-making under uncertainty and on the influence of human and cultural aspects on the implementation of lean philosophy.

Shipbuilding is an industry characterized by a high level of uncertainty related to the suppliers, the ship-owners, the production and the technology. In the planning and construction phases, decisions have to be taken in light of this uncertainty. A wrong first decision can seriously affect the following decisions with potentially amplifying effect, such as the bullwhip effect. One major objective is to reduce the risk of errors occurring each time a decision has to be taken. In addition to the uncertainty faced, organizations are becoming increasingly global and have to face cultural challenges in their expansion and in the implementation of new approaches. Cultural diversity influences people's ability to express their opinions and the ability to use active participation, which is also related to the organizational culture of the company. It can be either competitive or supportive, and can inhibit or encourage the expression of ideas and affect decisions made in meetings or individually.

Currently STX OSV Søviknes implements the lean planning system based on the Last Planner approach. Recall that one of the most important lean principles is that the problem should be addressed by the ones who face them. The aim of lean planning in the company is to deliver each part of a project in a specific period and keep solution space open as long as possible to tackle uncertainty effectively. This situation induces pressure on the decision-makers because they are submitted to deadlines. These deadlines induce time-pressure and different affective states affecting the decisions made by each individual along the organizational chain (Maule *et al*. 2000). Time-pressure is a phenomenon that may appear in different forms and circumstances. Decisions made under time pressure can be found in investment decisions such as stocks market trading where the profit depend on the speed of the trader's reaction to new relevant information (Kocher *et al*. 2006).

Moreover, the Japanese method of lean implementation was not rooted in the use of information technology only but was based first on human involvement (Riezebos *et al*. 2009b). Hence, it creates an increasing risk of human errors in decision-making related to an uncertain environment because employees are at the heart of the planning system. There is a need to educate thoroughly the employees before anything else (www.artoflean.com). The PDCA circle, on which the lean system is based, represents a powerful tool helping management to evaluate and control the different activities. But, it does not emphasize on the training and empowerment of the people who perform these activities. Behavioral investigation is then a prerogative for a full-scale application of new methods and philosophy in companies (Sacks *et al*. 2010). The current situation can be summarized in figure 28 where the decision process in the engineering department is in a lean environment; individual are subject to uncertainty, time-pressure and misconceptions and receive information gradually along the process. They have to make decisions at each step without having all the information. Therefore, there is a high risk of decision-making errors.

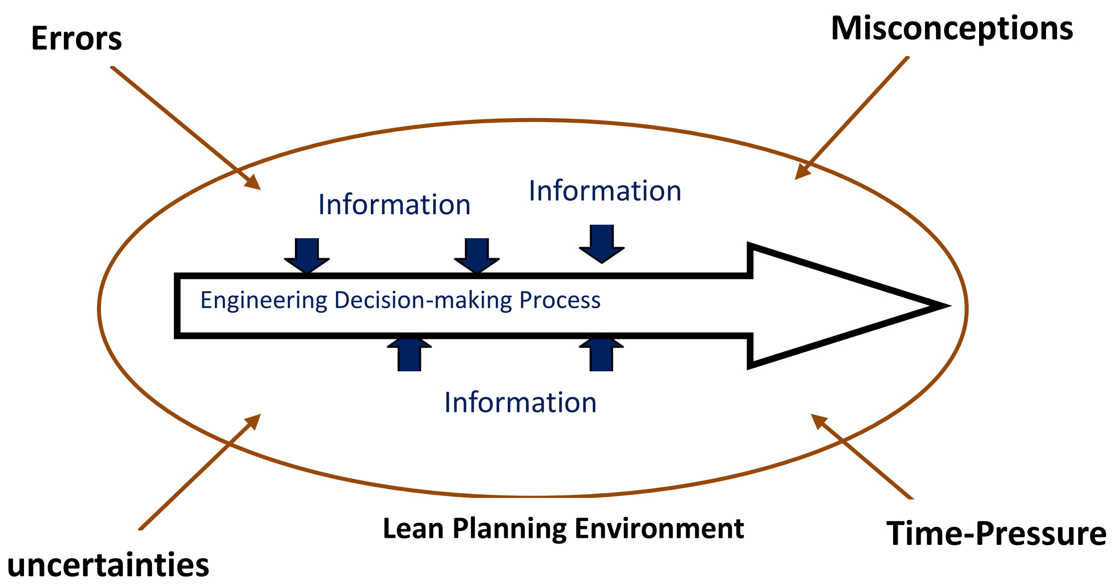


FIGURE 28: DECISION-MAKING ENVIRONMENT

The best way to make decisions is then to follow some rational and systematic methods to increase the likelihood to have high quality, accepted and ethical decisions. Some methods among others are operation research, options theory and utility theory. However, people do not make rational decisions but tend to satisfy rather than optimize.

That means they make decisions that meet their aspiration levels and that are acceptable (Simon 1991). One of the consequences of time pressure is that it does not permit to go for thorough and complete information processing so decision makers tend to use accessible information rather than continue to seek quality information if available. Under time-pressure, there is always a tradeoff between speed and accuracy. The speed represents the cost of gathering relevant information and the accuracy represents the resulting benefit. In this situation, the accuracy is an indicator of the decision's quality (Kocher *et al.* 2006). Thus, under time pressure decision makers tend to speed up the decision process or just switch to simpler strategies. They tend to filter heavily the information used or just omit to consider some information (Ordóñez *et al*. 1997). This can result in the so-called "closing of the mind" where people rely on heuristics and rules of thumb for decision-making (Kruglanski *et al.* 1983).

The lack of information increases uncertainty. Therefore, when they make decisions, they use heuristics as representativeness, availability heuristic or anchoring and adjustment. These heuristics, which are intelligent rules of thumbs lead to systemic errors due to human biases (among others bias of representativeness, availability bias or anchoring) and framing effects. They reduce the quality of the decisions made under uncertainty. In the same line, overreaction to stress and pressure, the overuse of intuition and the lack of communication accentuate the use of heuristics leading to subjective estimates and sometimes addressing the wrong problems. With respect to the case discussed later, not that the heterogeneity of the engineering department of STX OSV Søviknes in term of seniority, age and cultural diversity is a resource but this heterogeneity is also a source of bias in decision-making since there is mix of people with different background and culture. Moreover because uncertainty is the main driver of framing effect, in an industry like shipbuilding the risk of errors due to biases and framing is very high.

Due to this risk of errors, it is tempting to say that the engineers should make decisions based only on objective and logical analysis. But, we are subject to the powerful influence of our emotions and our instincts, and we have a bounded rationality (Campbell *et al.* 2010). Then although decision makers try to be rational they are constrained by limited capabilities and incomplete information.

Thus, these elements prevent us to do some thorough and complete logical analysis. Therefore, the search for objective and logical method of analysis overlooks the fact that we cannot get away from the influence of our gut instincts. We are constantly submitted to biases as anchoring and adjustment, representativeness and framing effects, affecting our risk perception and the way we estimate or evaluate situations. The impact of those biases and framing effect increases in the presence of uncertainty. They encourage decision-makers to put more effort and time into specific decisions compare to others, to collect more data in one area and not in another or to present a situation under one particular angle (March, 1994). In summary, those biases and framing effects influence the decisions even when the decision-makers try to be analytical and rational. From there we can say that the fact of being weak in our judgment, preferences and decisions is sometimes beyond our control due to biases, framing effects, uncertainties and bounded rationality.

Therefore, we are going to analyze the influence of biases and framing on the decisions made by the different actors individually or during the lean planning meetings. During those planning meetings, due to uncertainty, the estimates and decisions can be influenced and the issues can be wrongly addressed. The link between the uncertainty in shipbuilding and the occurrence of framing effect in a lean planning environment will be describe as in figure 29.

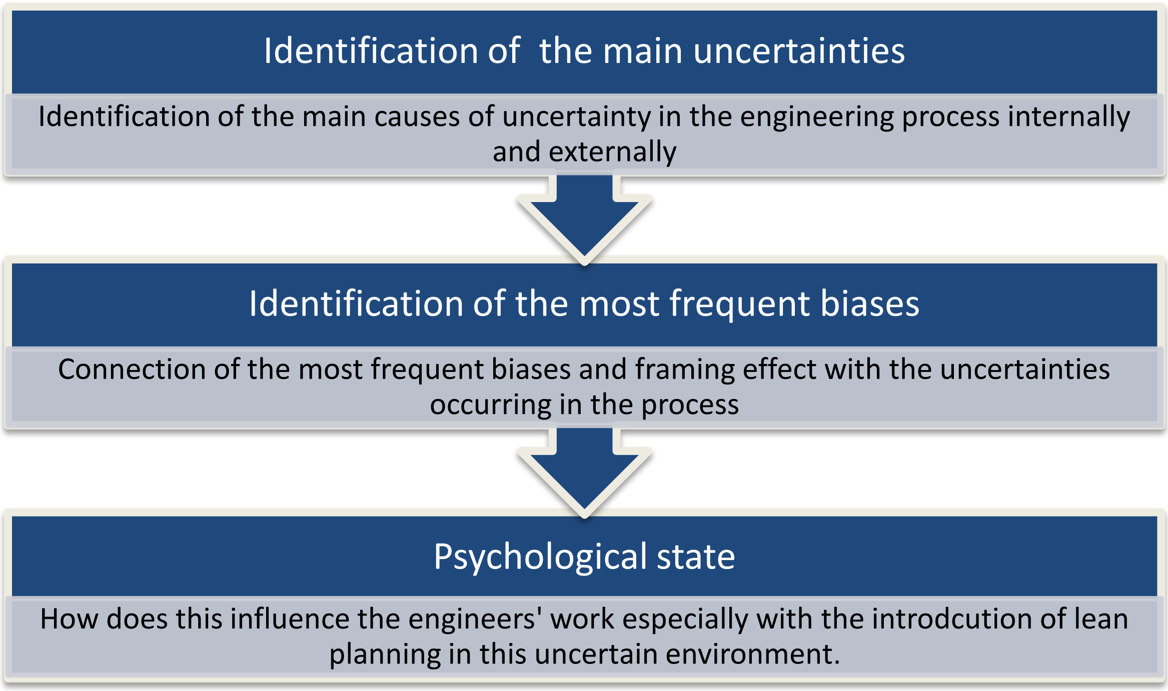


FIGURE 29: THE LINK BETWEEN THE CONCEPTS

In most cases, a defect-free process produces a defect-free product. Therefore, a quality product requires a quality process where quality decisions are made (Taghizadegan, 2006). We need then to identify the biases and try to reduce their impact as much as possible in order to maintain the quality of the decisions made to support the engineering process. We will present now an example, which illustrates the drawbacks of the use of heuristics and the effect of human biases on the planning process.

Assume that for a completely new project, an engineer has to make the drawings of the ship section, which will receive the crane but he does not know for sure what will be its final size. Such type of cranes was never used before and he has no opportunity to look on a previous project's drawings to clear up his assumption. However, he makes his drawings by remembering that the ship-owner has two ships built in the yard, which use specific National-Oilwell cranes. Then he base hiss drawings on this assumption. In light of this uncertainty, he uses availability heuristics to make his decision based on the facts he recalled easily from his memory. When the specifications about the crane will be clear, if he is wrong, he will have to redo the drawings. Moreover, this can affect other engineers who based their drawings on his works. That will create a series of reworks and cause subsequent delays on the planning and on the schedule.

This example shows the importance to identify the human bias occurring frequently in the company and find ways to reduce their impact on the decision made under uncertainty. It will permit to take advantage of the improvement brought by lean planning, which is an efficient tool to follow accurately the project execution. This will permit to conduct the planning effectively, create flexibility to tackle uncertainty more effectively and respect the delivery schedule.

CHAPTER 4 - THE CASE COMPANY

STX OSV is a part of STX business group, a worldwide conglomerate of industrial companies operating in shipping and trade, shipbuilding and machinery, construction, plant and energy. The group's portfolio consists of activities in different branches including shipbuilding equipment and material, marine engine manufacturing, shipbuilding and shipping activities. The group includes companies such as STX Pan Ocean, STX Offshore and Shipbuilding, STX Engine and STX Europe.

4.1 STX-OSV

STX-OSV is one of the major world shipbuilder, making offshore and specialized vessels used in offshore industries. The company core activity is to build Offshore and Specialized Vessels (OSV) including Platform Supply Vessels (PSV), advanced Offshore Subsea Construction Vessels (OSCV), Anchor Handling Tug Supply Vessels (AHTS) and a variety of specialized vessels of varying complexity and size. In addition, the company makes specialized vessels as LNG-powered ferries, coast guard, fishing vessels and icebreakers (www.stxosv.com). Despite the fact that STX OSV looks like a company working exclusively in shipbuilding, STX-OSV delivers different products and services. There is:

- Ship design, the company through one of its subsidiary delivers designs for standard and highly customized vessels. It focuses on research and development to offer innovative solutions to the offshore industry.
- Ship repair and conversion; this service includes docking and slipways, sandblasting, engineering, steel work, painting, repair of thrusters and electrical systems, propulsion systems, diesel engines and extension.
- Accommodation with STX Norway Accommodation specialized in interior outfitting of new-build ships.
- Electrical engineering, power and automation; STX OSV offers its customers a complete electrical system package including installation, integration, testing and commissioning.

- Piping systems and installations, through two subsidiaries in Norway and Romania, the company produces and installs piping systems for both shipbuilding projects and land-based construction projects.
- Trading; through STX OSV Trading that sells ship design, third-party equipment and electrical systems.
- Shipbuilding: the company has nine shipyards worldwide: five in Norway, two in Romania, one in Brazil and one in Vietnam.

Our thesis is written in collaboration with one of the Norwegian shipyards, STX OSV Søviknes located at Søvik. This yard is an outfitting yard of 57000 m2 established in 1936 and has now 167 permanent employees. The yard delivers some of the world most advanced and innovative offshore vessels.

The scope of our work is limited to the engineering department, which consists of roughly 30 engineers from different countries. The yard started to implement a lean planning system in April 2010 and the process is ongoing.

4.2 Work environment

To begin, it is very important to understand the environment in which the study was held.

Norwegian model of management is based on principles that have been providing the development of this country for a long time without social disruption, deep political conflicts, while ensuring a high standard of living and social guarantees for the majority of the population. The most important are

- in the social field - growing importance of human factors among the traditional factors of production (labor, capital, technology, natural resources) - qualified, creative nature of work, which was expressed in the concept of "human capital" and social orientation of economic development
- Management in Norway is decentralized and democratic - the organization of a typical Norwegian company has clearly horizontal structure. Distance between levels of power is low, and the manager of the company is usually available for staff and is open

to debate. The Norwegian firm has less levels of power than, for example, French or German. It is also assumed that the better the staffs is informed about organizational decisions, the more they are interested in their proper executing and, therefore, work better.

- high level of political culture, the co-operative relations between different layers and groups of population and political parties, which was formed on the basis of mutual understanding of the fundamental interests. In the economic sphere, the model is characterized by high industrial competitiveness, based on the creation of a special sector of the economy, based on the integration between science, education and production, on interaction of public institutions with private business. It also appears in the integration of various fields, ranging from the production of new knowledge to their exploration of innovative entrepreneurship and large-scale replication of developed samples of products (innovative climate) (Milner, 2003).

However, the Norwegian model has not been spared from criticism. The following weaknesses appear in the Scandinavians way of conducting of affairs:

- they avoid conflict or supporting one of the conflicting parties;
- they fear of confrontation;
- rely on the initiative of a group;
- tend to avoid competition within the company.

This makes employees confident in the security of their labor. This peculiarity of Scandinavian model of management allows to increase the motivation of staff and to reduce the degree of professional maladjustment (ibid).

4.3 Lean implementation: behavioral challenges

As given by Emblemsvåg (2010), the objectives of the lean planning project at STX OSV Søviknes are:

1. The reduction of reworks due to improved coordination between the outfitting yard in Norway and its hull construction yard in Romania
2. Reduced delivery times, improved quality and cost reductions due improved coordination in Norway and Romania
3. Motivated people through empowerment.

The projects selected for this implementation are YN 728, YN 729 and YN 719. YN 728 is a project with low order variations, with fewer challenges in term of lean implementation. YN 729 is the first project including the entire production process from engineering and hull fabrication to outfitting in Norway and in Romania. With the project YN 729, the planning involves inter-business units. Moreover, almost the same people as for the project YN 728 conduct the project. This will permit to have some kind of continuity in the training of the persons involved in the projects YN 728 and 729. The YN 719 is similar to the YN 728 but with several order variations adding some complexity to the planning. There will be an integration of some persons from the project YN 729 to the YN 719, this to facilitate somehow the transmission of knowledge between the team members from tacit knowledge to explicit knowledge (Emblemsvåg, 2010).

Using the lean approach, the plans are divided in master plans, period plans and week plans according to the Last Planner. The updates of the period plans and the week plans permit to evaluate the progression of the projects and are discussed on a weekly basis to determine:

a) Which actions are completed and which are not

b) What improvements can be done for the uncompleted actions

c) When can they be corrected

d) What are the causes of delays

e) What will be the plan for the coming week.

This follow-up process obliges work leaders to meet regularly; therefore, this planning approach is a structured way of communicating (Emblemsvåg, 2010). Communication is the heart of the implementation process especially in a cross-cultural environment as the engineering department of STX OSV. Therefore, despite the fact that most of the implementation issues are related to resistance to change due to poor communication and poor leadership, here the main issue is the existence of biases and framing effects during those weekly meetings.

According to Kuhberger (1998), framing effects refer to the fact that decision makers respond differently to different but objectively equivalent descriptions of the same problem. Therefore, the way the work leaders conduct the meetings and present the cases can give rise to important framing effect in the decisions they make. Pieters (2004) presents the case of the petroleum industry, which is not different from shipbuilding regarding the uncertainty factor. Through his research, he noticed that as the level of knowledge of a question decreases, the professionals do not decrease the corresponding level of confidence. And when there was uncertainty about the answer to some questions, sometimes they could make a distinction between a 30% and a 98% probability interval. This to emphasize on the fact that during a work leaders' meeting, the human biases can substantially affect the decisions made and mislead all the participants to the meetings. Those biased estimates depend on how the meetings are run, how the problems are presented and they can go unnoticed.

Framing and biases exist and cannot completely be removed because they influence the options the leaders choose to analyze. They cause them to consult some people and pay less attention to others (Campbell *et al.* 2010). Hence, uncertainty being the main driver of framing effect and other biases, the main challenge at STX OSV Søviknes is to identify those framing effects and try to reduce their impacts on the different decisions made in the planning meeting. Therefore, we have to identify what the engineers think are the main sources of uncertainty in their work that cause subsequent delays. The main biases occurring when they have to make decisions under those unclear conditions and the way they accept the change in their work have to be analyzed.

The identification of those uncertainties, the biases and the evaluation of the change acceptance has been done through some questionnaires. These will be the aim of the next chapter where they will be further explained and the results obtained will be analyzed.

CHAPTER 5 - RESEARCH

5.1 - Objectives

The research focuses on three disciplines: decision-making under uncertainty, behavioral psychology in decision-making and lean planning. The collect of the data was done in the engineering department. The data were collect through three questionnaires and we planned to run some interviews.

The first objective was to identify the main sources of uncertainty that cause subsequent delays in the engineering department and to evaluate the improvements brought by lean planning. Since the lean planning is used to somehow reduce the uncertainty, we wanted to evaluate its real impact on uncertainty reduction as perceived by the engineers.

The second objective was to distinguish the main biases and framing effect occurring in the engineering department. They can affect negatively both each engineer‘s activity and the whole project schedule because they affect the way people perceive information and analyze it.

The third objective was to evaluate the psychological condition of the engineers through a questionnaire. This will permit also to assess the impact of the change brought by lean planning in the engineers’ work and on their adaptation to these new working conditions.

5.2 - Methodology

The collect of data for our analysis has been done through questionnaires. There were three questionnaires addressing specific aspects of our research

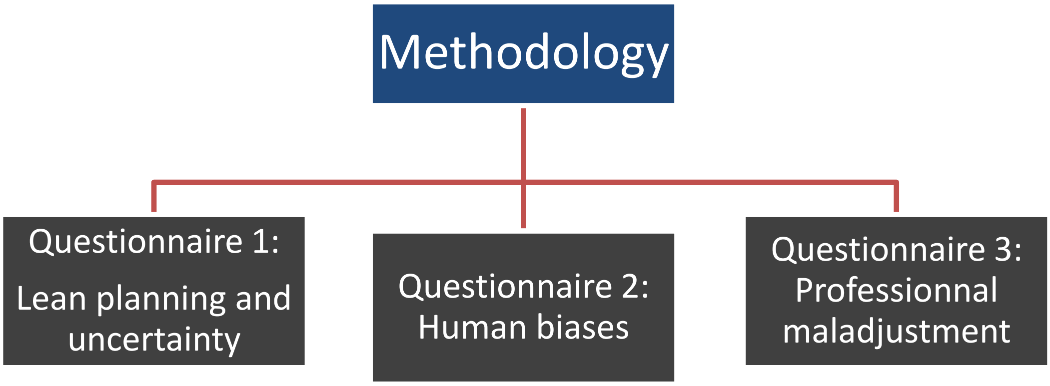


FIGURE 30: METHODOLOGY

However, the questionnaire 2 addressing biases and framing should have been run through individual interviews with the engineers. The next sections will present the three questionnaires; we are going to explain them and present the purpose of each part of them.

5.2.1 Questionnaire 1: Uncertainty and lean planning

This first questionnaire addresses the lean planning and uncertainty questions. The uncertainty factors occurring in shipbuilding are classified in three different groups: supplier uncertainty, production uncertainty and ship-owners' uncertainty (see Figure 1). The activities of the engineering department are divided in seven activity groups, which can be classified in internal and external activities as shown in figure 31 below.

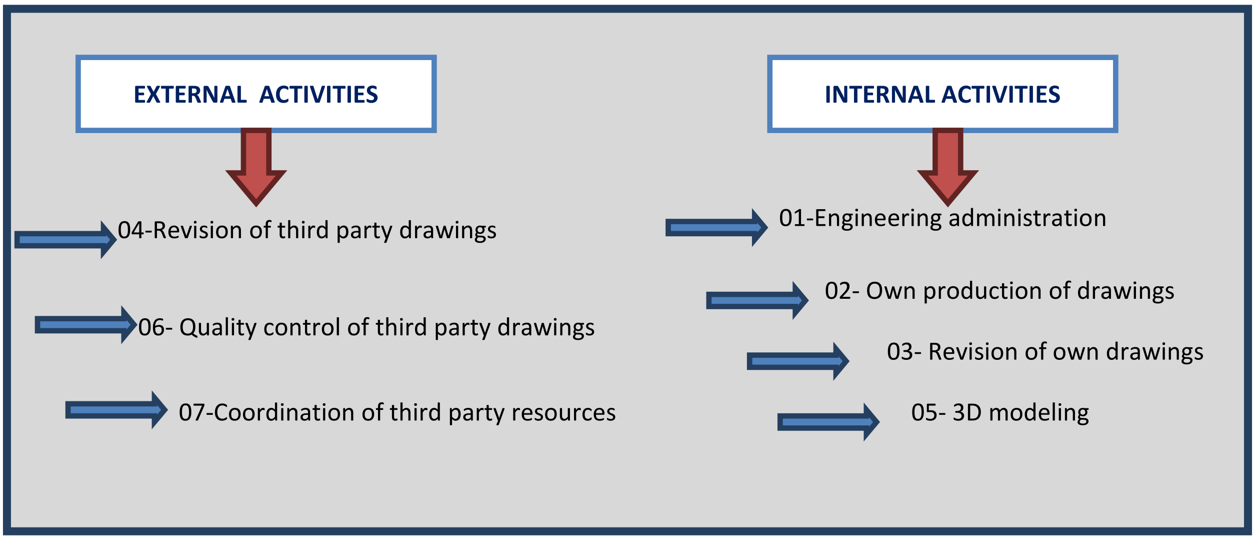


FIGURE 31: EXTERNAL AND INTERNAL ENGINEERING ACTIVITIES

We divided those activities in 4 groups according to the field covered and we had the following classification:

Group 1: Engineering administration and coordination of third party resources

Group 2: Own production of drawings and revision of own drawings

Group 3: 3D modeling

Group 4: Revision of third party drawings and quality control of third party drawings.

In the engineering department, the different activity groups are linked as in figure 32 below where the drawings and quality control lead to 3D modeling.

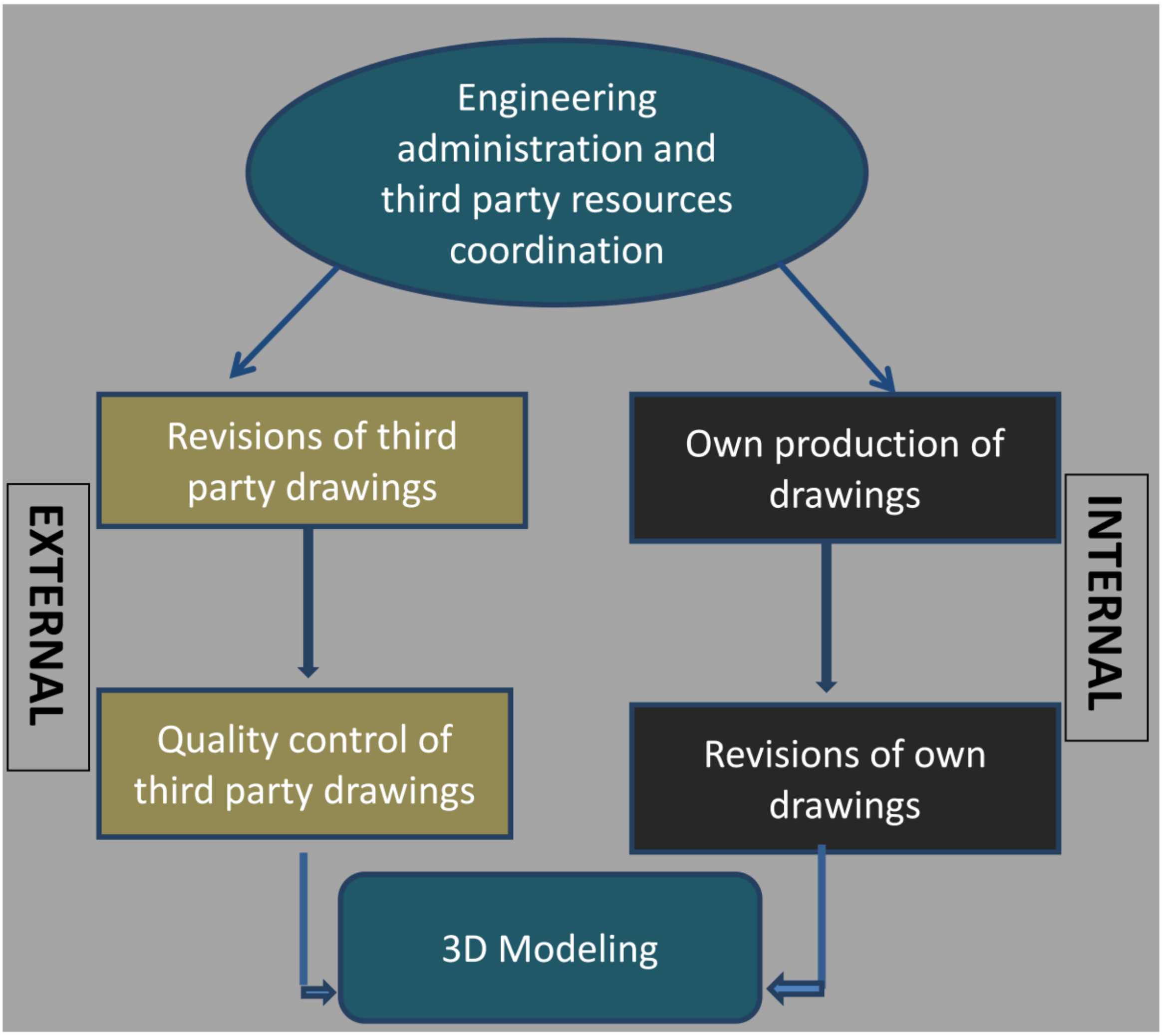


FIGURE 32: RELATION BETWEEN THE DIFFERENT ACTIVITY GROUPS

Thus, the aim of this questionnaire is to identify which ones of the uncertainty factors have the highest impact on the activity groups and cause subsequent delays in the planning, especially in the period and weekly plans. Another part of the questionnaire is related to the evaluation of the lean planning itself, to identify to which extend it affected the engineers' work.

The questionnaire is divided in three parts: the first part entitled Personalia gives an overview of the distribution of the engineers in the department according to sex, level education, age, and seniority in the company. This part permits to categorize each of the answer because it is where the respondents give their position in the department. The second part is where the respondents address the uncertainty aspects:

- Question 1 presents the level of uncertainty as perceived by the engineers.
- Question 2 ranks the reasons why the engineering work and the coordination of third parties are difficult.
- Question 3 focuses on the internal uncertainty by ranking potential reasons why the drawings, 2D and 3D modeling can be late on schedule.
- Question 4 focuses on the external uncertainty through third parties activities.

Those ranking will allow us to identify the main sources of uncertainty for each activity group.

The last part of the questionnaire concerns lean planning. Here through question 6, the engineers give an evaluation of the lean planning in relation with their work before and after its implementation. This will permit us to see if lean planning has improved in general their ability to keep the schedule, the coordination between disciplines and the information flow. Questions 7 and 8 evaluate the improvement brought by the lean planning in the uncertainty reduction and in the engineers' way of working.

5.2.2 Questionnaire 2: Framing and biases

Tasks, which were given to the subjects in these experiments, are of great interest both for logistics, as well as for behavioral psychology. The study was conducted based on the questions that Kahneman and Tversky used in their experiments. Note that the results of their experiments are statistical in nature, and in addition, their experiment involved a large number of people.

The questionnaire is made to identify the main biases and framing effect occurring in the engineering department. In decision-making people do some mistakes that are not intentional or rational. These mistakes occur because of biases or framing effect and induce decision-making errors. The questionnaire is divided in two parts.

The first part of the questionnaire consists of 21 different questions taken from prospect theory of Kahneman and Tversky (1979) and from the work of Kahneman et al. (1987). The questions are made to reveal different biases and framing effect.

Question 1, 2 and 6 evaluates the use of anchoring and adjustment heuristics. That permits to see if there is anchoring bias.

Question 3, 8 assesses the law of small numbers coming from the use of representativeness heuristics. It reflects representativeness bias.

Questions 4 and 5 address specifically framing effect related to risk seeking and risk aversion behavior using the Asian disease example of Kahneman and Tversky (1979).

Question 9 also evaluates risk aversion behavior.

Question 14 and 15 illustrate retrievability heuristics.

The second part of the questionnaire is a set of questions made to reveal the same biases. Subjects were asked questions that included the selection of two choices, "yes" or "no". It is interesting to evaluate the existence of those biases because they are the ones, which can have an effect on the decision made by the engineers individually or in the weekly and period plan meetings.

We should also mention that some of the answers that are not relevant for the study were deleted from the presented results.

5.2.3 Questionnaire 3: Professional maladjustment

The professional maladjustment test is a standard test used to obtain information on the workers' current psychological condition. In our case, this test will help to make a conclusion about the level of adaptation of workers to new working conditions. The test consists of 64 short questions related to the workers' feelings, their health and the way they interact with their coworkers. The questionnaire has six scales that describe the main manifestations of professional maladjustment: emotional shifts, characteristics of individual mental processes, reduction of the total activity, fatigue, somatovegetative violations, violation of the cycle "sleep - wakefulness", features of social interaction and reduced motivation to work. It will show how the engineers tackle changes in their new working conditions because this could have some impact on their inclination toward biases.

The test consists of 64 questions with three variants of answers: "Yes", "Not sure", "No". The respondent is supposed to choose only one variant.

5.3 - Limitations

Our data collection was conduct through questionnaires. The study faced three main limitations:

The first limitation of our research was the sample size. Small sample size increases the risk of statistical errors and the risk of false significant differences between the data. It also can increase the chance to miss significant differences. We had a population of 30 engineers and technical secretaries in the engineering department. And the response rate was 66.66%. However, the problem with the sample size is that it does not give a complete and accurate picture of the characteristics we wanted to evaluate.

Second limitation is the representativeness of the sample. Representativeness determines to which extent we can generalize the results obtained from a sample to the entire population (ILyasov, 2011). In our case, the representativeness of the sample has not been defined, as it is we do not know the general characteristics of the population.

The third limitation is the absence of individual interviews mainly due to time limit. At the time of the survey, the engineers were overburdened by their work and because of this; there was no opportunity to conduct individual interviews with them. These individual interviews would permit to reflect the real uncertainty aspect of the questionnaire with time pressure and lack of information and create the conditions, which could lead to the use of heuristics. Thus, the original conditions of research by

Kahneman *et al.* (1987), and Kahneman and Tversky (1979) were not met. Engineers answered the second questionnaire in written form. This gave them the opportunity to consult about the correct answers together and on the Internet. It gave them also more time to answer each question.

In addition, we had an internal validity problem. Due to the way questionnaires were answered, we could not control the necessary factors of the study. It could lead to one of the forms of internal validity problems - mixing of variables. This is one of the greatest threats to the validity of the experiment. If in the course of the experiment a random factor (not the experimental variable) interacts with the dependent variable, and this interaction cannot be measured separately from the interaction of dependent and independent variables, the effect of random and independent variables is indistinguishable.

However, we obtained results that correspond to the ones obtained by Kahneman et al. (1987) and Kahneman and Tversky (1979) in their studies.

CHAPTER 6. RESULTS AND IMPLICATION

From a population of 30 persons in the engineering department of STX-OSV Søviknes, we got 20 answers, so a response rate of 66.66%. The questionnaires were sent by email to the chief of the department who transmitted them to the engineers by email. The engineers printed out the questionnaires and answered them. We collected the answers in paper form and recorded the data for analysis. The following sections summarize the results obtain from the different questionnaires.

6.1 - Results

From questionnaire 1, we can see that 70% of the engineers evaluate the level of uncertainty in their work as clear enough. In addition, we identified the main sources of uncertainty causing delays in the engineers work and in the planning phases involving the engineers (Table 3). Those are issues addressed frequently in the weekly planning meetings. To find the final ranking of the cause, we determine the mode of the answers submitted by all the engineers to make a general ranking. We applied the 80-20 rule to the rankings to determine the most important reasons for each of the statements. The 80-20 rule states that roughly 80% of the effects come from 20% of the causes. Thus, we identified the main causes.

Questions	Answers	
How clear is the engineering work	Very clear	15%
	Clear enough	70%
	Not clear	15%
Reasons why the engineering work and the coordination of third parties is difficult	Information flow	
	Underestimation of scope and capacity	
	Too much concurrent projects	
Main reasons why the internal drawings, 2D and 3D models can be late on schedule	Imprecise technical documentation from previous activity	
	Delay of technical documentation from previous activity	
	Late customer requests and changes	
	Rework	

Main reasons why the third parties drawings and quality control is late on schedule	Unavailability of the technical documentation
	Lack of capacity on the supplier side

TABLE 3: MAIN SOURCES OF UNCERTAINTY AT STX OSV SØVIKNES

We also evaluated the lean aspect to determine if the uncertainty has been handled more effectively with lean planning, evaluate the overall improvement and the ease to keep the schedule. The engineers were asked to evaluate different statements summarized on table 4 related to the respect of the schedule and the adaptation to the customer requirements before and after the implementation of lean planning. The evaluation was on a scale from 1 to 4 (4 is the highest). From this evaluation we can say that the ease to keep the schedule, the ease to adapt to changes in ship-owners' requirements, the coordination and the information flow have improve of roughly 25% (from scale 2 to 3).

The lean evaluation concerning the uncertain is handled and the overall improvement was done by 17 persons. The two secretaries and one engineer did not answer this part.

STATEMENTS	Before	After
The difficulty to adapt to the change in the customer requirements	2	3
Respect of the schedule	2	3
The ease to keep the schedule	2	3
The ease to handle technology uncertainty in the design	2	2
The effectiveness of the information flow in the engineering process	2	3
Better coordination between disciplines	2	3

TABLE 4: LEAN EVALUATION

In this part, we evaluated the lean knowledge, the reduction of uncertainty and the overall improvement brought by this new concept in the engineers work. The figure 33 shows a graphical summary of the results.

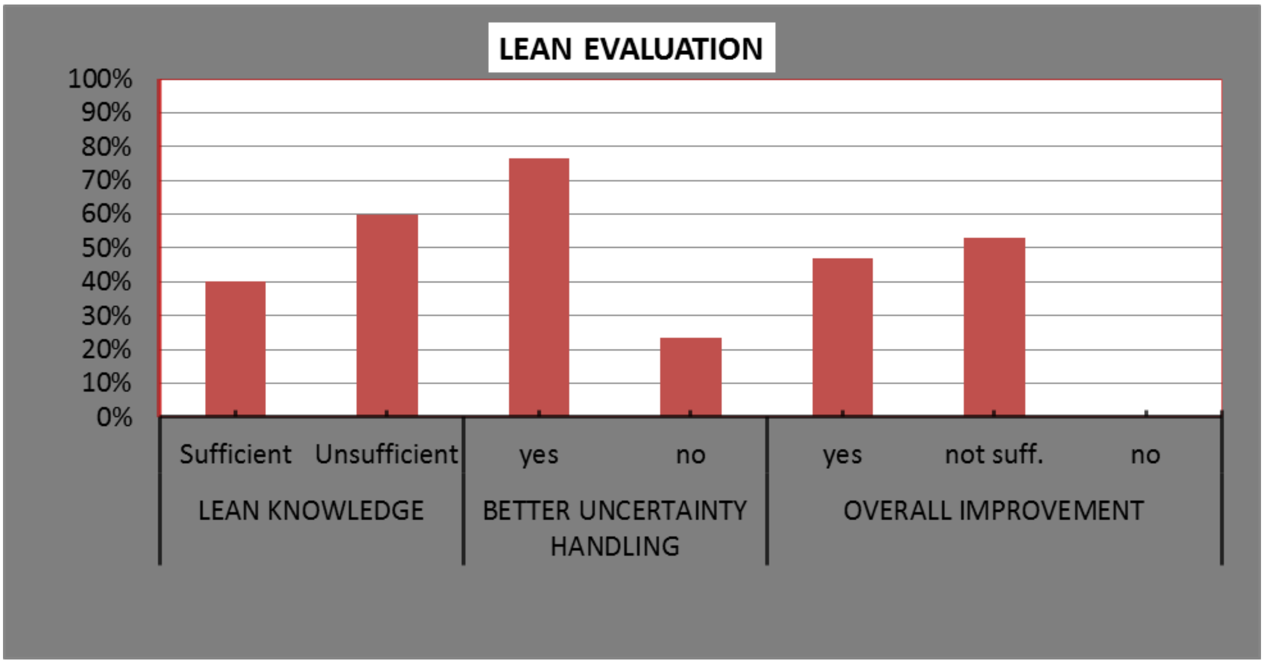


FIGURE 33: GRAPHICAL SUMMARY OF LEAN EVALUATION

In addition, a hypothesis analysis was made to test three statements:

The lean knowledge is not sufficient

The uncertainty is handled more effectively with lean planning

The overall improvement in the engineers work is not sufficient

The data obtained are not normally distributed as shown by the results obtained from the normality check with Shapiro-Wilk index equal to zero.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Uncertainty_Better_Handled	,497	17	,000	,470	17	,000
Overall_Improvement	,349	17	,000	,642	17	,000
Lean_knowledge	,349	17	,000	,642	17	,000

a. Lilliefors Significance Correction

TABLE 5: TEST OF NORMALITY (SPSS OUTPUT)

Thus, a non-parametric chi-square test was run with SPSS at a significance level of 95% to test the hypotheses.

Test 1 evaluates if the lean knowledge is sufficient, P is the proportion of the respondents saying it is sufficient. H_0: P=0.6, H_1: P=0.4 and P-value= 0.034 (Asymp. sig/2) so we reject H_0. The lean knowledge is not sufficient.

Lean_knowledge

	Observed N	Expected N	Residual
sufficient	8	12,0	-4,0
unsufficient	12	8,0	4,0
Total	20		

Test Statistics

	Lean_knowledge
Chi-Square	3,333[a]
df	1
Asymp. Sig.	,068

a. 0 cells (,0%) have expected frequencies less than 5. The minimum expected cell frequency is 8,0.

TABLE 6: SPSS OUTPUT TEST 1

Test 2 evaluates if the uncertainty is handled more effectively with lean planning, P is the proportion of respondents saying it is more effectively handled. H_0: P=0.8; H_1: P= 0.2 and P-value= 0.404 so we keep H_0. The uncertainty is handled more effectively handled. Here are the SPSS outputs:

Uncertainty_Better_Handled

	Observed N	Expected N	Residual
yes	14	13,6	,4
no	3	3,4	-,4
Total	17		

Test Statistics

	Uncertainty_Better_Handled
Chi-Square	,059[a]
df	1
Asymp. Sig.	,808

a. 1 cells (50,0%) have expected frequencies less than 5. The minimum expected cell frequency is 3,4.

TABLE 7: SPSS OUTPUTS TEST 2

Test 3 evaluates the overall improvement brought by lean planning in the engineers work, P is the proportion of engineers saying the improvement is not enough. H_0: P=0.4; H_1: P=0.6 and P-value =0.138 so we keep H_0. We have evidence to say that the overall improvement brought by lean planning is not enough.

Overall_Improvement

	Observed N	Expected N	Residual
yes	8	10,2	-2,2
not sufficient	9	6,8	2,2
Total	17		

Test Statistics

	Overall_Improvement
Chi-Square	1,186[a]
df	1
Asymp. Sig.	,276

a. 0 cells (,0%) have expected frequencies less than 5. The minimum expected cell frequency is 6,8.

TABLE 8: SPSS OUTPUT TEST 3

From questionnaire 2, we analyzed the results only on a quantitative basis and compared them to results of Kahneman and Tversky (1979) and Kahneman *et al.* (1987).

A town has two hospitals. In one about 15 children are born per day while in the other it is 45. We know that on average 50% of the children are boys. Over a year it was recorded the number of days each hospital recorded more than 60% of boys. Do you think:

a- it happens more often in the smaller hospital

b- It happens more often in the larger hospital

c- It happens equally often in both hospitals

This question (question 3) is an example of to assess the “law of small numbers ", which was studied by Kahneman and Tversky. Test respondents of Kahneman and Tversky’s experiments usually saw the probability in both cases as the same. But it is known that with an increase of the number of tests the probability of deviation from the mean is reduced. In our case, 57% of subjects evaluated the probability of happening of the event equally in both hospitals. This question reveals the use of representativeness heuristic and the existence of this bias in the department.

Imagine that a country is preparing for the outbreak of an unusual disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows.

a- If Program A is adopted, 200 people will be saved.

b- If Program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved.

Which of the two programs would you favor?

Kahneman and Tversky found that 72% of respondents did not want to take the risk, and they chose to save 200 lives, than to bet on the salvation of more people. In our study opinions of respondents were divided into two almost equal groups: 47% preferred the solution A, 53% preferred the solution B.

Changing the structure, Kahneman and Tversky have achieved that the responses were quite different. They gave a second group of respondents the same problem. But questions were formulated differently:

c- If Program C is adopted, 400 people will die.

d- If Program D is adopted there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die.

Despite the fact that the meaning of programs C and D is identical to the meaning of programs A and B, 78% of respondents of Kahneman and Tversky at this time decided to take the risk, they decided to make a bet, and not to lose 400 lives. In our case, 72% of respondents chose the option d. So in this question, our results correspond to results by Tversky and Kahneman. Therefore, the response obtained from question 4 and 5 reveals the existence of framing effect in the department.

Linda is 31 years old. She studied philosophy in the university. She is very beautiful, sociable and she is single. As a student, she was concerned about the problems of discrimination and social inequality, and participated in demonstrations against nuclear weapons. Please choose the most likely alternative:

Linda is a bank employee

Linda is a bank employee and a feminist

Most of subjects (55%) chose option B. According to Kahneman and Tversky, this was due to the **representativeness heuristic**. This question also shows the existence of representativeness bias in the engineering department.

If you come up with following choice, what will you choose:

100% chance of losing 500 NOK

25% chance of losing 2000 NOK and 75% chance of not losing anything

Most of the subjects (78%) chose option B. Most people (80%) interviewed by Paul Slovik, Baruch Fishhoffom and Sarah Lichtenstein in 1982 have chosen alternative B. So we can say that the result is somewhat the same. Most people prefer to take a risk when it comes to losing. They are willing to take risks and lose more (in this case 2000 NOK) than postpone the mandatory loss of the same value (25% chance of losing 2000 NOK has same estimated value as an indispensable loss of 500 NOK, because both alternatives lead to the same losses under repeated). This question illustrates **risk aversion** in the department.

John is envious, stubborn, and prone to criticism, impulsive, clever and hardworking. How emotional is he (please choose only one answer)?

Not emotional 1 2 3 4 5 6 7 8 9 Emotional

57% of the respondents chose the number less than 4, 5, reflecting John's emotionality as low. 43% of the respondents marked John's emotionality as high. This question describes the **representativeness heuristic** as well.

Imagine that you are the president of the airplane building company. You have invested 10 million euro to develop a plane that is invisible to the radars (stealth plane). When the project was 90% complete, a rival company began to sell stealth planes, which are cheaper & faster. Will you pay the remaining 10% of money to complete the development?

No, there is no reason to invest in this project

I have to complete what I've started, so I will invest the remaining 10% of money

That is the **anchoring effect** reflected in question 13. In their study, given the same question, 85% of respondents called for completing developments, despite the fact that it was pointless, if the aircraft is ready and the competitors are gaining market share. In our case, 94% of respondents choose to complete developments.

What is the most likely way to die in the USA?

To be crushed by fallen debris of the aircraft.

To be eaten by a shark

This example illustrates the **retrievability heuristics**. Most of people think that it is more likely to be eaten by a shark, than to be crushed by fallen debris of the aircraft, but in our case opinions were equally divided, 50% to 50%.

To get the numerical result on the biases in the engineering department, the proportion of each bias in overall result was calculated, the data was taken from part 2 of the second questionnaire. The results are presented in table 9 below.

Bias	Share in %
Adjustment	11,689
Anchoring	6,927
Reliability bias	12,121
Representativeness	19,048

TABLE 9: THE MAIN BIASES IN THE ENGINEERING DEPARTMENT

It is worth mentioning, that those are not all biases included in the questionnaire for evaluation. We excluded some biases, to focus only on those proposed by Kahneman and Tversky.

The graphical summary in figure 34 permits a better visualization:

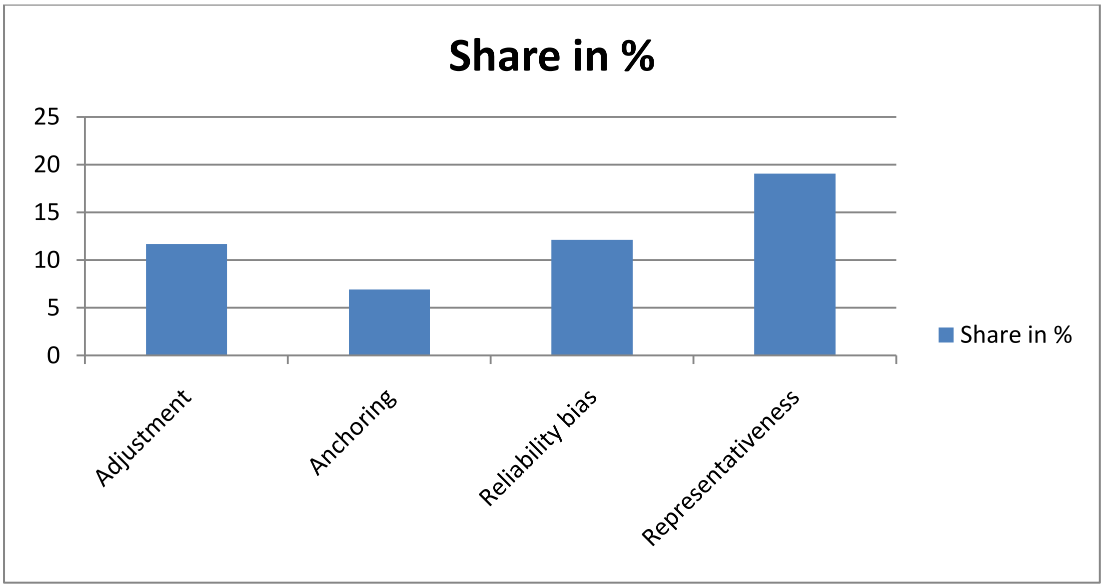


FIGURE 34: GRAPHICAL SUMMARY OF THE BIASES IN THE DEPARTMENT

The graph shows that the most important biases in the engineering department are **adjustment, anchoring, reliability and representativeness.** In the table 10, we present the overall results of points gained by each respondent in the biases questionnaire.

Employee	Points	Employee	Points	Employee	Points
TC1	19	TC6	9	ENG8	8
TC2	11	ENG1	13	ENG9	15
TC3	10	ENG2	17	TECH1	13
3D coordinator	14	ENG3	15	TECH2	6
TC5	14	ENG4	16	TS1	8
ENG6	12	ENG5	6	ENG7	5

TABLE 10: SCORE OF EACH RESPONDENT

This can be used to distinguish groups of employees with high level of biases, moderate level of biases and low level of biases: high level of biases - from 22 to 27 points (0%), medium - from 14 to 21 points (42,11%), low - from 0 to 13 points (57,89%).

From questionnaire 3, the degree of manifestation of maladjustment is defined by the number of points.

- 96 points or more - very high level of maladjustment, requires the adoption of urgent measures (psychological and medical);
- from 65 to 95 points - high level of maladjustment, requires compulsory intervention of specialists, change of profession or conducting program for rehabilitation;
- from 32 to 64 points - moderate level of maladjustment, requires assistance of experts to conduct rehabilitation;
- Up to 32 points - low level of maladjustment, it would be useful to conduct advisory work with specialists.

The scores on individual attributes is used to establish the degree of their influence on the overall level of professional maladjustment. Here are the results of the questionnaire:

Employee	Points	Employee	Points	Employee	Points
TC1	34	TC6	15	ENG8	13
TC2	13	ENG1	30	ENG9	8
TC3	18	ENG2	2	TECH1	17
3D coordinator	44	ENG3	16	TECH2	8
TC5	45	ENG4	4	TS1	35
TS2	27	ENG5	30	ENG7	10
ENG6	35				

TABLE 11: PROFESSIONAL MALADJUSTMENT RESULTS

The study of the share of each manifestation was carried out, here is the result:

Scale	Share in %	Scale	Share in %
Emotional shifts	9,653	Somatovegetative violations	28,218
Characteristics of individual mental processes	12,129	Violation of the cycle "sleep - wakefulness"	18,069
Reduction of the total activity	8,416	Features of social interaction	9,158
Fatigue	8,416	Reduced motivation to work	5,941

TABLE 12: THE SHARE OF EACH MANIFESTATION

The table shows that the criterions with the highest weight are **characteristics of individual mental processes, somatovegetative violations** and violation of **the cycle "sleep - wakefulness"**. The graph below gives us a better visualization.

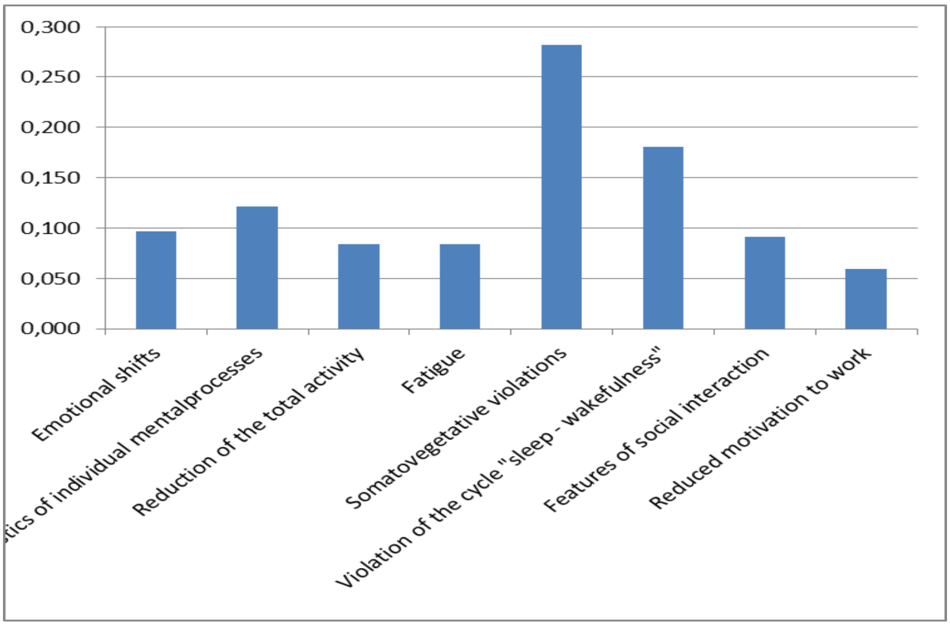


FIGURE 35: GRAPH OF PROFESSIONAL MALADJUSTMENT

According to the original scale of the questionnaire, 73.68% of workers have a low level of maladjustment (up to 32 points) and 26.31% of workers have a moderate level of maladjustment

6.2 – Elaboration of the case findings

During the research for a more accurate evaluation of the results and for obtaining sufficient findings, several statistical tests have been held. First, normality of the distribution of the results was determined using the test for normality of distribution. As a result, it was found that the distribution of test results is not normal.

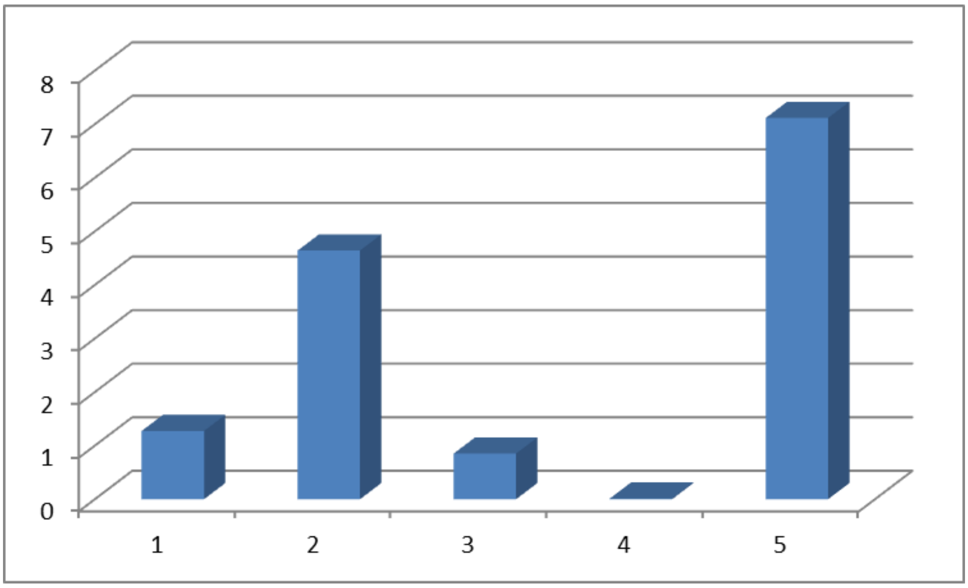


FIGURE 36: DISTRIBUTION OF NORMALITY TEST PROFESSIONNAL MALADJUSTMENT QUESTIONNAIRE.

chi2 statistical	13,89474
criterium	5,991465
Conclusion	not normal

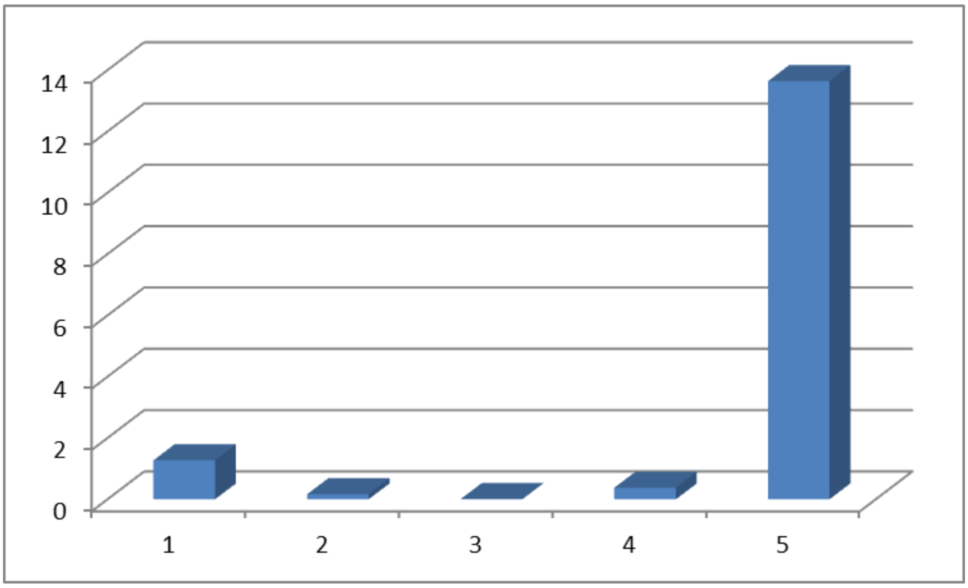


FIGURE 37: DISTRIBUTION OF NORMALITY TEST BIAS QUESTIONNAIRE RESULT

chi2 statistical	15,47368
criterium	5,991465
Conclusion	not normal

To determine the interconnection between the results of two questionnaires we used calculate the correlation coefficient. Correlation (correlative dependence) is the statistical relationship between two or several random variables (or variables that can acceptably, with some degree of accuracy, considered as such). At the same time, change of values of one or more of these variables lead to a systematic change in values of another, or other variables. In our case, no correlation between the results of questionnaires was found. The test on significance of the correlation coefficient was held.

Correlation between biases and professional maladjustment values	
correlation coefficient	0,122625
count	19
level of significance	0,05
t-statistical	0,50944
criterial value	2,109816

TABLE 13: CORRELATION BETWEEN BIASES AND PROFESSIONAL MALADJUSTMENT VALUES

So, as you can see from the results above show that the correlation coefficient cannot be considered as significant. Therefore, we might assume that the low correlation between biases and professional maladjustment may occur due to social security of workers of the enterprise - in fact, the level of biases cannot affect working conditions. In other words, employee cannot be fired or penalized for having his work influenced by external factors.

Nevertheless, there are also other factors that influence the overall result of questionnaires. This can happen due to small sample size, representativeness of the sample and validity of the results. So, regarding statistical reasons, we can suppose that the missing correlation between level of uncertainty and biases might have occurred due to the small sample size, and problem of representativeness of the sample. As we cannot distinguish the main characteristics of the parent population, we cannot pick the correct sample of respondents. That, in turn can lead us to a misinterpretation of results and obtantion of results that are not valid for the parent population.

6.3 – Implications and discussion

The general results gave us an idea of the main sources of uncertainty and the human bias, which can put the improvement brought by lean planning in jeopardy. Recall that at STX-OSV Søviknes, the discipline owners and the work leaders use the period and weekly plan meetings to discuss the deviations from plans and monitor different upcoming activities. These meetings are important because the problems are presented by persons involved in the work. Thus, they avoid information distortion. However, a wrong assessment or estimate of values or probabilities can mislead the whole group and lead to wrong decisions. Moreover, the way an issue or a meeting is framed can have the same effects. Sometimes individually, the engineers have to carry on they work concerning the drawings and 2D or 3D modeling without having all the required information. Here the use of heuristics leading to bias can affect the decisions they make. However, different approaches can be used to reduce the effect of human bias on decisions made individually or during weekly planning meetings. These approaches are:

1) Multi-person Process
2) Premortem Technique
3) Checklists
4) Memos

We have already described those techniques in a literature review. It is worth mentioning that multi-person process of decision-making (six thinking hats technique) is already being used in STX-OSV Søviknes. Those decision-making models that were described in chapter 2.3.2 can be implemented as well, because their main assignment is to cope with uncertainty and human biases.

One important thing to keep in mind is that there is not a magical technique that will remove all biases. It is more about putting in place a process that includes techniques to correct the biases we are susceptible to be subject to and help to avoid them in the future (Kahneman and Klein 2010). Moreover, one of the critical steps in decision-making is to identify what information should be collected and verify the quality and the independence of the information. This initial work permits to have informed intuition, which can lead to more adapted and logical decision (ibid). Especially when one has to decide in presence of uncertainty. Thus, the ideal is to postpone intuition as much as possible to gather all the relevant information to make a good and valid decision because when there is too much random element in a situation people are just bad at taking decisions.

We achieve the objective of the research, which was to determine the main sources of uncertainty and the main human bias occurring in the engineering department. We also identify potential techniques, which help to reduce the impact of these biases on the decisions since we cannot get rid of them. However, in order to generalize the results of this study the limitations presented earlier need to be corrected.

CHAPTER 7 - CLOSURE

7.1 – Final remarks

This thesis was based on an interdisciplinary framework combining decision making under uncertainty, lean planning and information in supply chain. The research we conducted in the engineering department of STX-OSV Søviknes permits to identify some of the main sources of uncertainty, which cause delays on the planning. We also identify the main biases occurring in the department and the sources of professional maladjustment. The presence of bias due to the use of heuristics as availability and representativeness lead to decision-making errors and wrong estimate of value and probabilities. They cause wrong decisions in case of uncertainty and affect the planning.

The main sources of uncertainty causing delays in the planning are incomplete or unavailable technical documentation, underestimation of capacity both in the company and on the third party side, inefficient information flow, late customer requests and reworks (see table 3). The evaluation of lean planning reveals an improvement of 25 % of the respect to the schedule and the coordination between the disciplines. The overall improvement brought by lean planning on the engineers' work is not enough. However as evaluated by the engineers, it permits to reduce significantly the level of uncertainty in the engineering process. The main biases occurring in the department are availability bias, representativeness bias, reliability bias and anchoring bias. Due to these biases, wrong problems can be addressed and wrong decisions create more delays and affect the planning. It is therefore important to keep the lean planning and take advantage of this planning approach. The main sources of professional maladjustment are characteristics of individual mental processes, somatovegetative violations and violation of the cycle "sleep - wakefulness".

The human biases above-mentioned cannot be completely eliminated but their impact on the decisions can be reduced. This allows decision makers to tackle uncertainty more effectively and provide some flexibility in the engineering process. The techniques use to reduce the impact of biases on the decisions are multi-person processes through six thinking hats technique, the premortem technique, checklists and memos. However, it is important to notice that we found no correlation between the uncertainty, the occurrence of bias and maladjustment in the department. Except from statistical reasons, this is mostly due to the horizontal management structure of the company and the work security existing in the country (Norway).

7.2 – Future works

Further researches can evaluate the impact of each of the techniques on the reduction of the effect of human bias. They can evaluate the impact of each technique for better decision-making under uncertainty. Also in the future works different ways of analyzing biases and uncertainty can be included, in order to see whether the use of lean planning is helping to reduce uncertainty level and human bias level. It would also be interesting, to our mind, to run the lean and uncertainty questionnaire once again to see if the level of understanding lean and handling uncertainty changed in the company.

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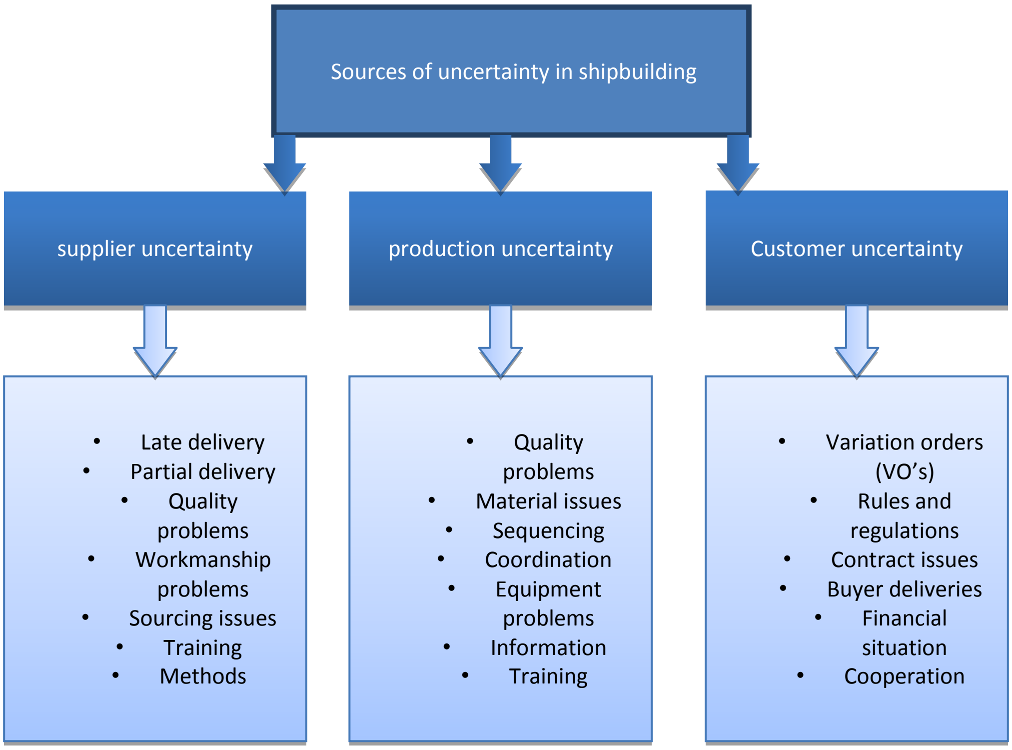
Appendices

I - QUESTIONNAIRE 1: Lean Planning and Uncertainty

We can notice that shipbuilding is one of the most uncertain industries, and lean planning is being implemented in the yard. Therefore, we attempt to see how this change has been implemented in the engineering department. We are also trying to identify the main sources of uncertainty in the engineers' work. We define uncertainty as:



Personalia

1 - You are ☐ Man ☐ Woman

2 - Age range: ☐ below 40 ☐ 40-60 ☐ over 60 years old

3 - Level of education: ☐ No education ☐ Technical school ☐ Bachelor ☐ Master

4 – Have you worked in other industries? ☐ Yes ☐ No

5-What is your seniority ☐ Less than 3 years ☐ 3 to 6 years ☐ more than 6 years

6-Your position in the engineering department

☐

General statements related to lean and uncertainty

1- To what extent do you think the tasks in your work are clearly defined:
☐ Very clear ☐ Clear enough ☐ Not clear

2- Rank from 1 to 4 the impact of the following reasons why the engineering and the coordination of the third party is difficult (1 lowest, 4 highest impact):

- Regulations and rules ☐
- Underestimation of scope and capacity ☐
- Information flow ☐
- Concurrent processes ☐

3- Rank from 1 to 7 the impact of the following reasons why your drawings , 2D and 3D models or documentation can be late on the schedule (1 lowest, 7 highest impact):

- Imprecise technical documentation from previous activity ☐
- Delay of technical documentation from previous activity ☐
- Late customer requests and changes ☐
- Rework from other reasons ☐
- Unclear rules and regulations ☐
- Slow approval from the authorities ☐
- Software issues ☐

4- Rank from 1 to 6 the impact of the following reasons why you think the third party drawings and quality control is late on schedule(1 lowest, 6 highest impact):

- Unclear information from prior activity ☐
- Unclear due date from third party ☐
- Unavailability of technical documentation (previous action not completed) ☐
- Rework ☐
- Late purchase ☐
- Lack of capacity by suppliers ☐

- **Other reasons (note which are they)__________________________________**

5- Are you familiar with lean planning? ☐ Sufficient ☐ insufficient

6- Rate each of these statements on a scale of 1 to 4, before and after the use of lean planning. 1 is the lowest and 4 is the highest.

	Before	After
The difficulty to adapt to the change in the customer requirements	☐	☐
Respect of the schedule	☐	☐
The ease to keep the schedule	☐	☐
The ease to handle technology uncertainty in the design	☐	☐
The effectiveness of the information flow in the engineering process	☐	☐
Coordination between disciplines	☐	☐

7- With lean planning, the uncertainty is handled more easily and effectively than before

☐ Yes ☐ No

8- Do you think that the lean planning system overall improved your way of working?

☐ Yes ☐ not sufficiently ☐ No

II - QUESTIONNAIRE 2: Framing and biases

PART 1: Please answer the following questions and do not think about too much calculus

1- You are going to start a project consisting of 10 different activities. Activity 2 can start only when activity 1 is completed. Each activity has a probability of 90% to be executed on time. Without calculations, what do you think is the probability of the whole project to be executed on time? P=

2- Give without any calculation an estimate of 1.2.3.4.5.6.7.8.9 S=___

3- A town has two hospitals. In one about 15 children are born per day while in the other it is 45. We know that on average 50% of the children are boys. Over a year it was recorded the number of days each hospital recorded more than 60% of boys. Do you think:

   a- it happens more often in the smaller hospital

   b- It happens more often in the larger hospital

   c- It happens equally often in both hospitals

4- Imagine that a country is preparing for the outbreak of an unusual disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows.

   a- If Program A is adopted, 200 people will be saved.

   b- If Program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved.

   Which of the two programs would you favor? ___

5- Imagine that we have the same disease, which is expected to kill 600 people. Two other alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows.

a- If Program C is adopted, 400 people will die.

b- If Program D is adopted there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die.

Which of the two programs would you favor? ___

6- Give without any calculation an estimate of 9.8.7.6.5.4.3.2.1 S=___

7- While you were parking your car, you unfortunately crash your colleague's car mirror. You are given two options to pay for the reparation:

a- Pay 1000 NOK in one payment

b- Pay 250 NOK each week for 4 months

Which option will you choose?

8- Linda is 31 years old. She studied philosophy in the university. She is very beautiful, sociable and she is single. As a student, she was concerned about the problems of discrimination and social inequality, and participated in demonstrations against nuclear weapons. Please choose the most likely alternative:

- Linda is a bank employee
- Linda is a bank employee and a feminist

9- If you come up with following choice, what will you choose:

- 100% chance of losing 500 NOK
- 25% chance of losing 2000 NOK and 75% chance of not losing anything

10- John is envious, stubborn, and prone to criticism, impulsive, clever and hardworking. How emotional is he (please choose only one answer)?

Not emotional 1 2 3 4 5 6 7 8 9 Emotional

11- Jim is clever, skilful, industrious, friendly, decisive and prudent. What other traits he does he have?

- Generous – Stingy
- Unhappy – Happy
- Irritable – patient
- With a sense of humor - Without a sense of humor

12- This question is for people under 26 years old only. Comparing yourself with other people of your age group and gender, how would you rate (in percents) the likelihood of occurring of following events in your life?

12a) You will have problems with alcohol

☐ 60-

☐ 40

☐ 20

☐ 0

☐ 20

☐ 40

☐ 60+

12b) You will buy your own house

☐ 60-

☐ 40

☐ 20

☐ 0

☐ 20

☐ 40

☐ 60+

12c) In 5 years you'll be earning more than 85 000 NOK per month

☐ 60-

☐ 40

☐ 20

☐ 0

- ☐ 20
- ☐ 40
- ☐ 60+

12d) You'll have a heart attack before you'll turn on 40

- ☐ 60-
- ☐ 40
- ☐ 20
- ☐ 0
- ☐ 20
- ☐ 40
- ☐ 60+

13- Imagine that you are the president of the airplane building company. You have invested 10 million euro to develop a plane that is invisible to the radars (stealth plane). When the project was 90% complete, a rival company began to sell stealth planes, which are cheaper & faster. Will you pay the remaining 10% of money to complete the development?

- No, there is no reason to invest in this project
- I have to complete what I've started, so I will invest the remaining 10% of money

14- What is the most likely way to die in the USA?

- To be crushed by fallen debris of the aircraft.
- To be eaten by a shark

15- Please choose in each pair the most common way of death in the USA

- Diabetes - Murder.
- Tornado - Lightning.
- Crash - Cancer of the stomach.

16- Consider the following historical scenario: "The government of a country located not far from a superpower A, after having changes in its government, has started to expand its trade relations with the superpower B. To stop these changes, the superpower A sends its troops for restoring the former government”.

16a) What is superpower A?

- USSR
- USA

16b) How confident are you in your answer?

No not confident at all 1 2 3 4 5 6 7 8 9 Very confident

17- Consider another scenario: "In the 1960's superpower A organized an unexpected invasion to the small country that borders with it with intent to overthrow the existing government. The invasion failed, and most of the occupants were killed or captured"

17a) What is superpower A?

- USSR
- USA

17b) How confident are you in your answer?

No not confident at all 1 2 3 4 5 6 7 8 9 Very confident

18- Which of the following scenarios is the most likely to happen in next 10 years?

- Total nuclear war between USA and Russia
- Total nuclear war between USA and Russia. None of the superpowers was going to enter the war, but both were drawn by third country like Iraq, Iran, Libya, Israel or Pakistan.

19- A sheet of paper was folded in half, and then folded repeatedly. After 100 of folding what will be the thickness of this folded sheet of paper?

(19a) It seems to me that the paper will be ____cm thick.

(19b) I am 90% sure that the correct answer is between _____cm and_____cm.

20- A year has 366 possible birthdays, including 27th of February. So, 367 people can be 100% sure that the two of them were born in one day. How many people can be sure of this at 50%? ___________

21- The average value of the intelligence quotient (IQ) of pupils of the 8th grade of the primary school is well known and it is equal to 100. You have selected 50 pupils randomly for conducting a research. The first child showed IQ equal to 150. What will be the average IQ for the group of students you have selected?

Answer:______________

PART 2

Please decide, whether the following statements describe you well. If you agree with the statements that have been given, please check the "Yes" box. If you disagree with the statement, check the "No" box. Please answer without much thinking. Remember, that the answer, which first came to your head, is the most correct one.

1. I agree with my colleagues most of the time, I tend to do what they do.

   ☐ Yes ☐ No

2. Even when my opinion on an issue is different from my colleagues' opinion, I prefer to agree with them.

   ☐ Yes ☐ No

3. When my friends want to go to a party and I have something else to do, I would rather go with them.

   ☐ Yes ☐ No

4. I can say that I am much less biased than the other people.

   ☐ Yes ☐ No

5. I make fewer mistakes than other people.

   ☐ Yes ☐ No

6. My decisions are not affected by my beliefs and emotions.

☐ Yes ☐ No

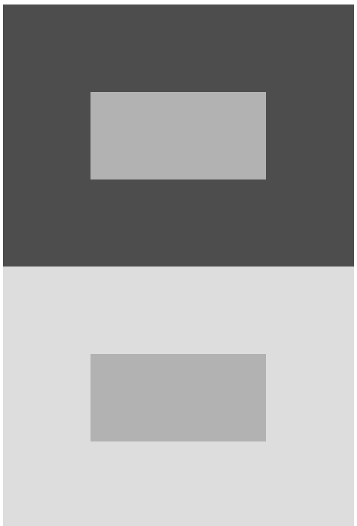
7. When I search information for a report, I tend to pay attention only to information that suits my beliefs.

   ☐ Yes ☐ No

8. When I make a research, I try to pay attention to the information that meets my persuasions, because it always appears to be more truthful.

   ☐ Yes ☐ No

9. On the picture below, you can see rectangles. Which of two inner rectangles has lighter shade of gray?

   ☐ Upper ☐ Lower

10. I believe that I can control almost everything that happens in my life.

    ☐ Yes ☐ No

11. I can predict and control events of my life.

    ☐ Yes ☐ No

12. I try to find as much information as possible on every issue I am facing.

    ☐ Yes ☐ No

13. The more information on the problem I solve I get, the more comfortable I feel about it.

    ☐ Yes ☐ No

14. I try to make decisions that suit everyone, even if they are not as effective as extreme decisions.

☐ Yes ☐ No

15. I would prefer not to risk while making a decision.

☐ Yes ☐ No

16. I always worry if I lose something, even if this thing is not important.

☐ Yes ☐ No

17. It is not easy for me to accept the loss of any thing

☐ Yes ☐ No

18. I think that my past was bright and happy.

☐ Yes ☐ No

19. When I meet my friend or colleague in a place I have never been before, I tend to like this place.

☐ Yes ☐ No

20. I cannot leave something uncompleted, even if it not necessary to complete it.

☐ Yes ☐ No

21. It makes me feel uncomfortable when I don't have a possibility to finish everything that I've planned for the day, though I can postpone these things.

☐ Yes ☐ No

22. I believe that actions are more harmful than inactions.

☐ Yes ☐ No

23. It is better for me to observe events than to take part in them.

☐ Yes ☐ No

24. It is hard for me to evaluate the time I need to complete an assignment.

☐ Yes ☐ No

25. It is complicated for me to complete my assignment in time.

☐ Yes ☐ No

26. I tend to avoid making decisions, if some information about the outcome is missing.

☐ Yes ☐ No

27. It is hard for me to do something, if I cannot predict consequences of my actions.

☐ Yes ☐ No

III - QUESTIONNAIRE 3: How are you?

Instruction:

Please, read the following statements carefully. Do they suite your current physical and emotional state? When you decide, please mark the appropriate box. Try not to think for too long, answer as fast as you can. Some statements may be difficult for you to evaluate, in that case you should mark in the "Not sure" column. But try to give defined answers.

1 I feel healthy most of the time

☐ Yes ☐ Not sure ☐ No

2 I'm in a good mood most of the time

☐ Yes ☐ Not sure ☐ No

3 I have a lot of hobbies besides of my job

☐ Yes ☐ Not sure ☐ No

4 I became grumpy

☐ Yes ☐ Not sure ☐ No

5 I became frail and sickly

☐ Yes ☐ Not sure ☐ No

6 I like to work in a team

☐ Yes ☐ Not sure ☐ No

7 My mood is constantly changing

☐ Yes ☐ Not sure ☐ No

8 I feel malaise lately

☐ Yes ☐ Not sure ☐ No

9. I have calm and even temper

☐ Yes ☐ Not sure ☐ No

10 I'm often overwhelmed by sad thoughts lately.

☐ Yes ☐ Not sure ☐ No

11 My relatives and friends begun to notice that my temper have started to spoil

☐ Yes ☐ Not sure ☐ No

12 It became difficult for me to communicate with new people

☐ Yes ☐ Not sure ☐ No

13 I feel depressed often

☐ Yes ☐ Not sure ☐ No

14 Recently I've become irritated by things that hadn't concerned me before

☐ Yes ☐ Not sure ☐ No

15 I became listless and indifferent

☐ Yes ☐ Not sure ☐ No

16 I am cheerful and sociable most of the time

☐ Yes ☐ Not sure ☐ No

17 I feel uncomfortable in places where there are many people

☐ Yes ☐ Not sure ☐ No

18 I often quarrel with my family, friends and colleagues

☐ Yes ☐ Not sure ☐ No

19 I don't want to spend time with my friends anymore

☐ Yes ☐ Not sure ☐ No

20 I enjoy coming to work

☐ Yes ☐ Not sure ☐ No

21 I don't like my job anymore

☐ Yes ☐ Not sure ☐ No

22 It is easy and pleasant for me to perform my job duties

☐ Yes ☐ Not sure ☐ No

23 It is hard for me to start working in the beginning of the day

☐ Yes ☐ Not sure ☐ No

24 I am often distracted by something while I am at work

☐ Yes ☐ Not sure ☐ No

25 I always want to finish my job as quickly as possible and go home

☐ Yes ☐ Not sure ☐ No

26 My working day is usually interesting and filled with useful duties

☐ Yes ☐ Not sure ☐ No

27 I perform my job duties in full

☐ Yes ☐ Not sure ☐ No

28 I often force myself to work more carefully

☐ Yes ☐ Not sure ☐ No

29 It is difficult for me to work

☐ Yes ☐ Not sure ☐ No

30 I often find myself thinking that I don't want anything from life

☐ Yes ☐ Not sure ☐ No

31 I became flaccid

☐ Yes ☐ Not sure ☐ No

32 I became oblivious

☐ Yes ☐ Not sure ☐ No

33 It is hard for me to keep in mind things I have to do for today

☐ Yes ☐ Not sure ☐ No

34 I always feel exhausted after work

☐ Yes ☐ Not sure ☐ No

35 In my free time, all I want to do is lay down and relax

☐ Yes ☐ Not sure ☐ No

36 I feel sleepy when I'm reading a book

☐ Yes ☐ Not sure ☐ No

37 My eyes begin to ache when I'm reading

☐ Yes ☐ Not sure ☐ No

38 I constantly feel discomfort in my eyes

☐ Yes ☐ Not sure ☐ No

39 My eyesight has deteriorated

☐ Yes ☐ Not sure ☐ No

40 I constantly feel pain in my temples and forehead

☐ Yes ☐ Not sure ☐ No

41 I always feel pain in my back and neck when I'm working

☐ Yes ☐ Not sure ☐ No

42 I feel pain in my legs

☐ Yes ☐ Not sure ☐ No

43 I often feel nauseated

☐ Yes ☐ Not sure ☐ No

44 I often have a headache

☐ Yes ☐ Not sure ☐ No

45 I often feel dizzy

☐ Yes ☐ Not sure ☐ No

46 I often feel heaviness in my head

☐ Yes ☐ Not sure ☐ No

47 I often hear noise and ringing in my ears

☐ Yes ☐ Not sure ☐ No

48 Sometimes my eyes are so tired that I see shining flies just in front of them

☐ Yes ☐ Not sure ☐ No

49 My heart is beating heavy sometimes, with no reason

☐ Yes ☐ Not sure ☐ No

50 Sometimes it is hard for me to breathe, with no particular reason

☐ Yes ☐ Not sure ☐ No

51 Sometimes it's hard to breathe in

☐ Yes ☐ Not sure ☐ No

52 I often find myself covered with sweat, with no reason for it

☐ Yes ☐ Not sure ☐ No

53 My palms sweat easily

☐ Yes ☐ Not sure ☐ No

54 Red spots often appear on my neck and cheeks

☐ Yes ☐ Not sure ☐ No

55 I fall asleep easily

☐ Yes ☐ Not sure ☐ No

56 I always feel sleepy in the daytime

☐ Yes ☐ Not sure ☐ No

57 I sleep soundly usually

☐ Yes ☐ Not sure ☐ No

58 I often have a restless sleep

☐ Yes ☐ Not sure ☐ No

59 It is hard for me to fall asleep

☐ Yes ☐ Not sure ☐ No

60 It is hard for me to wake up in the morning

☐ Yes ☐ Not sure ☐ No

61 I feel listless and sleepy after waking up

☐ Yes ☐ Not sure ☐ No

62 I often have insomnia

☐ Yes ☐ Not sure ☐ No

63 I feel tired most of the time

☐ Yes ☐ Not sure ☐ No

64 I feel myself completely healthy

☐ Yes ☐ Not sure ☐ No