Norwegian University of
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System Based Ship Design for Offshore Vessels

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Problem description

The overall aim and focus of the project is to suggest how a System Based Ship Design approach may support an efficient and innovative ship design process.

This Master Thesis will explore how the System Based Ship Design approach can be utilized in the initial sales and design process of Offshore Vessels, and consider how a simplified SBSD approach could support the initial sales and design process of a new build by creating a tangible discussion basis for the sales person, designers and the client at an early stage.

See also Appendix B: Problem description for a specified list of scope and main activities.

Assignment given: January 20th, 2011

Supervisors: Håvard Åsvoll and Stein Ove Erikstad

Preface

The report at hand was conducted as a Master Thesis during the 10th semester at Norwegian University of Science and Technology, spring 2011.

My Master Thesis builds on the theories of Kai Levander (2009) and my own pre-master thesis named "System Based Ship Design for Offshore Vessels" (Vestbøstad, 2010) and is written as a contribution to the Ship-4C project within System Based Ship Design.

Kai Levander has this spring in cooperation with Kjetil Østrem and STX developed a working prototype of the System Based Ship Design approach for Offshore Vessels. My contribution has been to investigate how the output of the approach can be visualized, and how a simplified approach can be utilized in the initial sales and design process.

Through the School of Entrepreneurship I've got the opportunity to write this Master Thesis at the intersection of two fields of studies. The Master Thesis combines theory of design methods and acquisition of design knowledge which is a combination that would be important when evaluating real life applicability. The Master Thesis is conducted at Institute for Industrial Economics and Technology Management while the problem description emphasizes aspects mostly within Department of Marine Technology.

I would like to thank my technical supervisor at Department of Marine Technology Professor Stein Ove Erikstad for great support through the project, and for connecting me with the Ship 4C-project within System Based Ship Design.

Thanks also to Kai Levander and Kjetil Østrem for their follow up in the technical aspects and my supervisor Håvard Åsvoll at Institute for Industrial Economics and Technology Management for reviews and suggestions.

Lastly, thanks to the sales man who willingly answered my interview questions.

June 8th 2011

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Summary

The design process is often referred to as sequential and iterative based on the descriptions by Evans (1959). As computers have entered the design space and become more and more important as tools for the designer, the models of Evans is not as accurate anymore. Mistree, Smith, Bras, Allen and Muster (1990) described the design process in a more up to date way supporting concurrent designing.

Levander (2009) presents a new approach to ship design, the System Based Ship Design (SBSD) which utilize a bottom up strategy in estimating the volume need before any drawing is sketched. The approach has been deployed for Cruise and Merchant Vessels, and through the spring of 2011 the approach has been developed to support Offshore Vessels.

Assuming that the SBSD approach is an efficient way for the designer to generate viable solutions, it still needs some prerequisites to work. For the SBSD approach to be used in practice at a design office the software supporting the approach need to be flexible to work for the variation of ship designs and give the designer the amount of control he need to be confident with the solution.

Currently design offices lack a sufficient way of storing knowledge for later use, especially tacit knowledge. The SBSD approach includes a database structure of statistics of successful vessels which gives the designer the opportunity to easily compare a new project with successful predecessors. This database can be a good foundation for building integrated software solutions for marine applications. In addition the database lets the design office acquire, store, and reuse both explicit and tacit design knowledge in the organization.

The output of the SBSD approach is a list of volumes needed for the new build. Based on these volume demands combined with some experience data several key numbers and useful values like hull form, stability check and costs can be derived.

Compared to the experience data, the SBSD approach can optimize the search for basis vessels and propose which changes are needed to make a basis vessel work for the new requirement specification.

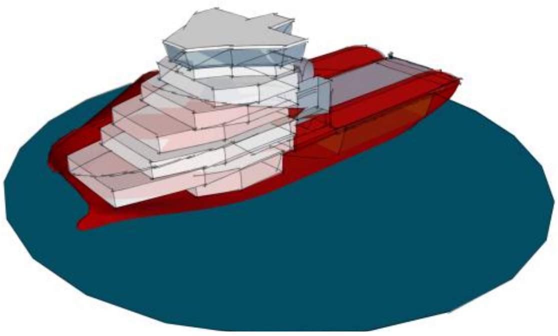

Figure 1: Output from prototype

The list of volumes combined with a template describing their order and constraints can be utilized to create early 3D-sketches of the new ship. A prototype has been developed and the output is shown to the right.

A simplified SBSD approach is proposed for the initial sales and design process. For the initial design phase, the SBSD approach can be of substantial value. The SBSD approach fulfills the requirements for sketching tools by Buxton (2006) and Gross (2006) and has the potential of being an efficient sketching tool for the designer that can follow the project through the initial design process.

The automatic sketching of the new vessel helps the designer to determine which solutions that are viable, and creates a better discussion basis for the design team and client.

Contents

Introduction

Researchers agree that initial design is important to create good products for less (Dewhurst and Boothroyd, 1988; Gatenby and Foo, 1990; Dixon and Duffey, 1990; Suh, 1990; Hundal, 1993; Whitney, 1990) summarized by the statement '*designers make million-dollar decisions every minute without ever knowing it.*' (Whitney, 1990).

The "basis ship"-approach is by far the most common way to develop designs for Offshore Vessels. The new design is then derived from a "basis" or "mother"-ship (Birmingham and Smith, 1997). Thus, accumulated data from previous designs is used extensively for short-cut design procedures (Tan and Bligh, 1998; Miller, 1965; Hekkenberg, 2010). This process is an efficient way to minimize the design time. In fact, the longer the design time, the less competitive are designers in bidding the contract (Tan and Bligh, 1998; Keane, Tibbitt and Maguire, 1996).

The Evans (1959) design spiral describes the design process as an iterative process from start to end of how ship design was done in 1959. However, a lot has happened since then, especially due to the introduction of computers. Today, ship design without the computer is no longer imaginable (Gallin, 1973). While the Evans design spiral is a much used model to show the sequential nature of a design task, it lacks aspects of concurrent engineering, deriving knowledge from former projects, and reuse of such knowledge. In addition, the important initial choice of basis ship is neither covered.

Mistree et al (1990) builds upon the Evans model and introduced a more up to date version that handles issues of concurrent engineering. Describing a "Frustum of a Cone", Mistree et al describe how the design task can be worked on in several directions at the same time. The Evans model is still much used as an example of the "ideal" design process, but has limited validity in describing the actual design process.

The System Based Ship Design (SBSD) approach by Levander (2009) depends on statistics that require the designer to codify properties of new builds in a structured way. A database of structured information of former designs, both own and competitors' has several benefits especially when searching for fitting basis vessels. Knowledge about current and former projects can be utilized in many ways through the initial design phase. Key numbers from earlier projects can give early estimates and give the designer a reasonable decision basis at a very early stage.

Designing is dependent on human expertise which can be both scarce and costly (Moynihan, 1993). This makes it important to utilize the human capital in the best way possible. An efficient decision support tool can help the designer in his routine work, enabling him to do what computers still can't, namely use his tacit knowledge and creativity to make the best design possible.

Dzbor and Zdrahal (2001) describe a model of how explicit and tacit knowledge interplay through the design process. The interaction of the designer through codifying and interpreting general knowledge and knowledge about the project at hand is important in order to build systems for acquiring knowledge.

The subject of acquiring design knowledge seems not prioritized at ship design offices. This is due to lacking software and routines, and probably the designer might not see the benefit from structured information.

Theory

Background

Organizations today face an alternating world affected by factors such as advancing technologies, shifting demographics and rising consumer expectations (Kim, 1993). To build competitive advantage in a world-wide industry the available resources need to be utilized fully (Jo, Parsaei and Sullivan, 1993).

"*Even when the environment is relatively tranquil, an organization faces the threat of competition from other extant players or potential entrants. It must therefore continually strive to improve itself against past performance.*" (Kim, 1993)

Researchers agree that the initial design phase to a large degree influences costs of the product, and its lifetime costs. Ford Motor Company estimate even though product design accounts for only 5% of total product cost, 70% of the cost is influenced by the design (Dewhurst and Boothroyd, 1988). Gatenby and Foo (1990) estimated that 80 to 90% of the total life-cycle cost of a product is determined during the design phase. In addition it is believed that 40% of all quality problems can be traced to poor design (Dixon and Duffey, 1990). Suh (1990) believes that as much as 70-80% of manufacturing productivity can be determined at design stage, which are confirmed by Hundal (1993).

All these numbers can be summed up in a statement of a manufacturing executive quoted in a prestigious paper referred to by Whitney (1990): '*designers make million-dollar decisions every minute without ever knowing it.*'

What is 'design'?

To explain what 'design' is, several researchers describe how it differs from 'science'. The comparison can be quite interesting. Coyne, Rosenman, Radford, Balachandran and Gero (1989) describe the difference as *"**Science** attempts to formulate knowledge by deriving relationships between observed phenomena. **Design**, on the other hand, begins with intentions and uses the available knowledge to arrive at an entity possessing attributes that will meet the original intentions.*". Further Coyne et al explain design as producing a description of form using knowledge to transform a formless description into a definite specific description.

Accordingly, 'designing' can be described as "*a process of converting information that characterizes the needs and requirements for a product into knowledge about a product*" (Mistree, Muster, Shupe and Allen, 1989; Kamal, Karandikar, Mistree and Muster, 1987). However, the outcome of the design process is not necessarily the optimal solution for the problem.

"*Moreover, design is a pragmatic discipline, concerned with providing a solution within the capacity of the knowledge available to the designer. This design may not be 'correct' or 'ideal' and may represent a compromise, but it will meet the given intentions to some degree.*" (Coyne et al., 1989)

Several scholars emphasize this statement, arguing that the result of the design process may not be the optimal solution, but rather represent a compromise. As the product designed gets complex, the design process gets difficult to describe in a model:

"*There is no single model that can provide a perfect or at least a satisfactory definition of the design process. One must look at the design from various angles in order to grasp a better understanding of the process.*" (Bahrami and Dagli, 1993)

However, the design might be a success even though it wasn't the optimal solution. There will always be a compromise between the resources used in the initial design phase and the optimality of the design. In complex systems it would even be difficult to select the most optimal design from a set of variations as the systems are so interconnected.

"*Judgment and previous experience are applied in concert with technical knowledge to select the correct values of the design parameters. Since engineering design is an open-ended problem domain, a given design may have a near infinite number of possible alternatives.*" (Moynihan, 1993)

Noble (1993) argues that it is important to consider the design as a whole, with all components and information considered interactively. 'Designing' is to convert requirements into properties of a product. As products get complex the task of designing transform into a challenge of structuring requirements and information.

How to gather design knowledge

For design companies, a major challenge is that their competitive advantage to a large extent lies in the competence and knowledge of their employees. This makes the company vulnerable for flow through of employees leading to loss of knowledge. "Knowledge" can be defined as "*facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject*" (Dictionaries, 2010) and can be divided into "explicit knowledge" and "tacit knowledge" (Polyani, 1983; Nonaka and Konno, 1999).

Explicit knowledge can be codified and expressed in words and numbers, and shared in the form of for instance specifications (Nonaka and Konno, 1999; Dzbor and Zdrahal, 2001). Provided the recipient has the cultural, linguistic and technical knowledge necessary to decode the sender's knowledge, explicit knowledge can relatively easily be transferred between persons or groups, independent of space and time (Widding, 2007; Choo, 1998).

Edvinsson and Sullivan (1996) describe explicit knowledge simply and elegantly as the knowledge that is left behind in the company when the employees have gone home.

Tacit knowledge is a more complicated concept because it contains subjective insights, feelings and intuition. This knowledge is personal, is deeply anchored in individual action and experience, and is therefore hard to transfer among persons (Widding, 2007).

Tacit knowledge prevails in the situations when designers talk about 'liking a solution'; they are not able to express what exactly is causing their attitude only that there is a tacit feeling of a hidden flaw (Dzbor and Zdrahal, 2001). As tacit knowledge by nature is intangible and difficult to codify, it is much more difficult to acquire and keep in an organization and probably more a hassle the more complex the design task is.

Edvinsson and Sullivan (1996) also emphasize that there is a relationship between the degree of codification of knowledge and the amount of value it can be said to command.

"*The value of knowledge is largely realized through applications of the knowledge*" (Edvinsson and Sullivan, 1996)

It is thus important when gathering design knowledge to codify information to be able to make it valuable. Discussions are also an important tool to distribute knowledge across the organization.

Edvinsson and Sullivan (1996) distinguish between the terms 'knowing about' something, 'knowledge', and 'know why', and explain the notion 'Knowing about' as to have an awareness of a subject or pieces of information about it. Knowing about something is perhaps the first step in the creation of knowledge assets that can be leveraged.

'Knowledge', in contrast, implies a specific or delineated set of 'knowings'. It tends to have a central focus or theme, and for this reason it is represented by the definition or codification that takes place just before an idea or innovation can be committed to pen and paper. 'Know-why' means to understand insightfully. 'Know-why' provides access to the factors which underlay value creation for the firm. It is therefore important for an organization to create 'knowings' by codifying their explicit knowledge which in turn can be used to create 'know-why'.

To create this 'know-why' the concept of 'reasoning' is important. Three modes of reasoning will be presented here, namely 'deduction', 'induction' and 'abduction' which describe different ways to conclude about a subject.

Deduction

"*Logical deduction is the mode of reasoning we can usually discuss with assurance. This type of reasoning lends itself to verification, and we recognize it in good argument.*" (Coyne et al., 1989)

The deduction operation was first demonstrated by Aristotle, which wrote about the syllogism. A much referred example by (Coyne et al., 1989) is the syllogism:

1. This is a house
2. All houses are buildings
3. Therefore this is a building

The components of the syllogism have been variously labeled as (1) *case/premise/fact,* (2) *rule/axiom/knowledge* (3) *result/theorem/inferred fact* (Coyne et al., 1989). In deduction the Cases and Rules are known, and the Results can thereby be derived:

Cases
<u>Rules</u>
Results

Induction

Induction on the other hand is when cases and results are known, trying to derive rules. For instance is this the case when testing hull forms and propulsion in model test of ships. Various cases are tested, the results recorded, and rules derived.

Cases
<u>Results</u>
Rules

"*Induction is the process by which the knowledge component of the syllogism is derived (such as the rule that 'all houses are buildings', knowing only the other two statements).*" (Coyne et al., 1989)

Abduction

For the design task, the process of abduction is the most relevant as it can be described as "*Abduction is reasoning when some outcomes are desired and we are interested in finding means for achieving the desired objectives.*" (Dzbor and Zdrahal, 2001)

Dzbor and Zdrahal (2001) illustrate the basic principle of abduction as "*Assume there is a set of desired design goals. In abduction, the designer looks for an artifact that implies the desired functionality consistently with the remaining design goals and constraints.*"

When discussing codifying of design knowledge, the term of 'Abduction' would be the most relevant as the most interesting part would be the premises ('This is a house') for why the design ended up as it did ('Therefore this is a building'). The step by which we might decide that 'this is a house' is abductive (Coyne et al., 1989).

The Rules for the design is known through physical rules and requirements. The end Result in form of a ship is also known, while the Case is unknown.

Rules
<u>Results</u>
Case

Dzbor and Zdrahal (2001) explain the basic principle of abduction in design as follows.

"*Abduction takes the explicit design goals and investigates how these may be achieved. (..). Abduction makes a tentative commitment that can be whenever abandoned for a better one. This is an approach addressing especially well the exploratory nature of the design and on-the-fly construction of a problem space.*"

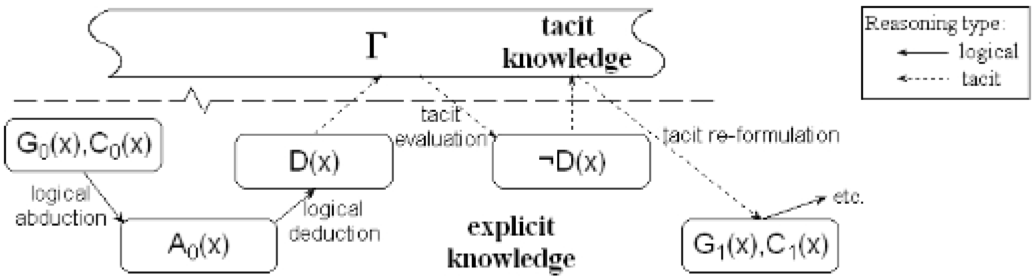

Figure 2: Interplay between explicit and tacit modes of reasoning in design (Dzbor and Zdrahal, 2001)

The interplay between explicit and tacit modes of reasoning in design can be explained as: First goals and requirements are set and made explicit, and then this explicit knowledge is interpreted and translated by tacit knowledge of the designer before it is explicitly codified as design documentation by the designer. This process is iterative as the designer commonly needs to try several solutions before he conclude. With complex systems the iterations are needed to find viable solutions.

How to design ships

This chapter will focus on current ship design methods, where they come from and what seems to come forward within ship design. While academia focuses much on expert systems, the basis ship approach is used in the industry.

The "basis ship"-approach is by far the most common way to develop ship designs because of time and risk issues. A new design is then derived from "basis" or "mother"-ships (Birmingham and Smith, 1997). Thus, accumulated data from previous designs is used extensively to short-cut design procedures (Tan and Bligh, 1998; Miller, 1965). In fact, the longer the design time, the less competitive are designers in bidding the contract (Tan and Bligh, 1998; Keane et al., 1996).

"*When starting the conceptual design of a new ship, it is an age-old custom to use reference data from other ships. In fact many preliminary estimation methods in the maritime industry, such as those for steel weight and powering are based on regression analysis of existing designs.*" (Hekkenberg, 2010)

The statement above does not seem to support innovative thinking as it locks the designer's assumptions early in the process. However, this is the most common way of designing ships as it save work and mitigates risk as the new build base on earlier successful designs.

The design process and focus

According to Rawson and Tupper (2001) ship design and building was a craft up to the 18th century, when science affected ship design appreciably. For the next two centuries, the designer started with a number of assumptions and iterated through the process to satisfy all requirements as described by Evans (1959).

However, despite the extensive research undertaken since the 1950s, there is no single model which is agreed to provide a satisfactory description of the design process (Bahrami and Dagli, 1993; Wynn and Clarkson, 2005). A model does not constitute a theory; theory emerges when there is a testable explanation of why the model behaves as it does (Bahrami and Dagli, 1993; Dixon, 1987).

"*In modeling design we do not attempt to say what design is or how human designers do what they do, but rather provide models by which we can explain and perhaps even replicate certain aspect of design behavior.*" (Coyne et al., 1989)

Further, design models can formalize and structure the process of designing, and can be a tool to describe the differences between the different methods. Throughout the design process, there are quite different objectives at different stages. Each stage of the design process would need different types and amounts of resources and a totally different amount of details, and should preferable be split and addressed separately. However, where to split the design process is a discussed topic. Almost every contributor within the design theory seems to have an own 'right way' of how to split the design process. Probably is the split dependent on how the design office works, how it fit into organizational departments and so on.

Kanerva (1999) divides design and engineering methods in phases responding to the different tasks in a new build project. The first phase is the feasibility studies which create input to a project development phase. This phase then hopefully results in a building contract. The Society of Naval

Architects and Marine Engineers describes four phases when designing a ship namely concept design, preliminary design, contract design and detail design.

The concept design is the phase when the requirements of the ship owner are translated into engineering characteristics. The main dimensions, the block coefficient, power need and the light ship weight is estimated, mainly by experience. Preliminary design determines the main characteristics that affect costs and performance. In the Contract design phase all aspects that are included in the design contract are getting finalized and accompanying documentation is developed. Then the Detail design is performed developing documentation for the ship yard.

When the term "concept phase" is used in this thesis it describes the phase from when the mission statement is ready until the basis ship is chosen or the main dimensions are set. "Preliminary design" is used for the following phase forward until ship building contract is signed while "Initial design" is used as a collective term for the concept and preliminary design phase.

Figure 3: Design phases

In addition to the split in stages of the design process, designs can be split in another way, namely categories or design variants which describes the nature of the design in question.

Moynihan (1993) cites Chandrasekaran (1990) which identifies *creative design* as characterized by true innovation, *variant design* which entails the modification or replacement of whole components, and *routine design* which tends to be limited variations on existing frameworks with known constraints. Sriram, Stephanopoulos, Logcher, Gossard, Groleau, Serrano and Navinchandra (1989) split designs in four categories: *creative design, innovative design, redesign,* and *routine design*.

Within ship design, Mistree et al (1990) identifies three types of design, namely

1. *Original design*: The mission requirements are known, but the "basis ship" approach cannot be employed.
2. *Adaptive design*: The standard "basis ship" approach is a common example where the designer starts with an already working solution for a similar problem.
3. *Variant design*: The arrangements of subsystems are varied.

Common for all contributors is that they distinguish "creative/disruptive" design from "routine/incremental" design. Even though most designers like to see themselves as making disruptive designs, most designs are probably in the latter category. While an automobile or airplane design is used for building series of products, nearly no two ships have the exact same design (Park and Storch, 2002). The key element in creative design is the transformation from the subconscious to conscious (Bahrami and Dagli, 1993).

"..creativity in ship design would be fostered by an approach to the initial ship synthesis which placed greater emphasis on the physical description for the ship's layout" (Andrews, 2003)

Within ship design most initial designs are adaptive designs based on former projects of the ship designer. These projects are cheaper to develop and as they are proved successful, the ship owner would limit his risk. Some designs introduce elements of original design, such as Ulstein Design's X-Bow and the PSV Avant design by Wärtsilä Ship Design. In these cases the concepts are not developed for a customer or tender directly, but rather by the discovery of an internal opportunity.

The design theory introduced in the following is mainly considering adaptive design and the common "basis ship" approach.

There will be various challenges during the design process due to variables that need to be decided. Erichsen (1989) defines three different types of variables in the design environment:

1. Decision variables. These are variables that the designer controls and influence such as main dimensions and speed.
2. Resulting variables are result of a function of decision variables. For instance like displacement is a function of main dimensions and fullness of the hull.
3. Independent variables are out of the designer's power to control, like ice, waves and costs of components.

For the decision variables, Levander (2009) defines three categories of problems: analytical, synectic and selection problems. Analytical problems have one right answer, and can be found by knowledge and training, not creativity. Synectic problems depend on creativity as the objective is to generate several solutions for further development as many alternatives increase the quality of the solution. Selection problems require well defined goals which the alternatives can be measured against. While independent and resulting variables can be derived by software, decision variables have shown more difficult to advice the designer (Levander, 2009).

Goldschmidt and Smolkov (2006) identified the importance of visual stimuli on the creative process in design when viewing the design process as problem solving. Historically sketching has been used in the early stages of ship design, both as an aid to the development of the design itself and as a communications medium (Pawling and Andrews, 2011). Buxton (2006) and Gross (2006) distinguish three main properties of sketches, namely

- "Fluid": the designer can easily move from sketches to more detailed schematics.
- "Forgiving": sketches can contain errors, or be under-specified
- "Functional": sketches contain enough information to allow an evaluation of the design.

For a approach or software to be a good tool for sketching, all three parameters should be in place and solved in a good way.

Evans: the design spiral

The Evans (1959) design spiral model is a well-known model describing characteristics of ship design processes and was developed through studies of designers back in 1959. Laverghetta (1999) described and summarized the design spiral as characterized by a sequence of specific tasks that

(1) incorporate initial design requirements,
(2) synthesize these requirements into a set of design characteristics,
(3) assess the design characteristics against the requirements and against one another,

(4) and iterate as necessary to achieve convergence of the values.

Design balance indicates the defined ship characteristics are physically stable while satisfying design requirements. It describes the design process as iterative, meaning that steps are dependent on each other in a defined order, and that to find an optimal design the process need to be iterative to generate continuously better solutions. By continuously getting better input data for the next step in the spiral, the iterations are fast getting quite good results. The purpose of the technique was to assist in organizing the design process to enable ship design problems to be solved more efficiently (Evans, 1959; Tan and Bligh, 1998). Though the spiral approach may generate satisfactory designs, it does not promote the identification of superior solutions (Mistree et al., 1990).

The Evans design spiral should be seen as a description of characteristics rather than a recipe for designing as the latter would be a time consuming process and designers have limited resources to explore many potential designs (Krömker and Thoben, 1996). The introduction of the computer in designing changed the process from being sequential to being collaborative and contradictory as files could be duplicated and worked on by several designers at the same time. Some scholars therefore have argued that the design process is not as sequential anymore and that the Evans spiral is inadequate as a representation of the ship design process as it describes steps rather than the process itself (Liang, Yan and Shang, 2009).

Because of this, several variations of the model have been developed. Levander (2009) introduced a more categorized spiral with superior titles. Buxton added economic issues to the spiral as the conceptual phase of a project sets the basis for the costs of the product (Buxton, 1972).

Andrews (1981) introduced time as a third dimension to the spiral. Present the ship design process as a helical “corkscrew” and stated that the advantage of this image is that many dialogues and constraints on a designer can be shown as fundamental to the process.

Mistree et al: Frustum of a Cone

However, Mistree et al (1990) argued that *“[The corkscrew] representation still relies on sequential activity and iteration*” and introduced “*The Frustum of a Cone*”. In this perspective Mistree et al argue that the design process can be seen as taking place on the inside of the cone, and not at the edge as Evans, Buxton and Andrews argued. This way, the ordering of calculation and progress is not strictly defined and differs from the sequential iterative approach to potentially a more “chaotic” process. Mistree et al describes the completeness of the information in the project as discs of the cone and thereby not dependent of the iterations.

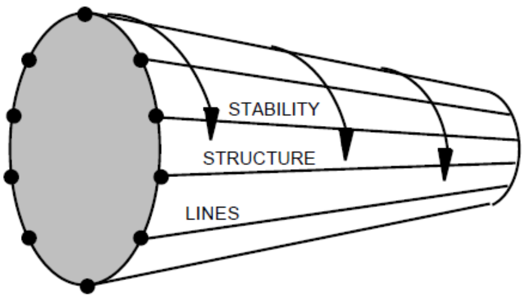

Figure 4: "Frustum of a Cone" (Mistree et al., 1990)

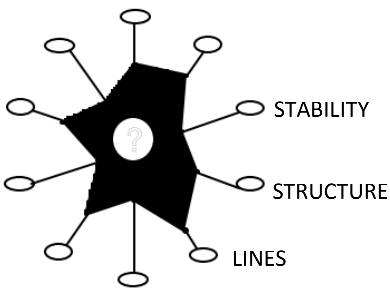

Figure 5: Cross-Section showing information completeness

“*By further refining this illustration, in the limit, as more becomes known of the object of design, the representative disc becomes geometrically complete and circular. The scale, however, on each radial connector is unique.*” (Mistree et al., 1990)

Each disc is a design phase where the radial connectors are disciplines in the design phase. Even though the tasks are different in each phase, it is describing an image of the design process. When the information is more or less complete, the next phase can be started.

Levander: System Based Ship Design (SBSD)

Hubka and Eder (1988) described a base for technical systems in their book “Theory of Technical Systems”. They emphasize that systems thinking presents an opportunity to treat problems as a whole which is a necessary pre-condition for a successful design and engineering effort. Systems thinking provide a framework for the design task and formalize many logical operations which computers can solve where logical treatment is possible. In addition systems thinking also support those human operations, that are not strictly logical, like intuition and creativity (Levander, 2009).

The System Based Design approach was developed for ships by Kai Levander. System Based Ship Design (SBSD) has similarities to both expert systems and case based design approaches, with focus on experience data and decision support and can probably best be described as a variant of an expert system.

The model has been developed for container vessels, RORO vessels and cruise vessels giving estimates of new builds based on earlier designed vessels. These vessels are to a large extent generic, and follow a pattern in the design with small differences thus the design task is more of a scaling issue. To estimate the need for displacement the method uses a bottom up strategy to determine the needed area, space and weight for each sub function of the new build, and thereby estimates the displacement, main dimensions and building costs.

A functional breakdown is used to be able to utilize the outcome for statistical purposes for new projects. Andrews, Pawling, Casarosa, Galea, Deere, Lawrence, Gwynne and Boxall (2006) distinguish the main functions of naval vessels in “Float”, “Move”, “Fight” and “Infrastructure” while Levander (2009) firstly split the vessel into the categories “Ship functions” and “Payload functions” where the “Ship Functions” are functions that are needed to operate the ship, independent of the cargo on board. The Payload Functions are functions and requirements which generates cash flow for the vessel. For instance is it a requirement for chemical tankers to have the ability to heat their cargo while the main function of the payload is the cargo space. For transport vessels with limited variations of products, it is normally easy to distinguish between Ship Functions and Payload Functions since the systems are more or less split. For Offshore Vessels this is a lot more challenging.

Currently, through the Ship 4C project Levander, NTNU and STX OSV explore how the approach could be deployed for Offshore Vessels such as Platform Supply Vessels, Anchor Handling Tug Supply Vessels and Offshore Construction Vessels. Levander has developed a new function hierarchy designed specifically for Offshore Vessels. Instead of the term Payload Functions, he uses Task Related Functions which is more wide-ranging and fits specialized vessels better. In this category all cargo related functions are added, as well as service related functions such as Anchor Handling Winch, Offshore Crane and so on.

By calculating without drawing, the System Based Design method does not lock assumptions in the concept phase and will thereby support a more creative process in the start of the project. Levander describes SBSD as:

"*System Based Ship Design is like a checklist that reminds the designer of all the factors that affect the design and record his choices. It gives the possibility to compare the selections with statistical data derived from existing, successful designs.*" (Levander, 2009)

The SBSD method is suitable for the early design decisions, and more of a tool to find the best assumptions before starting designing the vessel. The use of SBSD would secure that the new design is based on the most fitted basis ship, and thereby save iterations in the design spiral later on.

Expert systems and optimizing algorithms

As computers were introduced within design, expert systems emerged. The expert systems are software that supports the designer finding viable solutions more efficiently.

"*When making a preliminary design of a ship, manual input from the designer usually forms a major cost and time component in the design process. Therefore, if the input of the designer can be limited to making the most important choices and the more menial work can be delegated to the computer, the design process can be sped up dramatically, thereby creating the ability to make more designs in the same amount of time.*" (Hekkenberg, 2010)

The latest years there has been a growing focus on translating human expertise into a set of rules that can be understood by a computer (Erikstad, 2009). Several institutes have been working on automation of early stage ship design (Hekkenberg, 2010).

"*Expert systems are a subset of Artificial Intelligence that attempts to produce expert levels of performance in solving problems within a very specific area*" (Leonard-Barton and Sviokla, 1988)

Helvacioglu & Insel (2005) describe the expert system ALDES that was used to generate new concept designs and arrangements for evolutionary ship concepts and states that the system reduced the design generation time by factor of 10. It is believed that expert systems have a high potential to be support tool for the designer, however none of them is in extensive use in the industry due to integration problems, knowledge representation problems and costly maintenance and developing (Park and Storch, 2002).

Some computer aided tools has been developed using algorithms for number crushing and optimization. There has up to now not been a breakthrough in the use of these methods, but they might be a good foundation for forward versions of Expert Systems. The challenge with the number crushing methods is that one model works for one vessel type, and the solutions are generated by fixed equations and statistical data. This is efficiently done by the help of Genetic Algorithms, but as the method works for one generic vessel type at the time, the method has a long way to go to be usable for specialized vessels like Offshore Vessels.

Erikstad (2009) explains that genetic algorithms have been developed by trying to imitate the process of reproduction in the nature. By using historical information the search for new possibilities are directed towards expected increased performance. Genetic algorithms are using mutation and reproduction as known from nature, in combination with crossovers where new characteristics are made to search for solutions.

Wijnolst, Wergeland and Levander (2009) describe how ship design can be solved mathematically by describing all relations of the design in equations. By using computers this method can help optimizing the design and can be quick and easy to use.

Case based design, or case based reasoning is a way of making historical data more accessible for the designer. The approach is comparable to the basis ship approach which has extensively been used for the last decades, though the case based approach is more methodical in the indexing of relevant cases for later reuse (Erikstad, 2009).

For the concept phase of ship design, the choice of the most fitted comparison ship is a major decision. Lee, Kang, Ryu and Lee (1997) argue for using memory-based learning to index reference ships for case-based conceptual ship design. This method was developed using 122 bulk carriers and comparing deadweight and speed.

Though expert systems and optimizing algorithms have potential to make the design process more efficient, it is still the basis ship approach that is mostly utilized in the industry.

What Characterize Offshore Vessels?

For container ships and ferries, which are capacity carriers, the ship's size is determined by the volume of the cargo. The size of oil tankers and bulk carriers, which are deadweight carriers, are determined by the weight of the cargo (Liang et al., 2009). Offshore vessels are not fitting strictly in any of these categories, as they are service vessels with both weight dependent cargo under deck, and volume dependent cargo on deck in addition to their service purpose. To illustrate the difference a deadweight carrier can be seen as a tank lorry while the capacity carrier is comparable to a semi-trailer. The service vessel can then be a fire truck, needing water cargo to do its job, space for the firemen, in addition to space demanding pumps and equipment.

Today there is a large variety of vessels supporting the oil and gas industry. As the oil and gas industry has moved offshore into more and more hostile waters, the need for support vessels has grown (Lamb, 2004).

Stakeholders

The designer will by default try to find a basis ship that makes the design job easy and profitable. The shipbuilder is concerned for the building costs, which is mostly dependent on the amount of steel and the number of man-hours, especially for vessels with less demands for high technology installed. The ship owner on the other hand is more concerned by the potential upside, which is limited by the carrying capacity and operating costs, in particular the speed relative to consumption (Liang et al., 2009). The flag state, port and canal authorities , classification society, insurer, shipbroker and so on all have their own specific ship definition needs (Wijnolst et al., 2009).

The decision maker in a design process is the ship owner which is paying for the vessel. In some cases this generate conflicts as the revenue for the ship yard is a direct cost for the ship owner (Wijnolst et al., 2009).

The designer at the Department for initial design and the sales man at the ship design office have an overlapping role in the sales process. Selling ship design is mostly about creating good designs together with the client, thus the interplay between the sales men and the designers are crucial to get contracts. In this Thesis the terms “Sales man” and “Designer” may not be used consequently about the actual person, but can also describe the task performed. It is for instance not necessary the designer that performs the SBSD approach even though he is mentioned in the text. With technically competent sales men the “design task” can be performed by a sales man too.

Theory Discussion

‘Knowledge based’ companies depend on their human capital, their employees. In fact, commonly human capital is their most important competitive advantage. Despite the importance, it seems like many design offices lack a sufficient method for acquiring design knowledge for later use. Often they do not even codify information about their designs in a way that make the data reusable. Much of this knowledge is explicit in nature, and would thereby be easy to codify and structure.

For example would main dimensions, capacities, areas, volumes and weights be easy to codify, and to some degree this is done today; but there seems to be few who actually utilize the numbers in the design process. These experiences could easily be used to find key numbers for important factors like block coefficient and dead weight. If the designer could compare an initial design with key numbers from successful projects, using his tacit knowledge he would probably quickly be able to conclude if the numbers make sense.

The designers do not seem to utilize this information when choosing basis vessel for a new build. While many researchers argue that the Evans (1959) design spiral is more or less relevant, few are concerning how the input data for the model is generated. It seems like designers rather tend to rely on what they remember from earlier projects, and then directly start sketching.

Trower (1995) argues that in the case of basis ship there is no immutable order for the design process. Experienced naval architects may occasionally skip stages as they are able to make a good guess, based on rule of thumb (Tan and Bligh, 1998). This also fits well with the theory of a Frustum of a Cone (Mistree et al., 1990) where the design process is seen more concurrently and concerning the degree of information completeness.

Also tacit knowledge can be codified through templates of viable solutions. Then the designer easily would use his tacit knowledge to determine if the solution is viable or not. As shown later in this thesis, these templates can be used to quickly generate potential solutions.

Some designers are using a module based approach where the design task concerns the configuration of building blocks (Jolliff, 1974). Module based approaches is extra challenging for Offshore Vessels due to the level of specialization. Especially the split between functions, systems and modules is challenging for modular thinking when systems are getting interrelated.

Mathematical approaches have disadvantages regarding the fact that ship design is a complex task, and thereby needs lots of equations. In addition a strict mathematical approach does not allow much creativity. For designing in shifting environments the maintenance of the equations will be a challenging task. Probably would it be costly compared with the benefits using optimizing for design of offshore vessels considering the changing and specialized premises.

On the other hand, the SBSD approach is an efficient, flexible way to store and use explicit design knowledge that support the designer doing his job.

The introduction of computer aided tools in designing makes the sequential iteration process of the design spiral somewhat inadequate. It is no longer necessary to finalize the General Arrangement before the work with power, resistance, stability and hull form is started. This synchronous work by several designers might in some cases generate some extra work as the premises changes, but it also saves time as the premises is fed back to the other steps before they are finished. This minimizes the total time for the project. To compare it to the design spiral, it can be argued that the steps in the spiral are interrelated, having people working simultaneously at all steps, and changing the premises in real time while the project itself has a progress forward.

The model presented by Mistree et al (1990) fit with how the design process described above and seems as a realistic description of the design process of today. There are lots of considerations to take into account during the design process as it is a complex task, and converging to a viable solution is time consuming to do in the sequential way of Evans.

Independent of the model used, either the design spiral by Evans or "Frustum of a Cone" mentioned above, the input for the model can be optimized. The better fitted the input are, the shorter can the following phase be. Various computer algorithms for optimized designs have been developed, though none has shown to eliminate the need for work afterwards. Most of these algorithms also use some kind of iterations to optimize the design, and can thereby be seen as a way to automate the first iterations of the design spiral.

The result of the SBSD approach is optimized input data for the design process. By estimating the displacement needed, the designer can have viable dimensions at hand when he starts drawing the vessel. This might help the choice of basis ship, and let the ship designer skip some iterations at the start. He could also generate a list of space allocations he needs to add or change in the basis ship.

Each design office designing offshore vessels has their own way to perform designs based on experience, but few seem to have an organized method for collecting and transferring the knowledge to future projects.

Laverghetta (1999) described and summarized the design spiral as characterized by a sequence of specific tasks that also can describe how the interplay between tacit and explicit knowledge has sequential behavior. (1) Incorporate initial design requirements, (2) synthesize these requirements into a set of design characteristics, (3) assess the design characteristics against the requirements and against one another, (4) and iterate as necessary to achieve convergence of the values.

"*Tacit and explicit design specifications are also related. We distinguish an explicit design specification, which consists of explicit goals and constraints, from the unstructured tacit 'specification'*" (Dzbor and Zdrahal, 2001)

While tacit knowledge here is illustrated as unstructured information, tacit knowledge can also be the execution of such knowledge. However, for the practical use of specifications Dzbor and Zdrahal are correct.The requirement specification would be codified requirements for the new vessel and thereby be explicit knowledge that the designer can base his assumptions on. Using logical abduction, the designer develops sketches of the new build and thereby translates goals and requirements into a viable solution of explicit knowledge. Through interaction between tacit and explicit knowledge, the codified knowledge in form of specifications and drawings develop to become a viable solution that can be built.

The Laverghetta explanation only describes the explicit results of the Evans model. However, the process description fits well with the outcome of the interplay of tacit and explicit knowledge. Though Dzbor and Zdrahal do describe the design process in a general way, not connected to the Evans design spiral, the models fit together in a more superficial way. The interplay of tacit and explicit knowledge and how the designer works to codify and interpret design knowledge in a project is an iterative process of converging values translating knowledge between tacit and explicit modes.

Ship design has for the latest decades been introduced to advanced expert systems as computers entered the design office. It seems strange that they have not got more traction in the design process (Park and Storch, 2002). Probably are these expert systems not specific and flexible enough to work in all cases for the designer. Later in this thesis some prerequisites for the SBSD-approach are described. The factors mentioned would probably also apply to other expert systems.

It seems like there is more traction for decision support tools than for expert systems today. Even though there are similarities between these two, the name “Decision support tool” comprehends the influence of the human designer to a larger degree than “Expert systems” that might be interpreted to override the designer.

Decision support tools that prepare and organize the design process for the designer seem to have great potential in limiting the manual work by the designer in addition to store and reuse design knowledge.

Method

The SBSD approach is an early decision support tool for the designer, and a way for the designer to be able to structure the information he has gathered and generated about the new vessel. This report emphasizes to investigate how a simplified SBSD approach can be used in the initial sales process for a new offshore vessel. It can therefore be considered as an instrumental case study (Stake, 1995). The instrumental case study, named exploratory case by Yin (1989) attempts to answer how theories play out in real life context. A particular instance is examined to create insight into an issue or refinement of theory (Stake, 1995).

Case selection

As the goal of this report is to investigate how a simplified SBSD approach could be utilized in the initial sales and design process, an interview with a sales representative of a ship design office designing Offshore Vessels could give viable understanding of the usefulness of the approach.

The industry of ship design has matured the last decades and today there are a couple of large actors and additionally some smaller independent offices. While the internal structure is quite different between the offices, and their strategy differs from cost leadership to differentiation, the sales process would be comparable. The independent offices would sell design only while the larger actors utilize synergies in their organization to sell equipment or yard capacity.

For the interview a sales representative from one of these offices has been chosen. The interviewee has long experience from selling designs for Offshore and Specialized Vessels through the last decade all over the world. He was in the market through the high growth of 2002-2007 and the crisis in 2008. He started in the company as summer intendant through his studies, and has worked in several departments of the firm throughout the years.

Coming from various positions in detail engineering, he has been a central part of the sales department at a major ship design office where he has gathered insight into the industry. Mentored by an experienced sales manager, he quickly built a large personal network at board level of large ship owner corporations all over the world. The sales man interviewed is an early adopter of new technology and is able to see the potential in new solutions which is an important factor when evaluating new approaches like SBSD.

As a medium sized design office, he has been one of few in the sales organization and has thereby been involved in nearly all projects the company has worked with. While the number of contracts is strongly influenced by the market situation, the number of pre-contract projects is more or less constant. This is because in times with fewer contracts the sales and initial design departments need to follow leads they wouldn't have when the market is well preforming. It is not unusual for a sales representative to have about ten ongoing projects at the same time.

The selected interviewee is therefore considered as representative for the case study and as a viable basis for evaluating the approach in the initial sales process.

Some researchers of case study design, like Yin (1989) consider that reliability, replicability and validity are appropriate criteria for evaluating the case study research while Stake (1995) barely mentioned them, if at all (Bryman, 2001). Kirk and Miller (1986) defines the terms as *"..reliability is* *the extent to which a measurement procedure yields the same answer however and whenever it is carried out; validity is the extent to which it gives the correct answer*".

Reliability

Reliability considers whether the study has had consistency of measures and if the researcher has changed his measures due to the results of the study (Bryman, 2001).

The theory discussed in this report is gathered from published articles and books about design. The literature has been chosen to combined build an overview of what that has been done in the field of ship design and acquiring design knowledge up to now, and to give some indications of where the literature is heading. There are a limited number of articles in the area of ship design, and by selecting well-known and cited articles the sample would probably be representative for the ship design theory. An extra effort has been laid in the literature of SBSD and the references of Levander (2009).

To get an even broader basis, theory from airplane and automobile industry could be considered. These industries have had a high focus on design methods, and theories have in the past often been transferred from these industries to the ship building industry. Design theory within these industries could indicate what is coming, but have a limited necessity for describing today's literature. Even though there are some similarities, there are also several substantial differences between the nature of these industries (Park and Storch, 2002).

The case study, which is describing how the SBSD approach could support the sales process, is open for individual opinions, though the study describes the process as objective as possible. This is also a general critic for case studies, and would probably also concern this study.

Replicability

The replicability of the study considers if the research is possible to do again and get the same results (Bryman, 2001).

As a standalone interview the replicability can be discussed as both the interpretation of the content, and the setting of the interview could influence the result.

While the interview shows one sales man's comprehension of the industry, it is still quite representative as there are few sales men in this industry, and they all need to have a good overview of the marketplace in order to do their job. Despite the fact that his subjective opinion would inflect the results of the study, the answers of the interviewee were more a description of the industry than personal subjective opinions.

In this sense it is possible to argue that even though each one has their own opinions, the answers would probably be comparable with others in the same industry and thereby replicable.

Validity

Bryman (2001) divide validity of the study in four criteria. Internal validity concerns the causality between research and interpretation. Measure validity considers whether the measurements of the study are interrelating, and whether the information gathered is relevant for the project description. Ecological validity considers if the results are valid in a real life situation while the external validity considers if the results of the study can be generalized beyond the sample used in the study.

Internal Validity
A possible source of error in an interview is that the interpretation of answers isn't correct compared to what the interviewee really meant.

Such errors would compromise the study, and the results would be useless. If the errors aren't detected, the study could even become basis for false teaching.

To mitigate the risk, it is an advantage to be sure that the interviewer and the interviewee understands each other. It is an advantage to know the interviewee's mode of expression, and that the interviewer has some technical understanding of the interviewee's issues.

The risk of interpretation errors is further minimized by offering citation check letting the interviewee see their citations used in context. However, there will still be some uncertainty about the results as there is no quantifiable scale for personal opinions and two persons can interpret the same content very differently.

For the interview in this report, the interviewer has technical experience from the subject, and knows and understands the expression of the interviewee well. In addition the subject is not as vulnerable for subjective interpretation as a more personal subject could be.

External Validity
Case studies are criticized for being impossible to generalize (Bryman, 2001). However, it is argued that generalizing is not the point of case studies, as the single instance of study can give deep insight.

For this report the interesting issues regarding the sufficiency of the SBSD approach in initial sales process and design is mostly dependent on the few specific persons involved in this process, and generalization in such would therefore be obsolete. The ship design industry for Offshore Vessels is quite limited and it can be argued that generalization is not a goal at all.

However, to get a broader foundation which could have been generalized, more interviews could be done, both by interviewing more design offices, and possibly interviews with designers and ship owners as well.

Measure Validity
The problem description concerns how a simplified SBSD approach would support the initial sales and design process for an Offshore Vessel. An instrumental case study enlightening new elements could be sufficient to evaluate the usefulness of SBSD in the initial sales process.

The interview of a sales representative is relevant and necessary for the problem description, as sales men of ship design for Offshore Vessels would be the best source available to describe the sales process.

As described under Case selection the interviewee is a relevant person with much knowledge of the industry and the market. He sells ship designs for a living, and followed the market trends for the last decade though good and bad times.

Ecological Validity
Case studies are often considered to have limited real life validity as they are difficult or impossible to generalize.

It can be argued that the best method of securing ecological validity is to test the study in the market place. Interviewing experienced sales people with market insight and business mindset should be a sufficient way to do this. The interviewee answered the questions from a market perspective as he is in the marketplace and not academia. This could of course also inflect that he might not able to see the process in an objective way.

For the study to be translated into real life usage, there should be established a software that concretize the approach and displays the advantages clearly for all stakeholders.

How the SBSD approach supports acquiring design knowledge

This chapter will handle the benefits of using SBSD as the repository for knowledge in the organization. Design knowledge consists of both explicit and tacit knowledge. While explicit knowledge is easy to codify and store in a database, tacit knowledge is more challenging.

The SBSD approach consists of two parts. First there is a database of statistics from previously developed projects. This database stores characteristics such as length, breadth and displacement, but also key numbers like block coefficient, cost estimations and speed. The special element of the SBSD approach is that it in addition to the characteristics above also stores values for areas used for different purposes onboard, split by a function hierarchy. These numbers can be used to generate new key numbers for areas needed in a new build.

Currently, it is challenging to store such data because of missing systems and routines for doing it in an efficient manner as described by the sales man:

"*When the market moves at a high phase there is no time to systemize information, and we take shortcuts and copy-pastes from similar projects. When the market is flat, it is still not priority.*" A07

The database of designs would form a large knowledge base for the design office. In addition to own designs, the database would support to add information about competing designs. This way, not only internal knowledge is codified and organized in a useful way, explicit knowledge from similar designs by other design offices can also be stored and used for comparison.

The second part is the frontend view where the designer develops his new design. This part is where the knowledge from previous projects can be utilized for further development. The value of knowledge is largely realized through applications of the knowledge (Edvinsson and Sullivan, 1996). By establishing a new design based on successful factors from the database, the designer can get a jump start into the design spiral, without the need for the first iterations. By minimizing the amount of manual input to the model, the designer frees up time that he can use being creative and sped up the process making more designs in the same amount of time (Hekkenberg, 2010).

The combination of these two parts is crucial as the stored knowledge has no value if it is not used, and the second part benefits to a large degree from statistics of former successful vessels.

Prerequisites for the SBSD-methodology

For the SBSD approach to work at a design office the software need to support the designer in his daily work. This chapter will describe which prerequisites which are necessary to the approach.

In his daily work, the designer currently utilizes several software solutions. The software is to a little extent interconnected making the design and control job manual. This enables the designer to easily check that input and output makes sense based on his personal knowhow. However, it also makes room for errors as values often need to be transferred manually between the different models through the design process. This makes it difficult for the designer to ensure that he is working with the latest revision of input numbers.

"*Such a tool must be very flexible to work. In addition control is important. There can be reasons for not doing what usually would be considered obvious. It must be easy-to-use and very clear so that it is used in all projects or the data would quickly be outdated. If it doesn't fit all projects, the designer would probably mitigate the risk by avoid using it.*" A10

This aligns with the results of Vestbøstad (2010) that concluded with several opportunities and challenges for the SBSD approach. The challenges can be summarized in two factors, namely Control and Flexibility.

For the sake of this thesis it is presumed that the results of the SBSD approach are valid, and that the approach supports the designer making the process of designing more efficient, and thereby adds value for the design office as well as the designer.

Control

For the designer to be able to trust the methodology, the calculations and dependencies need to be transparent (Brathaug, 2008). In the end, if the design turns out to be a failure, it is the designer, and not his software or method that gets the blame. Therefore, the designer wants to have control of the process of the new design, and not just the input and output of a black box.

An important factor in the designers mind can be illustrated with the interplay of tacit and explicit knowledge described by (Dzbor and Zdrahal, 2001). If the designer should maintain control in the project, he has to agree with the interpretation and codification of project knowledge throughout the project. With missing links between how a result was generated, the designer automatically lacks overview and control.

An important part of the control factor is to help the designer maintain overview of the vessel, and all factors influencing it. The designer needs to see the "whole picture" to be able to decide efficiently.

In complex systems the control issue can be quite a challenge. This is also a limitation using spreadsheets as when systems get complex the overview is easily lost. As spreadsheets get complex it is especially hard for others than the creator to maintain overview. In the chapter "Mockup of a Graphical User I" standalone software therefore is sketched.

There are several ways to make the designer comfortable with the calculations performed. The software can

- Display and organize all parameters that influence a calculation in a well arranged order.
- Display all dependencies in the calculations in a graphical way giving the designer an overview of the process.
- Letting the designer easily override any input or calculation to fit special purposes.
- Use graphics and automatic 3D sketching to visualize.
- Display influence trees, including rules and legislations

Flexibility

Offshore vessels differ from cruise and merchant vessels in their level of specialization. There are various combinations of functions and tasks for these vessels which often make it difficult to label them to a specific subcategory. This creates high demand for flexibility.

"*There are so many parameters for a vessel. All ship owners have their own preferences, ideas and demands. All kinds of ships have their needs, and all segments have their own requirements. An example can be the fish boat owner that might build a new vessel every seventh year or so. Even though there has happened a lot in both technology and rules and legislation, we would base our first sketches on their last boat because of their familiarity with the project. This is not as rigid in the offshore segment though.*" A08

Even though the fish boat example might not be comparable to the offshore segment, the software needs to be flexible enough that it can be used for all of the ship designer's projects. If the software doesn't work for all cases, it would easily be avoided by the designer.

The designer needs much freedom and flexibility in the design process to be able to solve the design task in the most optimal way for the ship owner. He cannot be limited of strict categories or limitations in the software.

The flexibility issues can be solved by

- Establishing a flexible function hierarchy effectively splitting ship functions from task related functions.
- Using labels and not strict categories to distinguish between different vessel types and purposes and have the same basis model for every vessel.
- Using templates based on the labels above for different configurations and enable the designer to modify templates and configurations in an easy way.
- Implementing a general solution for special incidents in a way that any parameter can be overridden by a task related function.

The flexibility issue can be a difficult challenge to get to work in an easy and understandable way. Especially the issue of overriding standard values is important and it needs to be clear where the value comes from, and why it is overridden. Still, the flexibility challenge can be solved by building the software foundation in a smart way.

The sales process for design of Offshore Vessels

Even though every design office has their own way of solving the design task, the key elements of the process are more or less the same. The process of the ship design task is in this chapter tried described as general as possible.

The industry of ship design and building is compact but complex, everyone knowing about their competitors, and preferences. In fact, clients can also be competitors as their part of the value chain are interrelating in several markets.

"*Sales in this business are not like selling shampoo. It is a service and then the sales man needs to know a lot about the technical background.*" A01

The job of the sales man at a ship design office is concerned around developing good projects together with the ship owner to ensure that the vessel is decided built which in turn would generate work for the detail engineering department.

"*The clients often get impressed when we are calculating, drawing or writing specification together with them, but that's what they need. Our clients are to a large degree not economists, but people with technical competence. And they want to meet sales men that speak their technical language. We have even discussed to drop the name 'Sales department' and include it in the 'Department for initial design', because that's what it really is.*" A04b

There are in general two kinds of processes for building decisions for Offshore Vessels. The first one is when for instance an oil company needs a ship to do a long-term job.

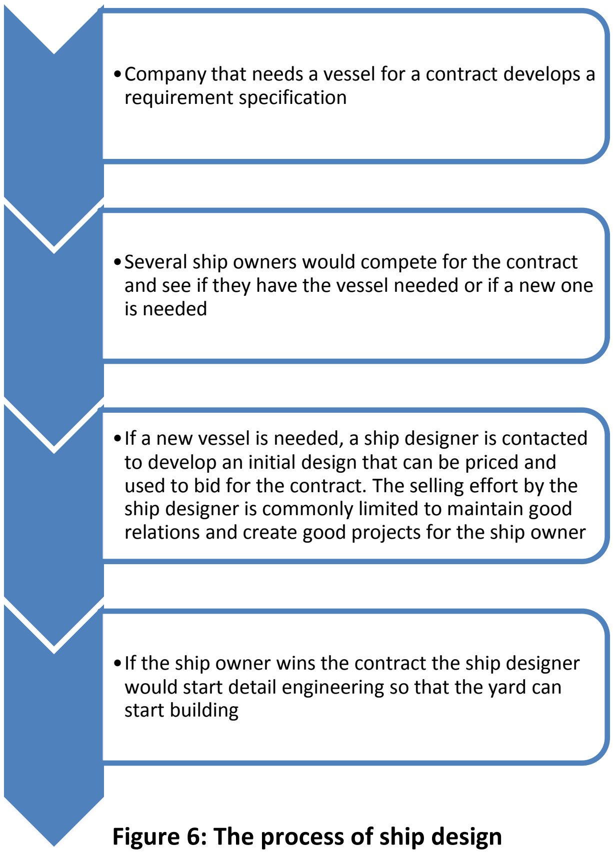

Figure 6: The process of ship design

"*Commonly, the oil service company develops a requirement specification of the vessel which they distribute to potential ship owners. The ship owners would then come to us to develop the best possible vessel in accordance with the requirement specification*" A11

Clearly, this process fit well with how Dzbor and Zdrahal (2001) describe abduction as explicit design goals that are investigated how to be achieved. The requirement specification can be both specific and general, but does often give quite detailed requirements for the new build, either as a list of details or as requirements for the system as a whole.

The second process is when a ship owner or investor sees a future demand, and builds a vessel on speculation.

"[Building on speculation] is done a lot in the industry. It could be a large company that needs a pipe layer and sees an internal need, or someone that just needs help to build a vessel that there is a demand for in the market. LNG could be a good example of this as there will be a growing demand for vessels with LNG propulsion forward." A12

In speculative projects the link to Dzbor and Zdrahal (2001) is more vague, but while the design goals are more superficial, several concrete requirements adds up as the vessel type is selected. To select vessel type, the sales man at the ship designer would recommend based on his tacit knowledge and impression of the current market situation. As the sales man both knows what is in the pipeline of new vessels, he also has a feeling of the market demand both currently and forward since he is involved with so many clients and partners in the industry on a daily basis.

Either way the ship owner contacts the designer, though with quite different requirements.

"*With starting point in the requirement specification, we are challenged to develop the optimal ship regarding building costs, operations costs, emissions, speed, stability, cargo load and so on. We would then iterate to find the optimal solution. If there is a ship owner behind, he would prefer joint operations in the fleet, like equipment from the same maker for all vessels, and so on."* A13

The goal for the ship designer is mainly to design the optimal vessel for the client, as a successful project would be a good reference. The ship design office also needs to utilize their internal resources as efficient as possible to compete in the marketplace.

For speculative projects, the investor might not yet have decided which kind of vessel to build.

"*Some has good technical understanding while others just want to invest and resell. Then they often ask us of advices to develop the optimal ship for the current market situation.*" A14

Through the initial design process the main dimensions and characteristics are set, the General Arrangement is solved, as well as stability calculations, installed power and speed requirements and similar decisions that affect the shape of the vessel are concluded.

When the contract of building the vessel is signed by the ship owner, yard and designer, most decisions are already taken, and it is up to detail engineering department and the yard to fulfill what the sales and initial design departments have promised. It is common by the ship designer to guarantee speed and stability, and it is therefore crucial to do a best possible job before contract is signed to avoid penalties.

Case: The Initial Sales Process

When the ship owner contacts a design office to ask for a new build, the first contact is commonly done through phone, email or a meeting at a conference.

"*If a ship owner does know what kind of vessel they would like, we send them some examples of earlier projects that we hope fit as a starting point. We would also suggest what we would like to do with such a vessel to meet the forward market demand as we know it.*" A15

A common initial sales meeting is done at the client's office, presenting some of the former projects of the designer. If the designer has received a requirement specification in front, they might present a sketch or at least some similar projects.

But what would happen if the designer together with the client easily could generate a visible result and possible solution of the design task during the initial meeting?

The potential in illustrating a new design in 3D at the first meeting is probably largest in cases when meeting with investors and persons with economical background. But for an early sketch of a new build, a 3D sketch can make a good foundation for discussion. However, it must be emphasized that it is only an early sketch as there are many time-consuming processes that need to be done before the vessel can be finalized.

"*It should not be done too fast either, that's what we get paid for. Of course as an early discussion basis it could be smart, but what takes time in these processes is to finally determine the lightship, and to calculate the stability to fulfill SPS-requirements.*" A17

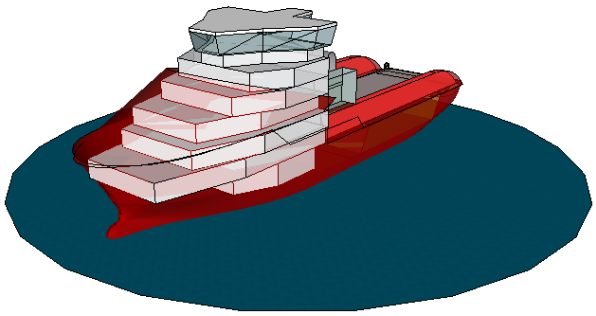

Figure 7: Exact model

Showing a premature 3D-model of a vessel to the ship owner that can be comprehended as a thoroughly worked solution can be dangerous when the designer do the exact calculations and finds that the vessel could not be designed as proposed.

In software like Google Sketchup there are predefined line styles that give the impression that the model is just a sketch of a possible solution and not an exact model. This is illustrated in the sketch to the right. Using such line style in the model helps making the model become more of a discussion basis than a viable solution. Often when discussing with basis in sketches, the sketch is not in scale, and the ideas are not at all viable when the designer later attempts to fulfill what was agreed. While the model might look like a sketch, the volumes and sizes of the sketch are correct and illustrate the results of the SBSD method.

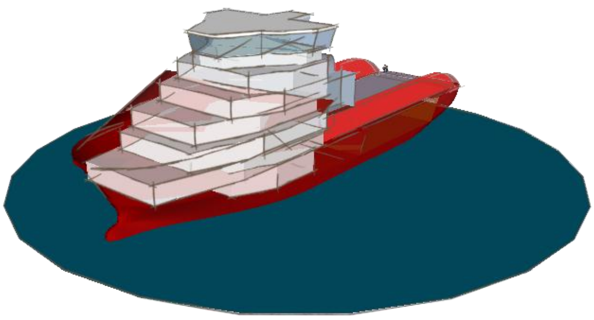

Figure 8: Sketch

Gross (2006) argued that CAD systems lacks the "Fluidity" which is true when sketching in CAD software. Looking at the Google Sketchup model alone, this is true. However, as the sketches above are generated based on a logical model in Microsoft Excel they are easily exported to the designer's software for detail engineering even though the usability might be limited. However, the "Forgiving" of the model is lacking. Commonly, the "Forgiving" factor lacks in 3D-software as the model needs to be complete to show, since it is based on components and not lines as in 2D.

While detailed 3D-models don't forgive at all, the SBSD approach with generalized modules are not as rigid. Since the values that are not set yet can be estimated by experience and the sketching can be seen as done in the SBSD GUI, and not in the 3D-software, the SBSD approach can be more "Forgiving" than 3D-software alone.

The issues of sketches might seem as non-important; however the psyche and interpretation by the stakeholders will be quite influenced. It can also be compared to the interplay of tacit and explicit knowledge illustrated by Dzbor and Zdrahal (2001) where an exact 3D model with thin, straight lines would easily be interpreted as explicit codified knowledge while the same 3D-model that looks like it is drawn by hand would be interpreted as an estimation or a suggestion for a possibly viable concept.

While a full SBSD iteration would be far to detailed for an initial meeting, a simplified model of the approach would certainly be manageable. As the database in the back would know a lot about the vessel type in question, and space demands for all kinds of spaces, the details can automatically be assumed based on experience from earlier projects. Using such a technology, the vessel can be sketched based on average values when the vessel type is chosen. As more and more details are set, the sketch would gradually be a better fit.

The interviewee has not yet seen a system that can organize such amounts of values in a systematically way. And it is a major task for the SBSD to manage and organize the data.

"*Even though there is a high potential in systemizing and reuse values in new projects, it is nearly impossible to do it consistently since there are just too many parameters to consider.*" A09

The sales process is to a large degree focused around the shaping of the vessel together with the client, and it is common to have a No Cure No Pay strategy in the project development. In this sense there will always be many unpaid projects for the sales and initial design departments. The ship designer might even work for several ship owners competing for the same tender in which they are doomed to lose at least one of them. Thus it is very important to do the initial design process as efficient as possible.

The SBSD approach supports quickly generation of viable solutions. The following case study investigates how a simplified SBSD approach could be used for initial sales support. This is done by basis in a requirement specification by Petrobras and using this information to generate a 3D-sketch.

The sales man's background

Since technical insight is important for a sales man's job within ship design, it sets requirements for the training of the sales men. The combination of technical and economical experience that is needed requires practical experience from the whole process of ship design.

"*I believe that to do well within ship design sales you need to have a broad overview of the ship design process. To get that you would need to try out several positions within a design office before entering sales.*" A02

However, the sales job can be less sales and more technical development as the clients often have long technical experience. This is also emphasized by Moynihan (1993) which states that judgment and previous experience are applied in concert with technical knowledge to select the correct values of the design parameters to create good projects. It is common for older seamen to get an office job at the ship owner's office in the last years of their career. They commonly get positions within the ship owners departments for new builds and are thereby technically competent and experienced discussion partners even though they might not be the decision maker.

"*I do realize that I fall short on typical sales men characteristics like extreme courtesy or hair gel, but that has not been our attitude at all. It is all about content, the competence, and sharing and helping the client.*" A04a

The balance between technical knowledge and presentation is obviously important for this kind of sales. This balance is a sort of tacit knowledge, knowing which solutions that is best for the client at hand. Such competence is difficult to obtain at school, and would more preferable be learned by studying others doing their job and being challenged and included in a sales team.

"*The most important factor for me starting in sales was my former boss that was mentoring me. He was skilled and thorough in everything he did. He treated everyone well, independent of our potential upside and how exiting the project was.*" A03

To get a broad overview, the mentor role can be an important and useful way for fast learning. When new employees are stuck in a technical department for too long, they often become too specialized in their field. For the sales department this can be a challenge.

"*The problem with those [persons] that are specialized in their exact field is that they don't see the whole picture, and a ship is a balance between lots of parameters. I believe that it is first when working in sales that you would consider the last piece in the puzzle, namely economy. Until then it is easy to just see the technical aspects, and even if the product is great, it might never get built.*" A06

Even though a structured representation of knowledge could be used as support through initial design, a sales man, and designers as well, need to 'know-why' referring to the definitions of (Edvinsson and Sullivan, 1996).

About the prototype

As a part of this Master Thesis a prototype of a visualization tool for the SBSD approach has been developed. In the following the prototype will be presented and illustrated. See also Appendix D-I for further information.

The output from the SBSD approach is a list of volumes required for a new build, and weights for each volume. By making templates for how these volumes connect, the sketching of different viable solutions can be automated as shown to the right.

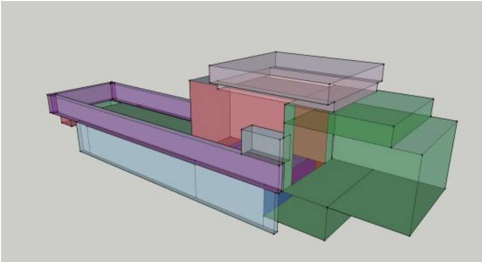

Figure 9: Prototype 1: Building boxes for volumes

The template states where a volume should be positioned, the breadth and height is set based on constraints and the length is scaled to fulfill the volume demand. For instance would the Winch module be placed in front of the Deck module and made as wide and high as possible within the constraints and then scaled by length.

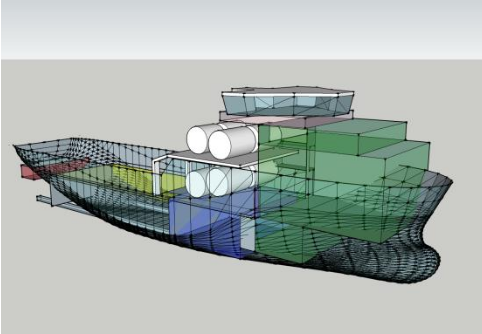

Figure 10: Prototype 2: Changing to scaled modules

The Graphical User Interface described in the following is only a sketch for how such a software possibly could work, but some static templates has been implemented using Excel to generate the 3D-sketches to the right based on a library of modules, scaled and positioned in three dimensions.

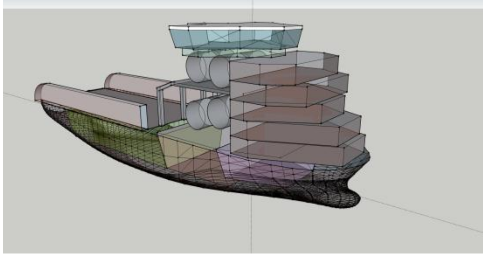

Figure 11: Prototype 3: More realistic split of volumes

The Excel spreadsheet is dependent on a short list of parameters such as breadth of the vessel, depth from first deck, deck spacing and so on. The spreadsheet has a column for volumes per module which is linked to the SBSD spreadsheet. These volumes are then divided by suitable breadth and height which generates a scaling ratio for the input file.

To do this in real time while changing parameters in Excel, a Visual Basic Script export relevant data to a text file in corresponding format (See Appendix D: Input file for 3D generation). The Visual Basic Script is a modified version of a standard script exporting information to a file.

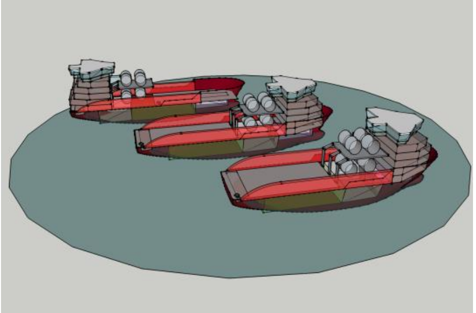

Figure 12: Prototype 4: Configuration design

In addition a plugin for Google Sketchup has been developed in Ruby to traverse the input file mentioned over, importing the modules needed and scale and position them. The modules are separate 3D-models that can be as detailed as the designer would like them. If the core model is updated, it would affect all new vessels that are generated.

A small JavaScript was also needed to actively call a catcher with small intervals. The catcher checks if the input file has been updated the last second, and if it has, the catcher calls the builder to generate the model, and then render an image.

The Excel spreadsheet export script assumes that the Google Sketchup plugin is running, and when the input file is exported the script would wait for a couple of seconds and then try to import the render made by the Ruby catcher. How long the VBA-script should wait depends on how quickly the 3D-model is generated, and would thereby be dependent on the speed of the computer. For now, the waiting time is hard coded in the VBA script.

The designer can thus work in Excel alone, with Google Sketchup running in the background, and still see an updated 3D model in the corner of his spreadsheet.

The technical process of the SBSD approach and the result in form of a 3D sketch are summed up in a process diagram shown under. For screenshots of the prototype, see Appendix H: VBA scripts in Excel.

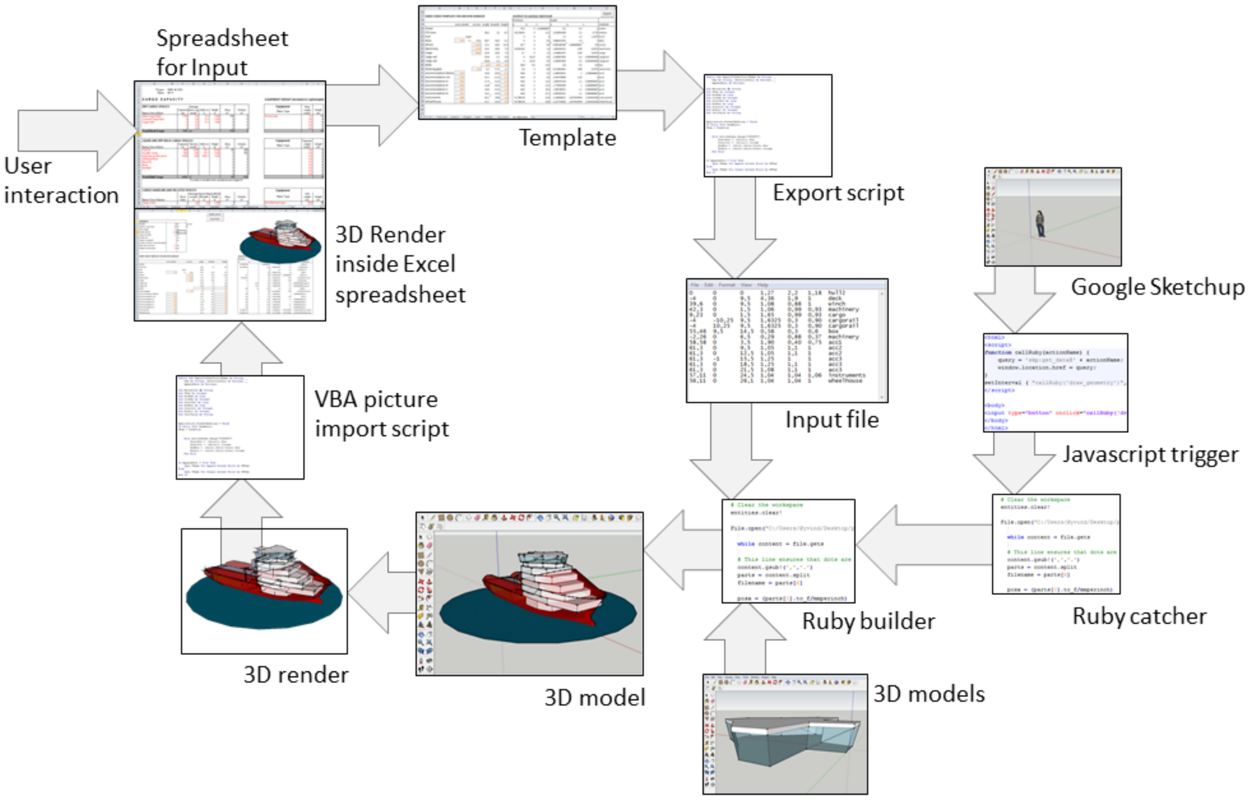

Figure 13: Prototype process explanation

The Excel output generator is connected with the Excel spreadsheet for SBSD for Offshore Vessels developed by Kai Levander the spring of 2011. The result of this spreadsheet is a list of volumes needed for the vessel in mention. These volumes are translated into a hard coded template in an own sheet which has the export script attached. The export script generates the input file for the Google Sketchup plugin. The Google Sketchup plugin would import the latest input file and build the model which in the end is imported back into Excel.

The loop takes a couple of seconds and the designer can have the Excel spreadsheet open and see the changes directly.

While the prototype is just that, a prototype, it does support the designer with valuable information with the 3D sketch. The most limiting part is probably the template system that is static formulas in Excel, but it can easily be changed by the designer and is built in a logic way that could easily be further developed to support other Offshore Vessels.

Technical requirements

The resources needed to use the prototype are minor as described in this chapter. The prototype would be able to get to work on all computers with platforms supporting Google Sketchup and Microsoft Excel.

Today computers have nearly no limits in capacity and speed. In addition more and more software packages open for interconnection to other software. The manufactures seems starting to understand that the benefit for the customer in opening for interconnecting is higher than the risk of making the product obsolete.

These factors open for lots of possibilities that weren't possible earlier. The benefit of avoiding duplication of information is substantial as every copy of the same information generates extra work, and possibilities of errors.

In this thesis Google Sketchup and Microsoft Excel has been chosen since both are powerful tools with possibilities to build upon by easy means.

Google Sketchup has a powerful plugin system based on Ruby which is quite simple to use. With a few lines of code the plugin can build a 3D-model based on a text file. It is also possible to create more advanced modules that dynamically changes preferences based on for instance the scale of the model. This can for instance be smart when scaling stairs; Google Skecthup can add steps to a component based on a step height. Models can be exported to well-known 3D-formats and used as foundation for further development.

Alternatively 3D software like Rhinoceros 3D could be a good substitute to Google Sketchup. Rhinoceros 3D is also known to have good opportunities for scripts to generate models. However, Rhinoceros is built on surfaces and has some limitations when exporting these surfaces to volume based software like Autodesk Inventor or Solid Works. While Rhinoceros 3D is easy to learn with a background within 2D software such as AutoCAD, Google Sketchup is built and designed like other 3D software such as Solid Works and Autodesk Inventor.

The convenience of a well-functioning development community online and the easy to use API, together with volume based 3D-models and good exporting possibilities made Google Sketchup the best tool for this prototype.

Microsoft Excel is chosen for convenience since it has powerful spreadsheet functionality as well as a well-known scripting language (VBA). The SBSD approach is also currently implemented in Excel which makes the generation of input data easy. As the spreadsheet software only needs to be able to do some simple calculations and then generate the input file, any software could do the job. Actually, while Excel is good for this prototype, software based on a regular database would be preferable at a later stage. This is because the template for model generation which currently is hard coded in Excel rather should be included in a flexible database controlled by some kind of server software.

The scripts have been tested on a Windows 7 platform with Microsoft Excel 2010 and Google Sketchup 8 (free edition). However, it should work on every platform that supports Google Sketchup and Microsoft Excel.

The PC used is a standard laptop with 2 GB of RAM and a duel core 2.3 GHz processor which has no trouble building the model. Thus the prototype should work on the computer of every interested designer.

Templates

For the prototype to know where to put and how to scale the different modules, a template has been developed for AHTS. The template translates the volumes needed into position and scale for the corresponding modules. This chapter handles the challenges and alternatives of mapping between functions, systems and modules made as a static calculation.

Currently the template for the configuration of the vessel is hard coded for an Anchor Handling Tug Supply (AHTS) Vessel. This template is static and would probably work for most similar AHTS Vessels, but not for ships without a winch as the bridge and machinery components are positioned based on the location of the winch module.

For the template system to work in a more general way there need to be done some modifications.

Functions, Systems and Modules

The SBSD approach is built on a thought of a function hierarchy describing the functions onboard, sorted in a hierarchy to distinguish Ship Functions from Task Related Functions. A function can be a service that the vessel is planned to perform or more explicit like cargo capacities.

A system on the other hand is the accumulated components that are needed to perform one or more functions. The cargo handling system on board an Offshore Vessel would for instance include pumps and pipes that interconnect with several other systems.

The modules that build the 3D-sketch in the SBSD approach are physical components preferably as compact and independent as possible. The mapping of functions against systems and modules is a known challenge in modular theory.

For the prototype in this thesis the functions have been mapped to modules principally following the third level of the function hierarchy for Offshore Vessels developed by Levander and STX OSV the spring of 2011 marked to the right. Where the third level was too general some parts have been split in the fourth level, while others has been combined. For instance are spaces in the accommodation combined and then split to one module for each floor.

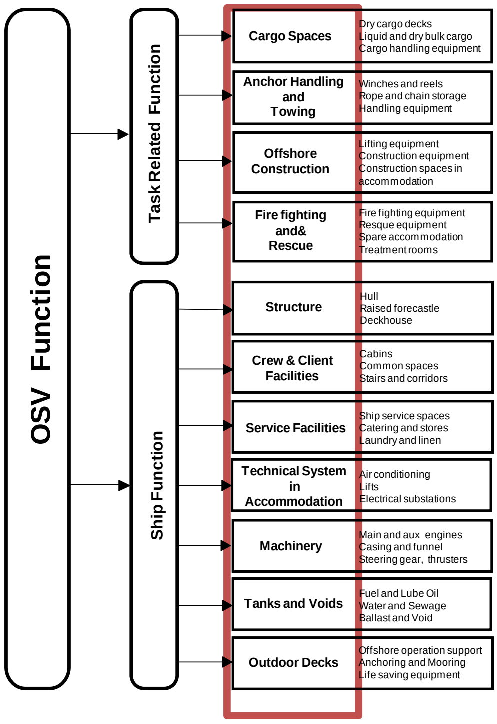

Figure 14: Function hierarchy for Offshore Vessels (Levander, 2011)

Template structure

The generalization of templates is important for the software to handle the vessels in such a flexible way that the designer isn't confined. To ensure the designers flexibility, he should be able to override the template and move and position the components as he would like; either in the SBSD GUI, or in the 3D-software directly. The first alternative is easiest carried out by changing position values for the modules and regenerate the model, while the latter alternative would require the designer to move and position in 3D which would set high requirements for logging of position to be able to track the changes back into the SBSD GUI for stability calculations.

The template can be built in at least two ways. First a template for each case can be built in a hierarchy structure. This would involve a set of rules that can be overridden downwards the hierarchy where the designer can chose specific variants of the design. This way the designer get much help on his way, but it can also limit the creative work as he would naturally limit his creativity to the boundaries of the templates.

The second approach utilizes that Offshore Vessels in general have quite similar configuration of main components as illustrated for AHTS Vessels under Task related functions later. Thus it might be possible and practical to build one or two generic templates that handle more or less all incidents. While an Offshore Construction Vessel is of totally different dimensions than a small Platform Supply Vessel, the order of the components seems quite similar.

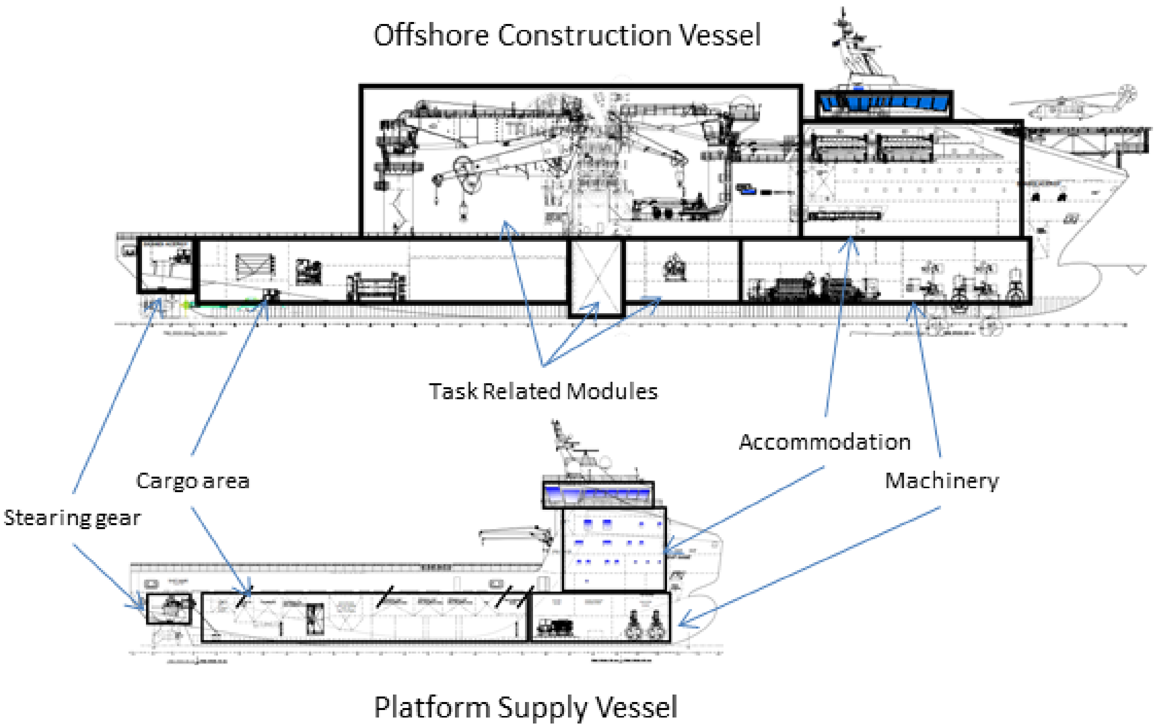

Figure 15: Configuration of main modules

As seen in the figure, the order of Steering gear, Cargo area, Machinery and Accommodation is the same. In addition the Deck and Hull modules are also similarly described. The scale of all modules is of course very different as the length of the Offshore Construction Vessel is almost double of the Platform Supply Vessel.

The advanced and space demanding modules for Task Related Functions are mainly positioned in front of the deck and aft of the accommodation, and in addition between the Cargo area and the Machinery module.

The modules used in this thesis is on a low level of detail thus the modules are large building blocks describing “sections” such as whole floors of accommodation or the whole cargo area in one module. Therefore, it seems sensible to use one general, but smart, template for all incidents.

If smaller modules are needed it could be possible to split the modules internally and combine them by internal templates for each “section”. The SBSD GUI could let the designer specify the configuration of each section as necessary which then can be generated in 3D.

The template itself could be structured as a set of rules for positioning modules. With a list of available modules rules can be made that can be interpreted and the results can be exported to the input file. The rules can be of the form: The **Winch** module is situated **in front** of the **Deck** module. To do this in a way that the exporter understand the modules should have an id, and the prepositions should have a number as indicator for easy handling.

Interconnect software

The SBSD approach can be even better at the design office in the design process working as a repository for data about a project.

Surprisingly there is no software solution that interconnects the software used to develop a ship. Many different software are used, for instance there would often be built several 3D models of the vessel from scratch instead of using the same data. The same data of the vessel is input to many of the calculations, but are still manually updated in each case. In the building industry on shore there are a trend towards connected software and uniting databases. This has not yet happened in the ship building industry and there are therefore lots of different solutions and duplication of data.

“*Many managers and directors as well as manufacturing engineers are frustrated with many different databases created for a single product. They are constantly seeking a single source for all information on the product.*” (Jo et al., 1993)

The first step towards such a solution is to create a database that is the source of all information, and implement the different software to synchronize with the database step by step. The SBSD-approach implemented in software has the potential to become such a database because it already needs to be able to store a lot of information about each vessel in a flexible way.

To avoid disruptive work flow for the designer when introducing such a tool would be to enhance the use of the current software for each specialized task.

2D Drawings – Autodesk AutoCAD

There have been projects testing if 3D can be used as an initial design tool, but it has not been introduced broadly; at least not for non-modular designs. The 2D-software such as AutoCAD have some of the “Forgiving” factor of Buxton (2006) and Gross (2006) as it is possible to solve parts of the arrangement like one floor without solving all at the same time. In addition 2D-software is “Fluid” in a larger degree than today’s 3D-software. The 2D-sketch can be developed further and become the final arrangement. In 3D software this is also possible to some degree, but in for instance Rhinoceros 3D the surfaces must be rebuilt to change them.

Until there is a 3D-software that is forgiving and fluid in a way that supports the designer’s process of developing, 2D will be used solving the General Arrangement in the initial design phase.

When a designer starts working with a new build, he would choose a basis vessel and start changing the General Arrangement drawing to fit with the new purpose. As AutoCAD is based on lines and not surfaces or volumes, and the lines don’t have metadata, it is difficult to build 2-way synchronizing with 3D-software. As a tool to find well suited basis vessels the SBSD approach can still present the designer with the right drawing from former vessels as well as blocks that can be imported to the drawings including lines and sections extruded from the 3D-model.

Illustrations – Autodesk 3D Studio

Early in the sales process illustrations are made for sales prospects for investors and other stakeholders. Software like 3D-studio is then often used because of the high possibilities to render photorealistic images.

Today, when the designer is going to make the illustration, he would start more or less on scratch building the model. The hull might be possible to export from NAPA or other hull developing software while the accommodation and equipment would be modeled based on the General Arrangement drawing.

As the 3D-model generated from the SBSD approach is getting better, it can be used as a basis for the illustrations and imported to for instance 3D-Studio.

Stability and capacities – NAPA

To calculate stability and find exact capacities for the vessel, NAPA is commonly used software. To define the bulkheads internally in the vessel a text file is imported with simple syntax based on coordinates. As the 3D-model gets more detailed, such information should be easy to extract and export to the format of the NAPA text file; at least generating proposal for less advanced vessels.

The other way, a plugin for NAPA should be able to extract information about capacities that can be automatically updated in the database.

In-house communication

For the initial design and sales departments the in-house communication can be a challenge. With lots of projects going on at the same time it can be hard to get and filter the information. When thinking on the statistical database in the SBSD approach as the main database of design knowledge at a ship design office, this opens for even more synergies.

Today, communication within initial design commonly utilizes email or verbal communication. The problem of verbal communication is that it is easily forgot, and difficult to roll back if there is a discussion of what was concluded earlier. Email is better as the information is codified and searchable, but it lacks easy filtering for who need to know what, and as it seldom is connected to a project or parameter, the information overload can make it nearly impossible to roll back.

It would be possible to build a communication GUI on to the database in which designers can discuss and inform each other in discussion threads connected to each project, or each parameter. This way for instance the person responsible for the calculation of lightweight for new vessels could get an automatic notice if someone changes a factor that is included in his calculations, or if someone discusses a parameter that influence the calculation.

The discussion of needed capacity for fuel oil can thereby be taken at the fuel oil parameter including all stakeholders. When someone in the future wonders what was discussed, the dialog would be found and could be continued.

Input data needed

There is some information that more or less defines a new vessel. By answering the questions in this chapter the SBSD approach would be able to give early estimates of most characteristics of the vessel in question. Implementing the 'Goal-Question-Metric' method as introduced by Kowalski (1998) this could be broken down to a set of questions and sub-questions that the sales man needs answered. For the purpose of the case study, the questions are answered based on a tender specification by Petrobras. Normally a requirement specification will be forwarded by a ship owner, and not addressed directly. Therefore, some of the questions are not answered. In a common case, the ship designer would estimate or contact the ship owner to find these answers.

Question	Requirement specification
1. What kind of vessel is needed?	The tender specification is for an Anchor Handling, Towing and Supply (AHTS) Vessel.
a. Freighter or a service vessel?	An AHTS is mostly a service vessel, but with some cargo capacities as well
2. What special needs is there to the tender?	
a. ROV? Moon Pool? A-frame? Offshore crane? Anchor handling winch?	Knuckle boom 5 tons and outreach of 16 m Anchor handling winches: - 2 drums, first layer: 450t - 1 drum, first layer 450 t - 2 drums, first layer 140 t
b. Other?	
3. What capacities are needed?	
a. Ship function capacities	- 300 m3 Fresh Water - 850 m3 Diesel
b. Cargo capacities	- 500 m3 Fresh Water - 500 m3 Fuel oil
c. Deck area	- 1500 tons, min 10 t/m2 - Free length: 34 m, width: 17 m
d. Total Deadweight	2000 t
4. How large must the accommodation be?	
a. How large ship crew is needed?	Ship Owners crew not mentioned in requirement specification
b. Will there be additional operating crew onboard?	4 persons, at least 1x2 berth cabin for Petrobras
c. Special needs for space in the accommodation?	
5. What power plant configuration should be used?	
a. What speed is needed?	Service speed: minimum 11 knots
b. What bollard pull is needed?	200 t
c. How is the operating profile for the vessel?	Unknown
d. Specified demands	- Aggregated power rating of bow thrusters: 2400 BHP At least one azimuth rated for a minimum of 1200 BHP - Aggregated power rating of stern thrusters: 2400 BHP

	At least one azimuth rated for a minimum of 1200 BHP
6. Any limitations affecting the vessel?	
a. Are there limitations for length or depth in port?	
b. Shall the vessel be able to service near offshore installations?	
c. Which rules and legislations apply?	- Classifying Society recognized by the Brazilian Maritime Authorities - DP 2
d. Under which flag will the vessel operate?	Brazilian

Table 1: Requirement specification summary

When the designer gets input for these questions, he would have a sufficient basis to decide many more detailed design issues, and be able to develop a first sketch of the vessel.

Furthermore, if these questions were implemented in software supporting the designer to easily answer each one, much of the logic for the first sketch could be automated. All the information above is given from the charterer, and would be "known" requirements for the vessel. In addition the ship owner would like to add preferences for the vessel to make the vessel the optimal one for the chart, as well as being able to get other jobs for the vessel when the chart expires.

In the following a mockup for a Graphic User Interface (GUI) of such software will be presented. This GUI is thought as a layer between the statistical model of SBSD and the user, and even though the mockup shows how a simplified approach to SBSD could be used, it should be used as the first iteration of SBSD letting the designer to add and adjust advanced parameters in the same model when he solves the design in question.

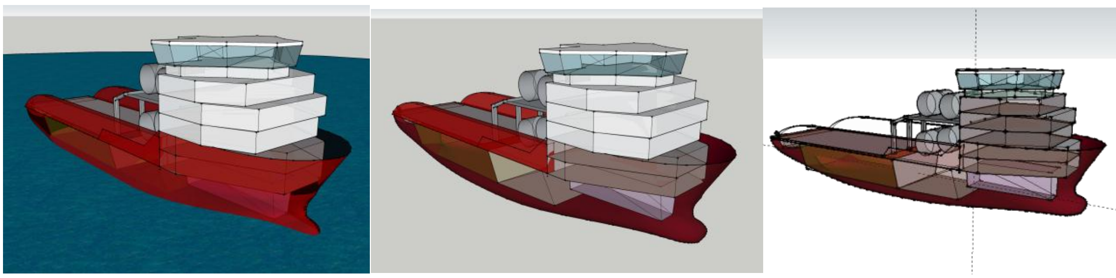

Figure 16: Automatic generated sketch of new vessel

Mockup of a Graphical User Interface (GUI)

To be able to quickly generate a sketch of a new design, the sales person needs a simple and smart Graphical User Interface (GUI) that can manage information received from the customer, save it, and analyze it to be useful.

When the customer requirements are inserted and estimates of capacities, accommodation and machinery have been added, a 3D sketch of the vessel can be generated. By trusting experience from similar vessels the 3D-model can be generated as early as the vessel type has been chosen.

A 3D-sketch is shown in the top right corner of the mockups. Because of the low requirements for calculation power, renders of the 3D-model can be automaticly updated in the SBSD GUI while the designer configures the design.

The mockup is made in Balsamiq, a program made to build sketches of how GUIs could look like and function. The mockup is structured based on the function hierarchy.

The Mockup is made to describe how such a GUI can look like at a concept level. However, it does not include every parameter that is needed, rather it tries to describe how the user can add parameters as generic as possible.

The GUI described is thought as a sketching software to quickly create a basis for further development. The three “f”s for sketches by Buxton (2006) and Gross (2006) is therefore still relevant. For the “Fluid” factor, the GUI request the user to add all first assumptions and requirements as a sketch for the new build. These can be made as detailed as necessary during the design phase by building on the existing model, and is thereby “Fluid”.

The model estimates values where details are not added, and the information might be limited. Even errors in the input data would just need refinement when the vessel is further developed, and would not make the model to crash. The software is thereby “Forgiving”.

Well arranged results from the analysis of the new build based on former projects and compeeting design would form a valuable and efficient decision basis. By visualizing various configurations of the vessel, the user would be able to conclude if the solution is viable or not. Thus the “Functional” factor should also be present.

The SBSD approach fulfill the Fluid, Forgiving and Functional requirements and seems to be a sensible sketching tool for a new build.

For each tab at the right of the GUI, a pane with settings will show. These are split into subchapters in the following.

Customer requirements

The requirement specification, combined with requirements and whishes from the future ship owner normally form the input and starting point for the ship designer.

Instead of adding this information in several sub chapters, it would be better to collect them in one view as the requirement specification should be prioritized and the designer should always know what requirements that came from the requirement specification and which that was derived during the process.

The software should recognize this early process and have a view where the designer can add all the information he knows about the new build. This might be vessel type, notations, speed requirements, capacities and so on.

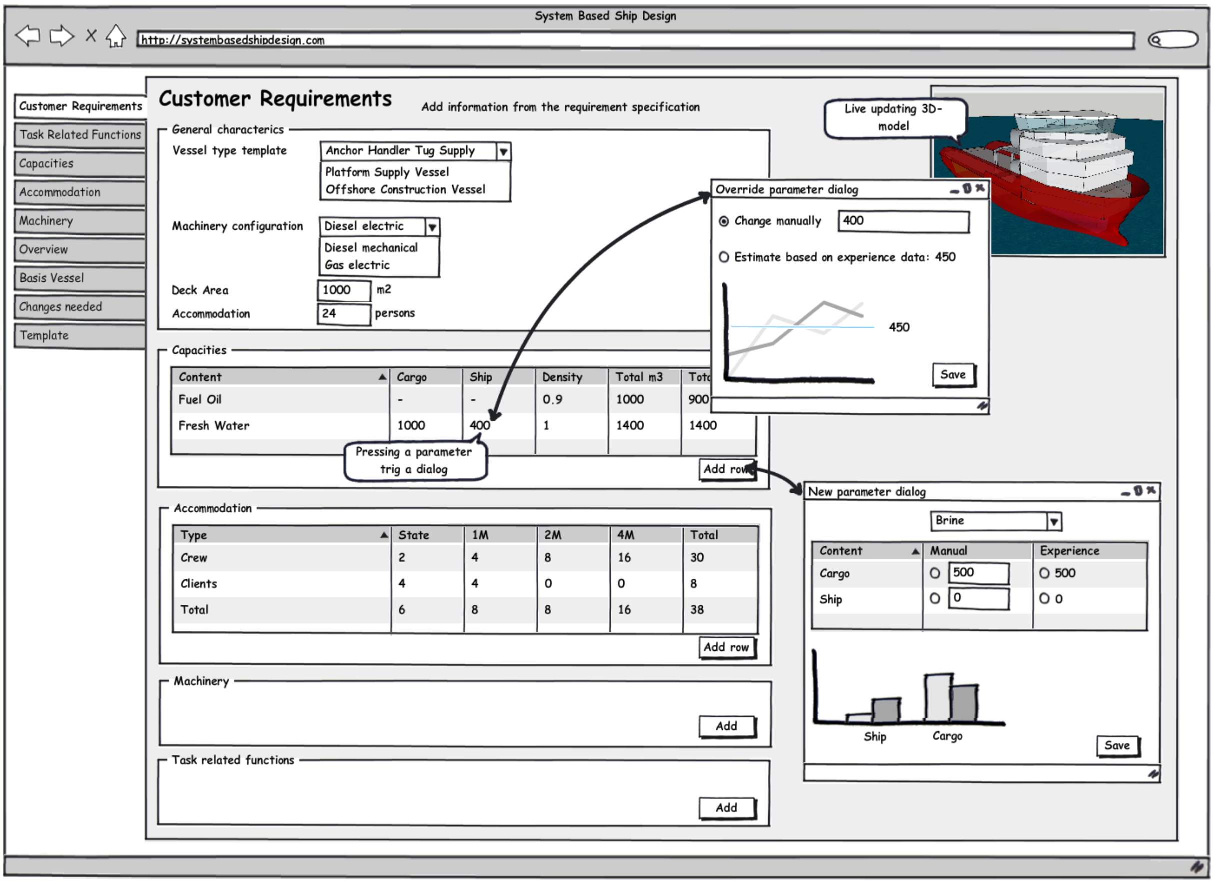

Figure 17: GUI for Customer requirements

The data normally include capacities, deck requirements and minimum speed. It is important to make the GUI flexible to alternatives and easy to add new products and configurations. This can be solved backend by establishing flexible parameters independent of content. With a flexible backend to a database, the frontend can support the designer adding new products, combine tanks for different products and so on. For instance is often a tank included in several capacities dependent on operation profile. The ORO capacity is for example including tanks that normally are used for cargo.

The different parameters need to be recognized by the software and interpreted in the right way to be included in the logic so that it can derive valid results. This can be a challenging task to do in a general way. If the parameter's resulting volume is calculated as early as possible and summed up in a hierarchy structure based on the function hierarchy, it should be possible. This is also the way the Excel spreadsheet by Kai Levander is built.

This information is added to the database, and used to search for similar vessels while the designer steps through the functions in the hierarchy more detailed.

For the following views where specifics can be added, the values from the customer requirements screen will found a starting point for the development.

Task related functions

The functions that make the vessel special are also commonly the volumes that to a large degree define the vessel. For instance would task related functions like an Anchor Handling Winch set severe limitations to the arrangement of the vessel.

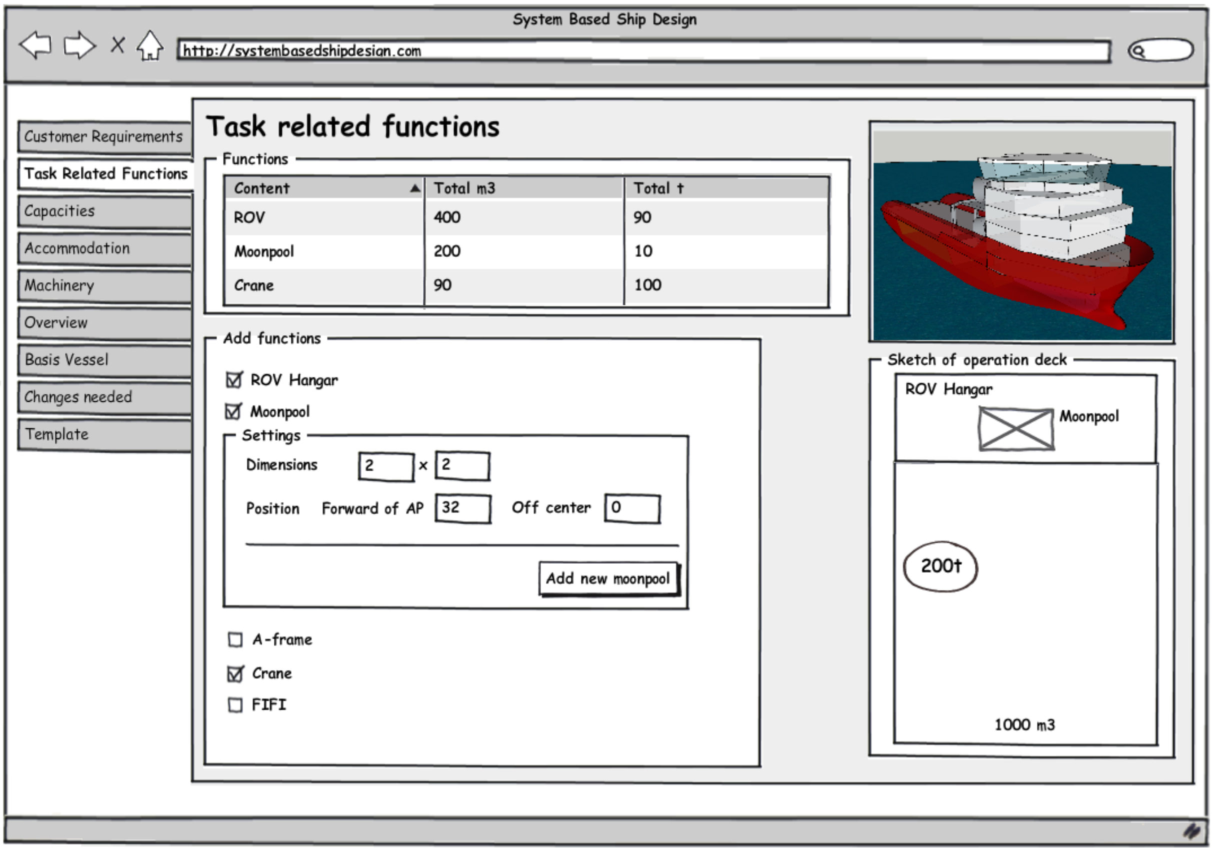

Figure 18: GUI for Task Related Functions

These limitations can have dependencies that can be summarized as follows:

- The winch normally needs to be placed on the main deck due to stability and operational issues.
- The winch needs to stand in direct connection to the main deck for operation of chain and anchors.
- The chain needs to flow from the chain boxes, through the winch and into the sea at the back of the vessel, with no obstacles in between. Therefore the deck connects the sea surface with the winch.
- The deck needs a safe haven at each side for the crew to escape.

- The Steering gear must be at the aft of the vessel, underneath the deck.
- The chain boxes must be in connection with the front of the winch.
- The crew need line of sight from the wheelhouse to the operation deck.

All these statements are requirements for the vessel based on its operations. Despite the fact that these requirements was quite easy to codify, they are normally tacit knowledge among designers and clients.

However, when the statements mentioned above have been translated to a set of rules for the arrangement, as shown below, the main line of the vessels arrangement has been set.

The rest of the modules are placed based on optimal utilization of volume, optimization of building and operation costs and requirements for stability and speed.

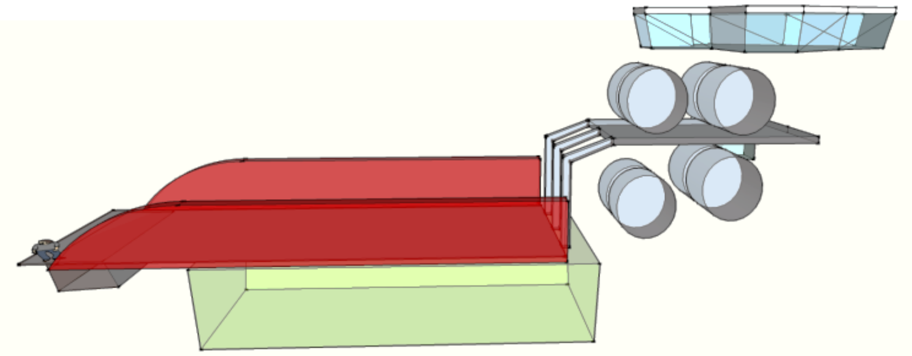

Figure 19: Modules more or less preset when Anchor Handling Winch is set

This limits the number of possible variations for the main components, which also makes it possible to create templates for common configurations that can be used to visualize early alternatives.

Even though there are many variations that in theory could work well, with the preset limitations mentioned and showed above, the typical Anchor Handler Tug Supply Vessel has more or less the same configuration of main components.

Views for each function

The software now knows some main assumptions of the new build, and can present the designer with choices based on a function hierarchy with the vessel type chosen.

Capacities

The designer would probably by now have a clue about which kind of vessel the client seeks. This would make him able to give some early estimates of cargo capacities needed for the vessel.

Minimum requirements for cargo capacities are often defined by the requirement specification. Ship functions like water ballast is filling the “void space” of the vessel, and these capacities are therefore often set as a result of the design process more than a goal. For vessels with clean design notation, liquids like fuel oil will need to be put in the cargo area in the vessel, while vessels without this notation would be able to put fuel oil in the double bottom.

Experienced ship designers have rules of thumb for all needed capacities for the ship function of all kinds of vessels. These rules can be implemented in the software, either as rules calculating based on for instance kilowatts or number of persons onboard or the software can estimate the need based on former projects alone. Both do work for the purpose, but probably is a combination the best solution where the designer can see the result of their common rules of thumb for the volume along with what they actually has ended up with historically.

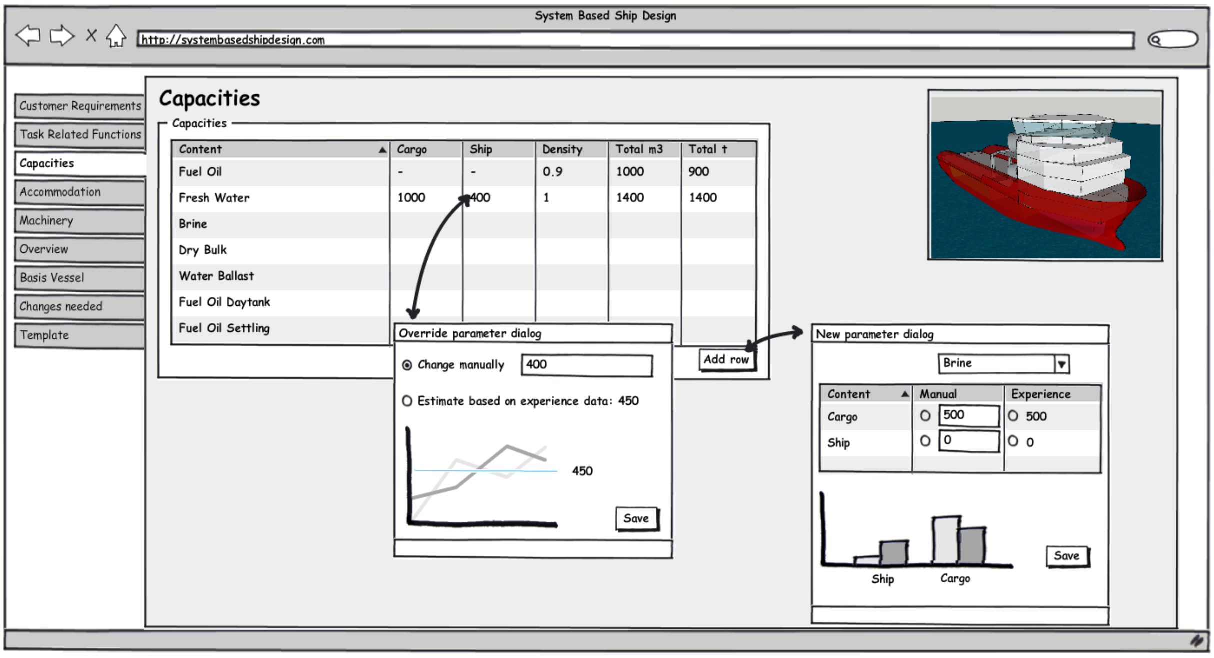

Figure 20: GUI for Capacities

Accommodation

The accommodation for offshore vessels normally holds a high standard, and the areas are to a large degree dependent on the number of persons onboard. However, the accommodation of an Offshore Vessel distinguishes from Cruise Vessels by the modularization of the accommodation. Where Cruise vessels more or less are building blocks with standardized cabins and hallways, this is more difficult to do in the relatively little accommodation of an Offshore Vessel. However, cabins are tried to be as similar as possible, and commonly with modularized bathrooms.

The accommodation is fitted in the stern or bow of the vessel so that it is not occupying well suited cargo area. The accommodation is therefore not adding much to the length of the vessel, the designer would rather add decks to make the necessary area.

Based on the size and purpose of the vessel, the number of persons onboard will be more or less defined. Often the number of beds is specified in the requirement specification.

Based on the number of persons onboard, and their ratio of work and spare time, areas for the accommodation can be estimated. Like tank capacities this can be estimated based on former projects or rules of thumb, or a combination giving the designer the final word.

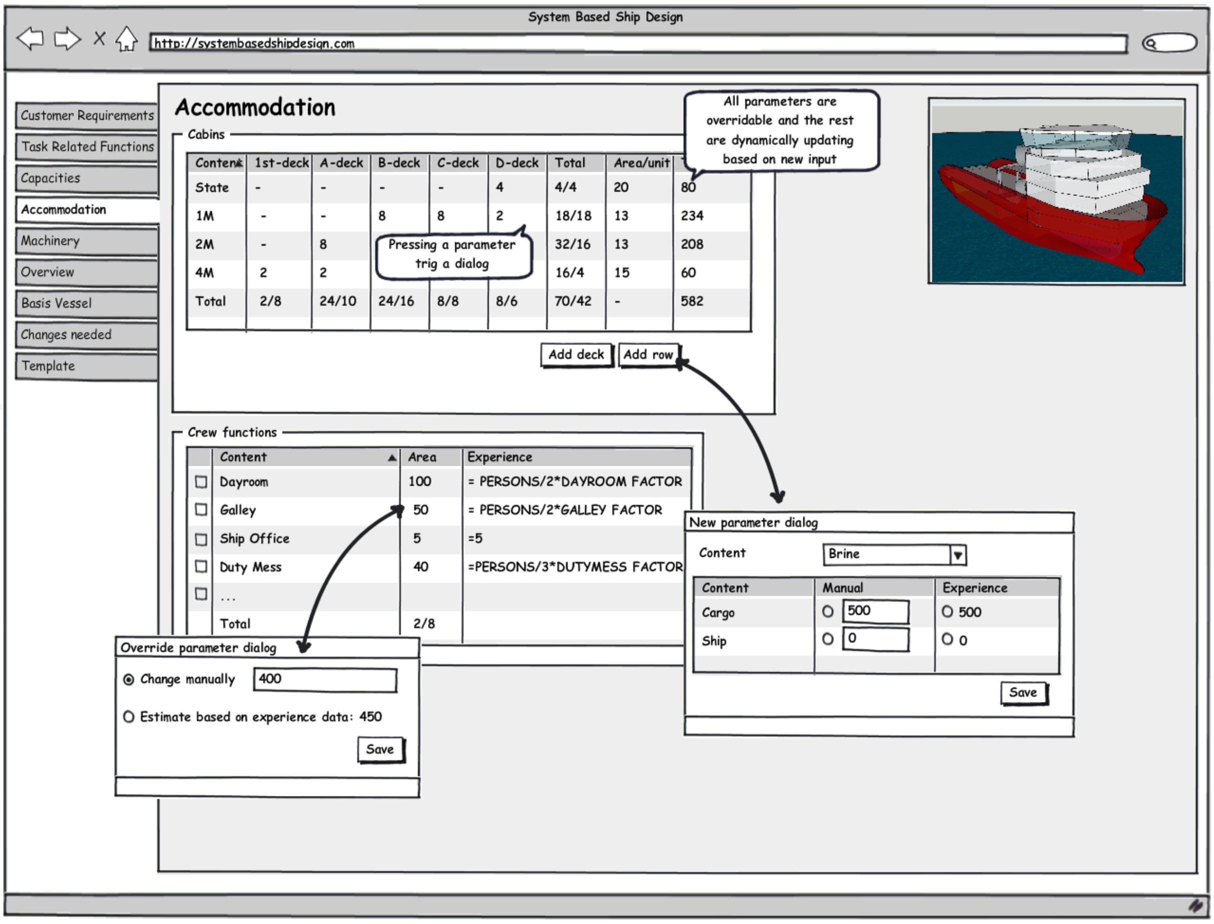

Figure 21: GUI for Accommodation

Machinery

For Offshore Vessels, the machinery is a very important function, in which there are high requirements to be able to operate close to offshore installations. There are high requirements for redundancy meaning that if an engine or other component is failing, the vessel still should have propulsion and be able to get away from the platform also when the weather is bad.

The machinery is therefore also very dependent on which class notations the vessel shall fulfill, stated in the first view.

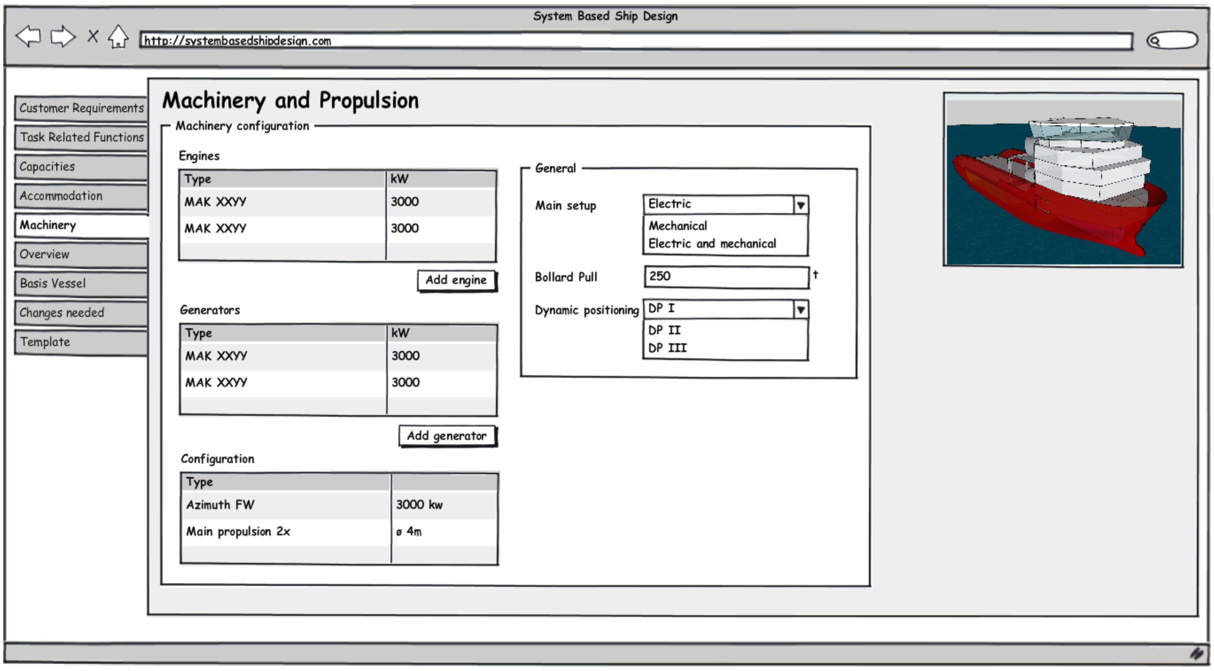

Figure 22: GUI for Machinery

The results from the capacities and accommodation spreadsheets, together with speed and bollard pull requirements would give an early estimate of the power need.

The engine configuration, and thereby weights and volume requirements are highly dependent on the purpose of the vessel, together with rules and legislation. For instance would different notations for Dynamic Positioning highly affect the weight and volume demands onboard. The configuration of the engine system is a complex task, and it is not concluded until several alternatives are tested. The software would benefit from being able to calculate fuel consumption with different configurations as well as comparing engine configurations.

This can for instance be based on a template system for some variations of configurations that can easily be chosen and recommended by the software based on former projects.

Overview and results

Based on the input in the earlier views, the designer can now get an overview and summary of his new design.

General information and main results

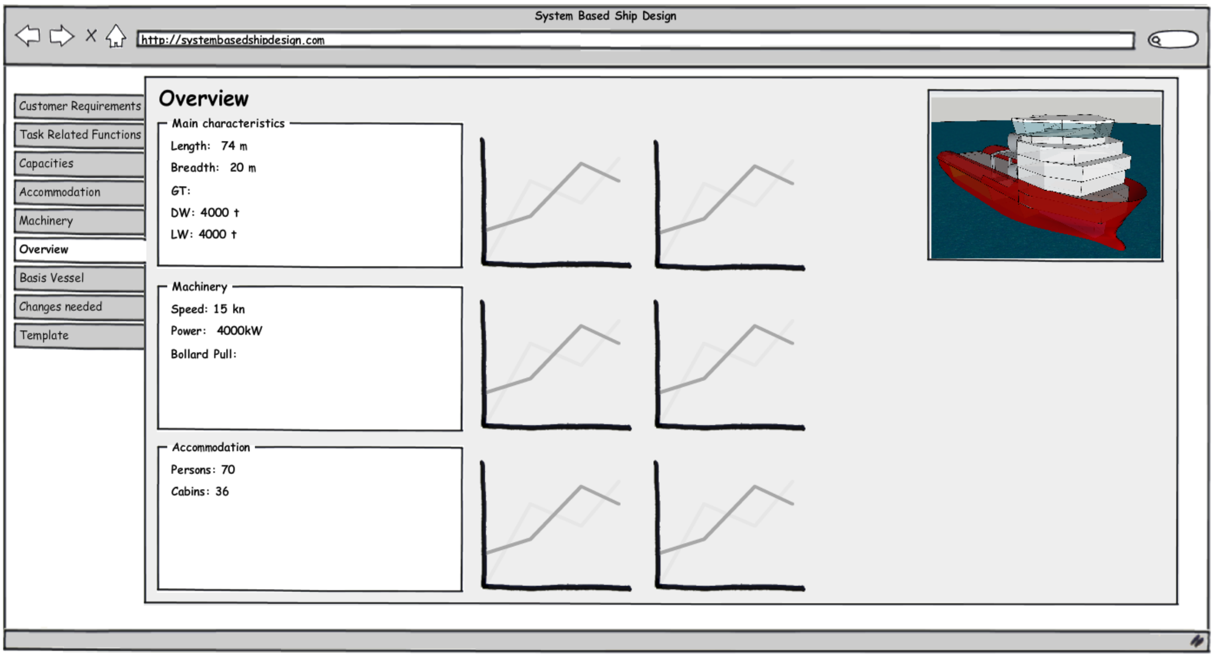

Figure 23: Overview of the vessel with graphs comparing the new build to existing vessels

The input data can be compared to requirements, physics, rules and legislations, and it can be used for calculations to find optimized main dimensions, coefficients and in the end costs.

Schneekluth and Bertram (1998) emphasizes the importance of six decision variables as they lead to most crucial characteristics for a vessel, like stability, hold capacity and so on. These six variables are length (L), breadth (B), draught (T), depth (D), freeboard (F) and block coefficient (Cb).

The weight and volume data from adding up the sub functions gives the displacement directly. When the displacement is known, and block coefficient is inherited from statistics of similar vessels, Lpp can be determined by Schneekluth's formula for length with approximately the lowest production costs are defined

$$L_{pp} = \Delta^{0.3} * V^{0.3} * 3.2 * \frac{C_B + 0.5}{\left(\frac{0.145}{F_n}\right) + 0.5} \qquad \text{where } \Delta \geq 1000\ [t] \text{ and } 0.16 \leq F_n \leq 0.32$$

L_{pp} is the length between perpendiculars [m]
Δ is the displacement [t]
V is speed (kn)
F_n is Froude number $= \frac{V}{\sqrt{g*L}}$

This formula is not made for Offshore Vessels though, and it should probably be refined based on new statistics. N alternative to Schneekluth's formula is to use block coefficients and length/breath- and length/draught-ratios from successful projects. An estimate for length, breath and draught can be determined based on the displacement and speed. The breadth, draught and depth have to satisfy stability, statutory freeboard, reserve buoyancy and spatial requirements (Schneekluth and Bertram, 1998).

The block coefficient can also be determined as a function of the Froude number, speed and displacement (Schneekluth and Bertram, 1998). When the six important variables are determined, most crucial characteristics can be derived; such as costs, stability and hold capacity.

Even though the numbers are not exact, they could be a good starting point for discussion and will be good enough to generate 3D-sketches.

Lightweight and deadweight

The deadweight can be estimated directly from the capacities added through input data combined with experience from former projects. For the ship designer it is important to know that the vessel has the deadweight that the ship owner asked for as this can be crucial for the profitability of the vessel.

Lightweight is more complicated to calculate as the amount of steel can be hard to estimate, but an early suggestion would be to sum up weights in the input data, and experience from weights for volumes and items needed onboard. The lightweight tells the designer much about the building cost for the vessel.

Building cost estimate

Based on the lightweight of the vessel and the special components onboard an early estimate of building costs can be derived. The building cost is a very important factor for the sales man when arguing and discussing with the ship owner as it is an important part of the decision basis for the ship owner.

The ship designer would on the behalf of the ship owner ask several yards for a building price of the vessel towards the end of the initial design phase. Until then, it is important for the designer to know which factors that influence the building cost, and which that doesn't.

Fuel consumption and emissions

There is a growing focus on emissions and consumption of new vessels. Continuously enhancing requirements through rules and legislation lead to higher investments in emission reducing technology. The charterers have started prioritizing environment friendly equipment which creates a demand for better documentation. Most of the information needed for such documentation is already stored in the SBSD model and can be presented in report form.

Stability check

As the service purpose of Offshore Vessels often make it challenging to calculate the stability, it will be difficult to do a qualified stability check this early in the process. Many Offshore Vessels are today affected by the SPS code which puts high demands on stability calculations. While a quick check for center of gravity and center of buoyancy could give a sanity check, this would probably quickly be discovered by the designer or sales man based on experience anyway with a glance of the main dimensions or the 3D sketch.

Design summary

While the software would be able to compare the new vessel to former designs by graphs and factors, a link with 3D software like Google Sketchup would give the designer and especially the client hands on experience.

Based on the information stated in the previous steps, some experience data from similar vessels and templates for how these vessels can be designed; several different configurations of the vessel can be generated.

Configuration alternatives

The figure below shows three variations of the same ship; the volume of each component is the same in all three variants. The one in the back has same main dimensions as the center one, but with a different configuration of the placing of modules. For an AHTS which is described, the idea of having the winch in front of the accommodation is not viable. The winch needs free access to the sea surface, and the stability would not be good enough to handle the chain over the side of the vessel. This would easily be concluded by an experienced designer when he sees the 3D-model.

The two variations in center and forward to the right have the same configuration of modules, but with different breadth, and thereby also length so that the volume is constant. With a glance of the 3D-model an experienced ship designer would see that shortest one looks a bit “chubby” while the center one seems to have a reasonable length/breadth ratio. The designer is then using his tacit knowledge and gut feeling to determine which solution that would be the best guess.

While it is quick for the designer to choose which solution he believes in, this can be limiting the creative process as he might not consider other alternatives that those that are proposed. However, for routine designs that normally have little innovation to limit risk and workload, the proposed configurations can be an efficient way of finding viable solutions.

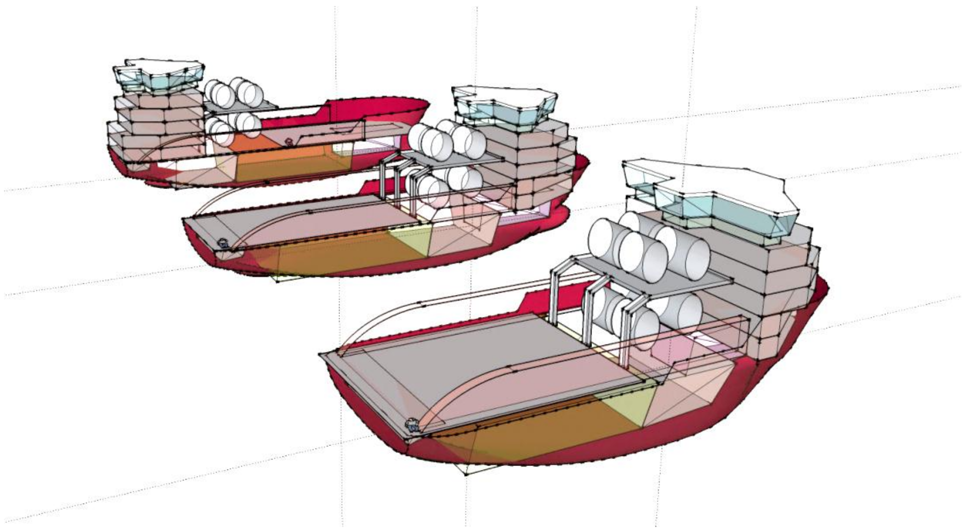

Figure 24: Three different configurations of the same volumes and functions

Selection of basis vessel

With an extensive database of former successful designs, there is a large potential of finding well suited basis vessels for new projects. As illustrated in the paragraphs above there can be derived much information about a new build when the requirements are added through the GUI.

Search

Thus the software has premises for finding well suited basis vessels as different designs can be compared on many parameters.

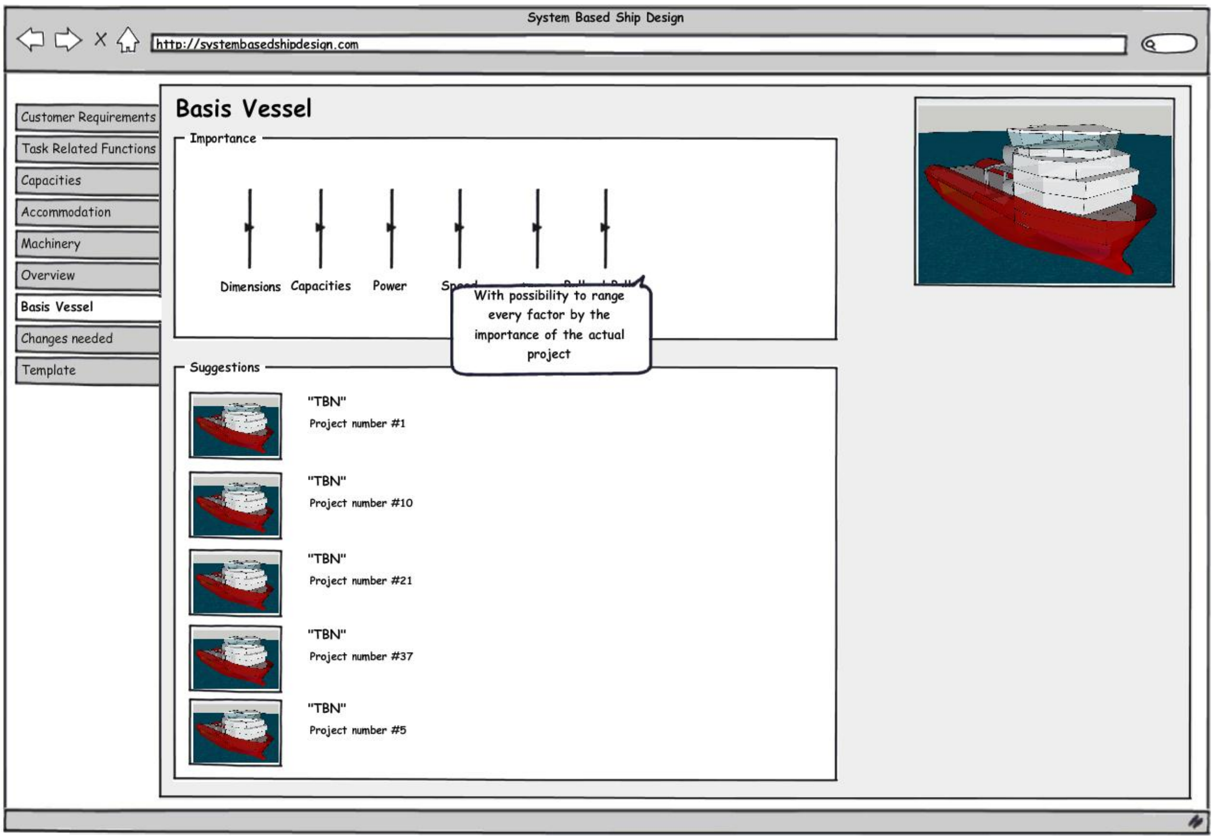

Figure 25: GUI for basis vessel selection

The search algorithm for basis ships can also include prioritizing based on the importance of parameters, modified by the designer. Thus the designer can utilize what he know about the vessel and rate less important and unsure parameters lower and thereby get more well suited results.

Selection

The prioritizing function should also be learning, thus it could give better ranging of search results the more it is used. It is not obvious which factors that are the most important to compare when choosing basis vessel.

The reason it is so difficult is that the influences later in the process is hard to predict. An example can be the length/breadth scaling. It is easy to add a few frames in the middle of the vessel making the vessel longer without changing anything else. Then there are just a few drawings that need to be updated. On the other hand, changing the breadth of the vessel will influence nearly all drawings, and be a much bigger task both in the initial design and later.

Benefits

Solving the General Arrangement is commonly a converging process. The basis vessel is often made larger to add space for the added requirements and commonly through the process made smaller again when the designer realize that there is space enough already.

With all designs of potential basis ships stored in a database with defined space demands that is accurate when compared to the General Arrangement, the task of solving a new arrangement can be minimized. The software knows the demand of space in the basis vessel and in the new build. Presenting this information to the designer, he would quickly know what to change and how much larger or smaller the vessel could be and still have the space required. The software could actually propose what changes that should be done to quickly and efficiently solve the new vessel.

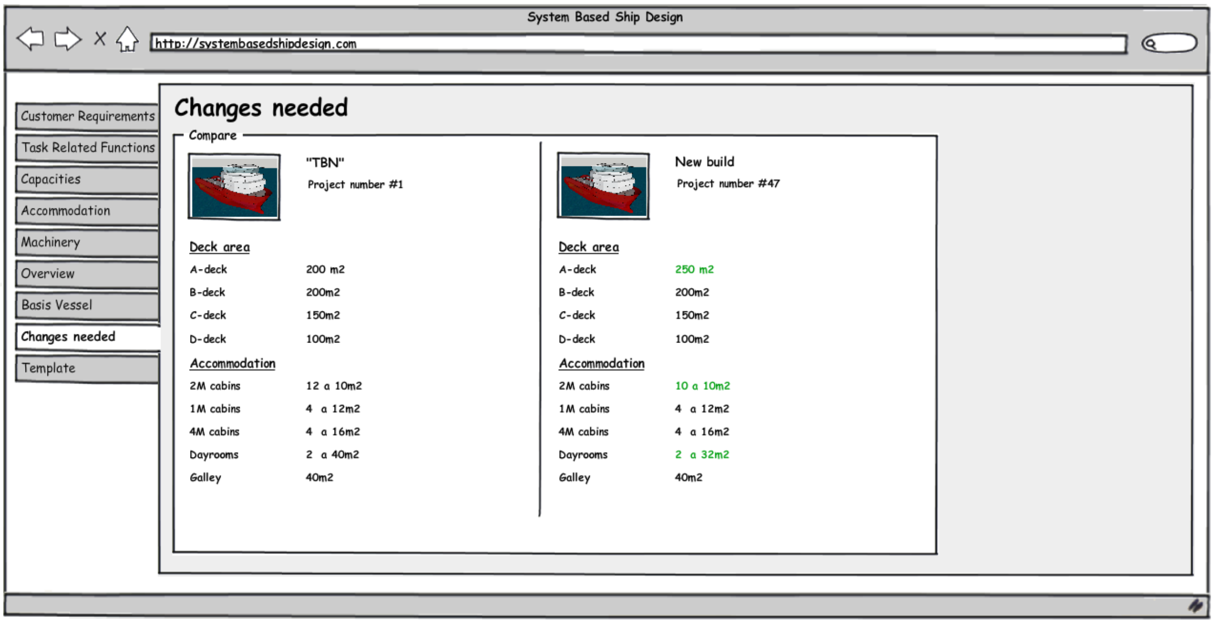

Figure 26: GUI for overview of changes needed

Adjusting configuration

While the templates can illustrate the vessel with standard configurations, to support the flexibility of the approach the designer should be able to change the configuration and optimize it for the requirement specification.

As the template is built within the calculating software and not the 3D-software, the template can utilize the logics and inputs by the user. The GUI described underneath could give the designer the opportunity to override the template and give directions for how the vessel should be configured.

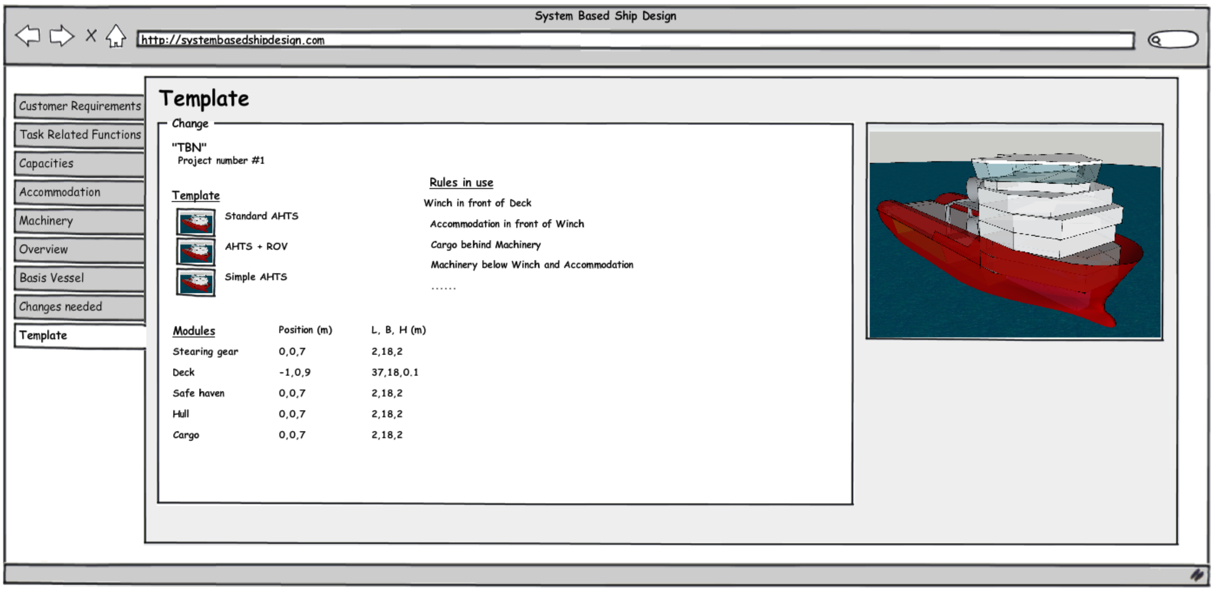

Figure 27: GUI for adjusting templates

With live updating screen shots from the 3D-model the designer can monitor how the changes affect the vessel. Probably would the order of selection of basis vessel and configuration of template be simultaneous or iterating. The optimal basis vessel is dependent on the configuration chosen, and the configuration would need to be adjusted after words anyway.

Optimally, the software would be able to log changing positions in the 3D software so that stability calculations can be done in the SBSD software while positioning is done in well suited 3D software. This shall be possible using the Google Sketchup API for listening to the model behavior.

The mockup is not specifying which platform or framework the application should be made on, and there are several possible alternatives. To be sure not to limit the opportunities new technology would be preferable, using platforms such as Web 2.0 or Adobe Air which can be interconnected with third party online software.

The mockup describes how standalone software for the SBSD approach could be looking. Compared to Excel of today the benefits of a standalone software package are especially the control of the calculations, the opportunity for many-many-relations and that the new software can be more "Forgiving" using experience data without losing control.

With a database structure in the back, changes can be logged, and parameters can be discussed in the software. This is nearly impossible to do in Excel without losing overview.

Forward opportunities and challenges

To quote Jo et al. (1993) which predicts about the future in design:

"*It is not difficult to predict that there will be an effective combination of human and artificial intelligence, with the human intelligence creating a design and the artificial intelligence analyzing every designing phase and suggesting the possible improvements based on previously constructed knowledge base.*"

In 2011, 18 years after the citation above, decision support tools within design still have a substantial way to go. As early as 1965 Mann and Coons described what was needed if the computer should be useful in creative processes.

"*It is clear that what is needed, if the computer is to be greater use in the creative process, is a more intimate and continuous interchange between man and machine. This interchange must be of such nature that all forms of thought that are congenial to man, whether verbal, symbolic, numerical, or even graphical, are also understood by the machine and are acted upon by the machine in ways that are appropriate to man's purpose*" (Mann and Coons, 1965)

Major challenges for the SBSD approach

For the SBSD approach to work in a real life setting at a design office for Offshore Vessels, the Prerequisites for the SBSD approach have to be met. These are important because failing to meeting them would make the designer feel overridden by a system he can't control. Then the system would quickly lose its value for the designer.

Secondly, there must be a well-functioning system for gathering design data from new projects; at least internal projects, but preferably also competing designs.

If the database is used as the main source of information about a project, the following choice only concerns the measurement of spaces; however before the SBSD approach is the center of knowledge about the projects at hand in the design office one choice has to be taken: Shall every pre-contracted project be added to the statistical database?

There are clear benefits by adding every project to the database as the SBSD approach then can be used in initial design to find former initial projects. It is often used lots of resources on projects at initial design which are not sold and built. These projects are valid both for comparison and basis vessel even though there isn't done any detail engineering yet.

The problem by adding every initial design to the statistical database is twofold. At the initial design department at a design office for Offshore Vessels, there are lots of projects going on concurrently. It will be hard to demand that the designers should use their time adding design specifications to a statistical database. But the most important question for these projects is: When would a project be included in the database? The nature of a project at initial design is that it is changing with large fluctuations. Should the data be updated with every change? The project can even be on hold for years waiting for financing or market situation. Especially the job of measuring spaces for the statistics would be a challenge.

The other solution is to only add contracted vessels as they are finalized. This would give a lag in the database for at least a year or two, in addition to exclude all initial designs that the design office loses. When times are bad, and few vessels are built, this would affect the statistics badly. There is also a question of whom that would measure and add the design specifics to the database. As the SBSD approach is a tool for initial design, the detail engineering department probably feels little benefit from using their time measuring old projects.

Further development of the proposed 3D-sketching

In this paper the Google Sketchup API has been utilized to build the 3D-model. It has shown to be quite powerful and suited for the task. As mentioned earlier the import plugin currently includes predefined models, scale and position them in x-y-z.

For forward development of the importer, the commercial version of Google Sketchup would be recommended. The commercial version includes:

- Dynamic Components: Google Sketchup opens for different ways of scaling. For instance is it possible to make a stairs-component that adds additional steps when scaling instead of making the steps higher. This can be utilized in most models making the vessel more realistic. For instance could the winch rolls be constrained circles while scaling.
- Trim: Components can be trimmed against each other. For instance could the operation deck be trimmed against the hull.

The scaling of models are currently just an estimation, and not exact as they are scaled based on length, breadth, height, and area of the original model. It is exact for cubes, but when the models are shaped, which they mostly are, the scaling becomes inaccurate.

It should also be possible to extract information of the position of modules in Google Sketchup through the API. This information could be fed back into Excel for stability calculations. The modules could then be moved around in the 3D sketch and the template and stability calculations could be updated on the go. There are some challenges around the mapping of modules in Excel that need to be solved first: Each volume in the spreadsheet would need to be a module in the 3D software to make the stability calculation accurate.

Decision support tool for specification development

In parallel to the sketching and calculations for the new build, a specification needs to be developed. This document is normally quite a task to establish, and summarizes lots of data from the design process. Much of these data is already explicit defined in the SBSD-methodology, and there are synergies if the numbers in the specification could be automatically updated, controlled by the designer.

Automatic data mining from web sources

By using web sources like Skipsrevyen (mostly for vessels with a Norwegian connection) and DNV a quite good overview of the offshore vessels can be established. This data can make a good background for the statistics in the SBSD-methodology and can also be used to easy compare the new build against her competitors.

The data is not always structurally organized so the data mining needs to be built smart and probably manually controlled before it is added to the database.

Common format for requirement specifications

Today requirement specifications typically are written in Microsoft Word or similar text management software. Then it is exported as PDF and sent to the recipients.

If they rather used a common format, for instance based on XML, for their requirement specifications the requirements could be imported directly in the SBSD software. Imagining, it can also be possible to make special software to generate requirement specifications that works along the same lines as the SBSD approach.

Conclusions

This Master Thesis started off trying to find how a simplified SBSD approach could support the designer and sales person in the initial sales and design process to quickly sketch a vessel in 3D.

Most decisions affecting the life cycle cost of a vessel is decided in the initial design phase (Gatenby and Foo, 1990). The communication with the client is important, and by letting the client see the influences of their requirements at an early stage, they might change them while the switching cost is low.

Through automatic 3D-generation based on simple input and experience from the SBSD approach the designer and the client could easily get a sketch for discussion. Even though the prototype for 3D generation works as it is, there are a lot to do before it will be a product that can offer substantial value in the design process. For the initial sales process, the interviewee saw limited value in such a tool, besides the “wow” effect.

The simplified version of SBSD described through the mockup can be a valuable tool to search for basis vessels, and quickly compare the new build with former successful projects. It can be discussed if the extended SBSD approach might be too extensive for this matter, and whether the SBSD approach would work in a real life setting.

The systematic way of structuring information would nevertheless enhance the acquisition of design knowledge. Human capital is important and a scarce resource for design offices. By building software that can support the designer in his daily work enabling him to become more creative and efficient would directly affect the bottom line of the company.

The SBSD approach support short loops in the initial design phase before any drawing is made, making the loops efficient and without limiting creativity. While this Master Thesis has handled the initial design process, it should be emphasized that the process of ship design should be seen as an integrated process from the sketching stage until the ship is delivered. The sketching preferences of the SBSD approach can in this sense make the software extra valuable. The approach supports the design process from the vague sketching start and forward until every detail is set later in the process and can be an efficient decision support tool for the designer through the different stages. Thus it fulfills all three requirements for a sketching tool introduced by Buxton (2006) and Gross (2006).

Even though there are some enhancements that need to be done in addition to the actual development of the software, there is a potential of building a well working decision support tool based on the SBSD approach. Such a tool could be very useful within initial design and has the potential of making the design process more efficient, without locking the creativity of the designer.

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Appendix

A: List of Figures

B: Problem description

Background

Most initial ship designs are developed through a tender by a ship owner or agent, and are on average initially solved by consultants within a three weeks cycle.

The Evans spiral model expresses an iterative method of ship design, but does to little extent cover the initial choice of comparison vessel. It is not an efficient tool to establish main dimensions.

The short cycled projects are heavily based on comparison ships from the archives of the ship design consultant. The comparison ship is usually found by experience of the consultant and adjusted to fit for a new purpose.

Overall aim and focus

The overall aim and focus of the project is to suggest how a System Based Ship Design approach may support an efficient and innovative ship design process.

Scope and main activities

The candidate should presumably cover the following main points:

1. *Provide a brief summary of design methods and innovation theory, both basic principles and available frameworks with special attention to the System Based Design approach.*
    a. *Ship design theory with most attention to Evans, Andrews, Mistree and Levander*
    b. *Innovation theory and theory within acquisition of design knowledge*
    c. *Discuss briefly the theory presented*
2. *Discuss and suggest how the SBSD approach would support the end users need for Control and Flexibility.*
3. *Develop a case study of the initial sales process of a new build discussing*
    a. *How the method should look like as a software to support innovation and efficient ship design (By making a mockup of the GUI)*
    b. *How automatic 3D-sketching of the vessel would support the sales process (By use of Excel and Google Sketchup)*
    c. *How these tools would support the discussion ensuring that the early assumptions between the sales person and client are correct*
4. *Optional opportunities for further development if time:*
    a. *Decision support tool for specification development*
    b. *Practical use of the SBSD approach in the design process*
    c. *Automatic data mining from the web gathering experience data*
5. *Discuss, conclude, and propose a forward plan for the development of the methodology.*

C: Definitions

AHTS: Anchor Handling Tug Supply Vessel. Used to move and maintain anchors at Offshore Installations. Has a big winch and high Bollard Pull.

Bollard Pull: The amount of force the vessel is able to transfer to a chain behind the vessel at zero speed.

Deadweight: The weight of the cargo, ship consumables and persons

Displacement: The volume or weight of the liquid displaced by the hull. Displacement = deadweight + lightweight.

General Arrangement (GA): The main drawing describing the space allocation in the vessel. Commonly the first drawing drawn.

Lightweight: The weight of the ship itself.

OCV: Offshore Construction Vessel. Vessels that install equipment at the seabed and performing services offshore. Has often a big crane and ROV.

PSV: Platform Supply Vessel. Service vessels for the offshore installations. Used to transport commodities to installations and waste back to shore.

ROV: Remote Operated Vessel. Small submarines often with manipulators for inspection and maintenance of equipment at the seabed.

SBSD: System Based Ship Design

SPS-code: "Special Purpose Ships" is an IMO regulation setting high requirements for stability calculations.

STX: A company designing and building ships.

STX OSV: The design office of Offshore Vessels within STX.

X-Bow: A concept with a new volume distribution in the forebody of a vessel.

D: Input file for 3D generation

As shown below, the input file is built up with a module on each row, and values split by whitespace. From the left, the numbers mean:

Position x: The x-position of the local origin of the module imported. The x-axis is laid along the length of the vessel. The local origin is consequently positioned in the back of the module. The global origin of the vessel is at the aft perpendicular.

Position y: The y-axis goes along the breadth of the vessel, with origin in the aft perpendicular and center of the breadth.

Position z: The z-position has origin at the keel and the axis goes along the height of the vessel.

Scaling x: Scaling factor for the length of modules. Each module has a length, breadth and height described in the Excel document in which the scaling factor is calculated by.

Scaling y: Scaling factor for the breadth of modules.

Scaling z: Scaling factor for the height of modules.

Module: File name of the module. Each module is stored as an independent 3D-model in a folder on the hard drive.

File Edit Format View Help

```
0       0       0     1,27    2,2   1,18  hull2
-4      0       9,5   4,36    1,9   1     deck
39,6    0       9,5   1,08    0,88  1     winch
42,3    0       1,5   1,06    0,99  0,93  machinery
9,23    0       1,5   1,65    0,99  0,93  cargo
-4      -10,25  9,5   1,6325  0,3   0,90  cargorail
-4      10,25   9,5   1,6325  0,3   0,90  cargorail
55,46   9,5     14,5  0,58    0,3   0,6   box
-2,26   0       6,5   0,29    0,88  0,37  machinery
58,58   0       3,5   1,90    0,40  0,75  acc1
61,3    0       9,5   1,05    1,1   1     acc2
61,3    0       12,5  1,05    1,1   1     acc2
61,3    -1      15,5  1,25    1     1     acc3
61,3    0       18,5  1,25    1,1   1     acc3
61,3    0       21,5  1,08    1,1   1     acc3
57,11   0       24,5  1,04    1,04  1,06  instruments
56,11   0       26,1  1,04    1,04  1     wheelhouse
```

Figure 28: Input file

E: Module scaling and positioning plugin for Google Sketchup

This plugin for Google Sketchup grabs the data from the input file and use it to position and scale predefined modules.

```ruby
require 'sketchup.rb'
# for debugging, remove #
# Sketchup.send_action "showRubyPanel:"
# Add a menu item to launch our plugin.
UI.menu("PlugIns").add_item("Build modules") {
  # Call our new method.
  draw_geometry
  view = Sketchup.active_model.active_view
  new_view = view.zoom_extents
}
def draw_geometry
  # Convert factor for mm per inch.
  mmperinch = 0.0254

  # Get handles to our model and the Entities collection it contains.
  model = Sketchup.active_model
  entities = model.entities

  # Clear the workspace
  entities.clear!

  File.open("C:/SBSD/input.txt") do |file|
    while content = file.gets
        # This line ensures that dots are used for decimals
        content.gsub!(',','.')
        parts = content.split
        filename = parts[6]

        posx = (parts[0].to_f/mmperinch)
        posy = (parts[1].to_f/mmperinch)
        posz = (parts[2].to_f/mmperinch)
        scalex = parts[3].to_f
        scaley = parts[4].to_f
        scalez = parts[5].to_f

        parts_def = Sketchup.active_model.definitions.load("C:/SBSD/modules/#{filename}.skp")
        parts_location = Geom::Point3d.new posx,posy,posz
        transform = Geom::Transformation.new parts_location
        entities = Sketchup.active_model.active_entities
        instance = entities.add_instance parts_def, transform

        t = Geom::Transformation.scaling parts_location, scalex, scaley, scalez
        status = instance.transform! t
    end
  end
end
```

Figure 29: RUBY script for scaling and positioning of modules

F: Catching plugin for Google Sketchup

The catching plugin loads the JavaScript and catch the JavaScript calls forwarding them by calling "draw_geometry" if the input file has changed for the last second. In addition the plugin zoom extents and grab a render of the current model that can be used for instance in the SBSD software without the need of having Google Sketchup in focus.

```
# Create the WebDialog instance
my_dialog = UI::WebDialog.new("Trig", false, "Trig", 200, 200, 200, 200, true)

# Attach an action callback
my_dialog.add_action_callback("get_data") do |web_dialog,action_name|

    # If the input file has been modified during the last 2 seconds
    if (Time.now.to_i - 2) < File::mtime( "C:/SBSD/input.txt" ).to_i

        # If the action called is "draw_geometry"
        if action_name=="draw_geometry"

            draw_geometry

            # Zooming extents to view the whole model
            view = Sketchup.active_model.active_view
              new_view = view.zoom_extents

            # Rendering a image of the model that can be imported into Excel
             keys = {
               :filename => "c:/SBSD/render.png",
               :width => 640,
               :height => 480,
               :antialias => false,
               :compression => 0.9,
               :transparent => true
             }
             model = Sketchup.active_model
             view = model.active_view
             view.write_image keys

        end
    end
end

# Find and show our html file
html_path = Sketchup.find_support_file "javascript.html" ,"Plugins"
my_dialog.set_file(html_path)
my_dialog.show()
```

Figure 30: Trigging plugin for Google Sketchup

G: JavaScript for automatic updating

The JavaScript is opened from the Sketchup plugin and calls the Ruby catcher every half second.

```
<html>
<script>
function callRuby(actionName) {
    query = 'skp:get_data@' + actionName;
    window.location.href = query;
}
setInterval ( "callRuby('draw_geometry')", 500 );
</script>

<body>
<input type="button" onclick="callRuby('draw_geometry')" value="Build">
</body>
</html>
```

Figure 31: JavaScript for automatic updating of 3D model

H: VBA scripts in Excel

Export to input file

This script is based on a standard script for exporting data to text files. It exports all data in in the range called "OUTPUT" to the file "input.txt" in the format described in Appendix D: Input file for 3D generation.

```
Sub DoTheExport()
    ExportToTextFile FName:="C:\SBSD\input.txt", Sep:="  ", _
       SelectionOnly:=True, AppendData:=False

    ImportPictureAtSize
End Sub

Public Sub ExportToTextFile(FName As String, _
    Sep As String, SelectionOnly As Boolean, _
    AppendData As Boolean)
Dim WholeLine As String
Dim FNum As Integer
Dim RowNdx As Long
Dim ColNdx As Integer
Dim StartRow As Long
Dim EndRow As Long
Dim StartCol As Integer
Dim EndCol As Integer
Dim CellValue As String
Application.ScreenUpdating = False
On Error GoTo EndMacro:
FNum = FreeFile
    With ActiveSheet.Range("OUTPUT")
        StartRow = .Cells(1).Row
        StartCol = .Cells(1).Column
        EndRow = .Cells(.Cells.Count).Row
        EndCol = .Cells(.Cells.Count).Column
    End With
If AppendData = True Then
    Open FName For Append Access Write As #FNum
Else
    Open FName For Output Access Write As #FNum
End If
For RowNdx = StartRow To EndRow
    WholeLine = ""
    For ColNdx = StartCol To EndCol
        If Cells(RowNdx, ColNdx).Value = "" Then
            CellValue = Chr(34) & Chr(34)
        Else
           CellValue = Cells(RowNdx, ColNdx).Value
        End If
        WholeLine = WholeLine & CellValue & Sep
    Next ColNdx
    WholeLine = Left(WholeLine, Len(WholeLine) - Len(Sep))
    Print #FNum, WholeLine
Next RowNdx
EndMacro:
On Error GoTo 0
Application.ScreenUpdating = True
Close #FNum

End Sub
```

Figure 32: Export script

Render import script

This VBA script is called by the export script and make Excel wait for a couple of seconds and then try to import a rendered 3D model.

```
Public Sub ImportPictureAtSize()

Dim DrObj
Dim Pict
Set DrObj = ActiveSheet.DrawingObjects
For Each Pict In DrObj
If Left(Pict.Name, 7) = "Picture" Then
Pict.Select
Pict.Delete
End If
Next

Application.Wait Now + TimeValue("00:00:05")

  With ActiveSheet.Pictures.Insert("C:\SBSD\render.png")
    .Left = Range("i1").Left
    .Top = Range("a1").Top
  End With
End Sub
```

Trig at change

This little snippet get Excel to call the exporter when a value is changed in the spreadsheet.

```
Private Sub Worksheet_Change(ByVal Target As Range)
 Call DoTheExport
End Sub
```

I: Screenshots of prototype

View 1: Input in Excel

Project: SHIP-4C OSV
Name: AH 11

CARGO CAPACITY

EQUIPMENT WEIGHT (Included in Lightweight)

DRY CARGO SPACES Name / Use of Deck:	Capacity ton	Average Deck Load ton/m²	Add-on %	Height m	Area m²	Volume m³
Open Cargo Deck	1750	2,5	5 %	0,00	735	0
Covered Cargo Deck	0	2,0	5 %	3,00	0	0
Cargo Hold	0	2,0	5 %	3,00	0	0
	0	2,0			0	0
	0	2,0			0	0
Total Deck Cargo	1750 ton				735	0

Equipment Make / Type	Area weight ton/m²	Weight ton
Wood cover	0,1	74
	0,0	0
	0,0	0
	0,0	0
	0,0	0
		74

LIQUID AND DRY BULK CARGO SPACES Name / Use of Deck:	Capacity m³	Density ton/m³	Add-on %	Height m	Area m²	Volume m³
Fuel Oil	500	0,85	10 %	10,00	55	550
Potable Water	500	1,00	10 %	0,00	0	550
Drill Water (in BW tanks)	3 000	1,00	-100 %	0,00	0	0
Oil Based Mud					0	0
Base Oil					0	0
Brine					0	0
Dry Bulk					0	0
					0	0
					0	0
Total Bulk Cargo	4000 m³				55	1100

For tanks in double hull or double bottom height=0

Equipment Make / Type	Capacity weight ton/m³	Weight ton
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
		0

CARGO HANDLING AND RELATED SPACES Name / Use of Space:	No of Units	Average Space Demand/Unit Length m	Breadth m	Height m	Area m²	Volume m³
Cargo crane	1	1,0	1,0	2,90	1	3
Transfer pumps and piping	3	3,0	2,0	4,00	18	72
					0	0
					0	0
					0	0
					0	0
					0	0
Cargo deck side coamings	2	40,0	2,0	3,1	160	496
Cargo Handling					179	571

Equipment Make / Type	Unit weight ton	Weight ton
Knuckle boom type	15,0	15
Pumps and piping	10,0	30
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
	0,0	0
		45

TOTAL CARGO SPACES	970	1670	TOTAL PSV EQUIPMENT	120

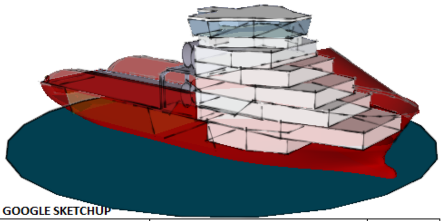
Cargo Spaces / Anchorhandling & Towing / Offshore Construction / Fire Fighting & Rescue / Crew and Client / Service

View 2: Adjust template

Update picture

Export data

VARIABLES			
Breadth	22	m	B_hull
Depth to main deck	9,5	m	D
Deck height	2,7	m	
Double bottom	1,50	m	
Cargo rail width	1,5	m	
Double hull	1	m	
Height of cargorail	5	m	
Number of decks of accommodatio	5		
Main deck structure	0,5	m	
Height of instruments	1,6	m	



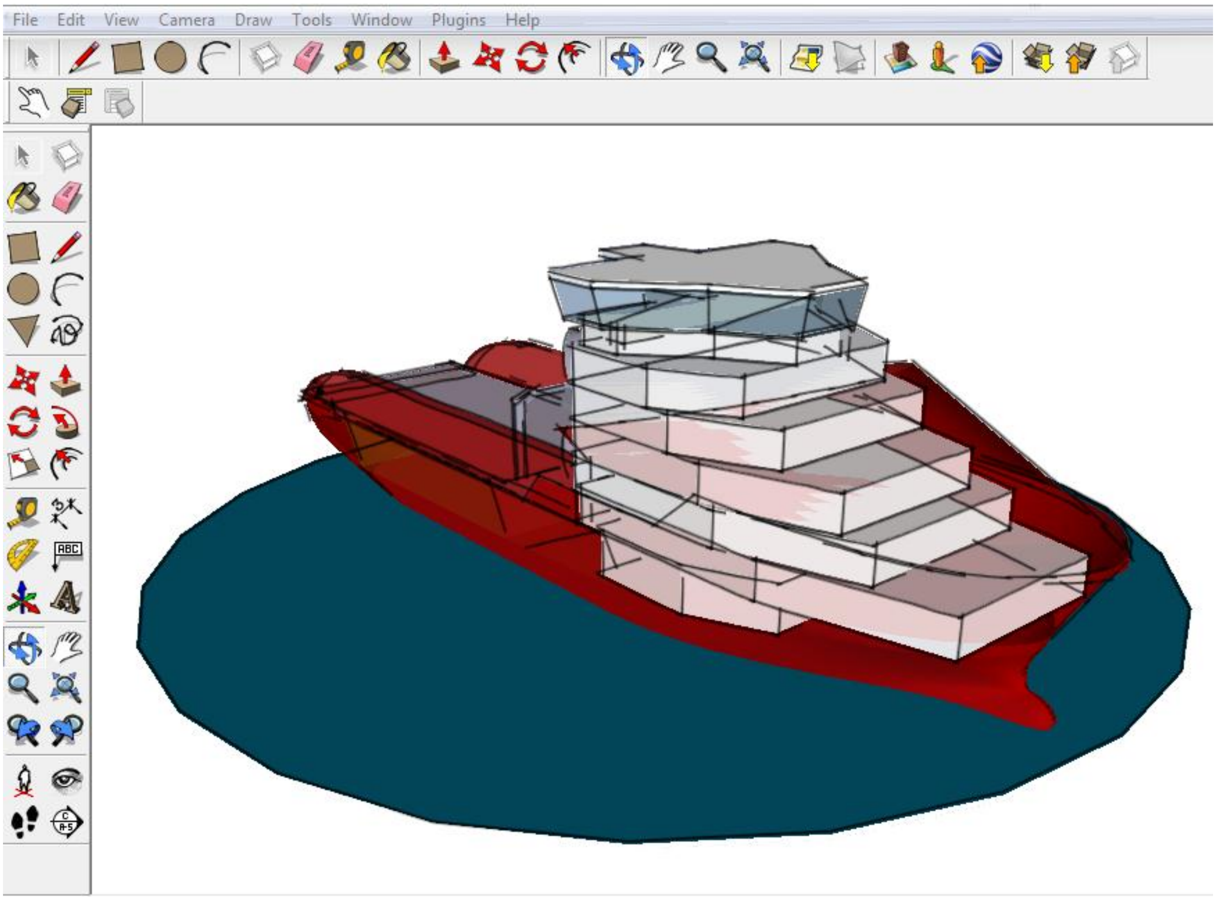
HARD CODED TEMPLATE FOR ANCHOR HANDLER

	area needed		volume	Length	Breadth	Height
Ocean						
STX-bow				38,2	22	8,7
Hull		height		89,0		
Deck	735	0,1	73,5	38,7	19,0	0,1
Winch			2 614	12,1	16,0	13,5
Machinery			2 400	16,2	19,8	7,5
Cargo			4000	26,9	19,8	7,5
Cargo rail				50,8	1,5	5,0
Cargo rail				50,8	1,5	5,0
MOB				8,0	3,0	6,0
Steering gear			154	3,2	17,6	2,7
Accommodation Below	311			16,6	20,0	4,1
Accommodation 1st	670			34,1	21,0	3,0
Accommodation A	565			27,4	22,0	2,9
Accommodation B	464			24,8	20,0	2,9
Accommodation C	392			19,0	22,0	2,9
Accommodation D	312			15,2	22,0	2,9
Instruments	280			20,1	19,8	2,0
Wheelhouse	280			22,1	22,0	3,1

OUTPUT TO GOOGLE SKETCHUP

Position			Scale			
x	y	z	x	y	z	module
44,48653349	0	3,166666667	0,177946134	0,177946134	1	ocean
48,15603353	0	15,3	1,909257637	2,2	0,725	stxbow
0	0	0	1,3	2,2	1,1875	hull2
-4	0	9,5	3,868421053	1,9	1	deck
34,7	0	9,5	0,605185185	1,066666667	0,9	winch
32,6552543	0	1,5	1,063264221	0,99	0,9375	machinery
5,7	0	1,5	1,346801347	0,99	0,9375	cargo
-4	-10,25	9,5	1,269697856	0,3	0,909090909	cargorail
-4	10,25	9,5	1,269697856	0,3	0,909090909	cargorail
38,8	9,5	14,5	0,8	0,3	0,6	box
-1,6	0	6,8	0,212652844	0,88	0,3375	machinery
48,8	0	5,4	1,188335021	1	1,366666667	acc3
46,8	0	9,5	2,435478008	1,05	1	acc3
46,8	0	12,4	1,960444136	1,1	0,966666667	acc3
46,8	-1	15,3	1,770992366	1	0,966666667	acc3
46,8	0	18,2	1,360166551	1,1	0,966666667	acc3
46,8	0	21,1	1,082581541	1,1	0,966666667	acc3
41,78817776	0	24,0	1,139658011	1,047619048	1,333333333	instruments
40,78817776	0	26,0	1,127733026	1,047619048	1,033333333	wheelhouse

View 3: 3D-model



J: Master Contract

NTNU
Det skapende universitet

MASTERKONTRAKT
- uttak av masteroppgave

1. Studentens personalia

Etternavn, fornavn **Vestbøstad, Øyvind**	Fødselsdato **27. sep 1986**
E-post **oyvind.vestbostad@gmail.com**	Telefon **97069425**

2. Studieopplysninger

Fakultet **Fakultet for Samfunnsvitenskap og teknologiledelse**
Institutt **Institutt for industriell økonomi og teknologiledelse**
Studieprogram **NTNUs Entreprenørskole**

3. Masteroppgave

Oppstartsdato **20. jan 2011**	Innleveringsfrist **16. jun 2011**
Oppgavens (foreløpige) tittel **System Based Ship Design for Offshore Vessels**	
Oppgavetekst/Problembeskrivelse The overall aim and focus of the project is to suggest how a System Based Ship Design approach may support an efficient and innovative ship design process.	
Hovedveileder ved institutt **Førsteamanuensis Roger Sørheim**	Biveileder(e) ved institutt
Merknader **1 uke ekstra p.g.a påske.**	

4. Underskrift

Student: Jeg erklærer herved at jeg har satt meg inn i gjeldende bestemmelser for mastergradsstudiet og at jeg oppfyller kravene for adgang til å påbegynne oppgaven, herunder eventuelle praksiskrav.

Partene er gjort kjent med avtalens vilkår, samt kapitlene i studiehåndboken om generelle regler og aktuell studieplan for masterstudiet.

Trondheim 20.01.2011

Sted og dato

Øyvind Vestbøstad

Student

Hovedveileder

Originalen oppbevares på fakultetet. Kopi av avtalen sendes til instituttet og studenten.