



Industry Needs Report

Report: 01-EN



European Boat Design Innovation Group - Wind Farm Support Vessels (EBDIG-WFSV)

OVERVIEW: Recent research has indicated that current wind farm support vessels will not be appropriate for accessing far shore wind farms. In order to improve operability of WFSV accessing the far shore wind farms, mothership vessels will be required. Interior design principles applied to vessel accommodation will help to reduce the adverse effects of shift work, through creating a low stress appealing living environment. Human Factor Integration (well established in the defence sector) in the design of the bridge will reduce cognitive workload and hence reduce the risk of human error, the most significant cause of marine accidents.

DESCRIPTION; Extrapolating the European Wind Energy Association's (EWEA) growth scenario for the period up till 2030 employment in the installation, operation and maintenance, of offshore wind farms is expected to produce skilled employment of 851,400 and requires specialist marine vessels.

AIM: To provide innovative professional development training and networking to commercial marine industry employees (Naval Architects, project managers) by transferring embedded practices within interior design and the leisure marine industry (superyachts) which will enable the European commercial marine sector to understand and exploit growing design opportunities in the wind farm support vessel sector to produce more appealing working conditions for this new and growing sector to help recruit new staff and reduce the risk of human error.

OBJECTIVES: To use an e-learning platform www.ebdig.eu (video conference, moodle etc) to transfer innovation from the interior design and leisure marine industry to Wind Farm Support Vessels (WFSV Design; WFSV mothership design; Human Factors Integration (HFI) via 3 courses and a networking framework.

OUTCOMES:

1. Industry survey to understand operator needs and concerns
2. courses developed in Wind Farm Support Vessel design (Marine Design; WFSV Design; WFSV mothership design; Human Factors)
3. Industry pilot of online training material(each country)
4. Dissemination of a recommended methodology for the commercial boat industry design cycle

IMPACT: Greater understanding and awareness of the needs of the wind farm vessel industry in Germany, Netherlands, Sweden and UK, and the market potential for ship builders in Italy and Turkey. Better trained commercial marine industry staff who are more aware of emerging technologies and techniques. Leading to boat industry standardised qualifications in Wind Farm Support Vessel (WFSV Design; WFSV mothership design; Human Factors Integration (HFI)).

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Disclaimer

The authors gratefully acknowledge the grant support received to carry out the work presented in this paper as an integral part of the Leonardo TOI funded project EBDIG-WFSV, funded under the EU Lifelong Learning Programme, grant number: UK/13/LLP-LdV/TOI-621. The content of this publication is the sole responsibility of the authors, the European Commission is not liable for any use that may be made of the information. While the information contained in the documents is believed to be accurate, the authors(s) or any other participant in the EBDIG-WFSV consortium make no warranty of any kind with regard to this material including, but not limited to the implied warranties of merchantability and fitness for a particular purpose.

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Advanced Human Factor (HF) Analysis

User Centred Design (UCD) is a sequenced problem solving process that requires marine designers to analyse and anticipate end user behaviour in working on a vessel or system, and to test the validity of these assumptions through ethnographic analysis of real users. Ethnographic analysis is necessary due to the challenge for marine designers to intuitively understand the experiences of a first-time user (crew member) of their vessel or system design. UCD answers questions about users, their tasks and goals, then uses the findings to inform the design process with specific user scenarios. A recent EBDIG-WFSV paper [1] reported on first reported ethnographic analysis carried out onboard a WFSV to evaluate current navigational practices and other command and control activities specific to WFSV, including technician transfer to the turbine. The ethnographic analysis informed an ergonomic analysis carried out using the Digital Human Modelling (DHM) software RAMSIS, which allowed the bridge displays to be evaluated in the virtual design space.

The Hierarchical Task Analysis (HTA) of the navigation of the WFSV was carried out by marine Human Factor researchers with qualified crew background. This offered unique user insights and has informed the objectives of the bridge layout anthropometric analysis using DHMs in RAMSIS, and the analysis of the readability of the display screens using RAMSIS Cognitive Toolbox. The aim of this ongoing project is to engage in the multidisciplinary approach of Marine Design in order to optimise the bridge layout and information displays of a WFSV, while minimising the design development costs. Achieved through the integration of Dynamic NAVigation (DYNAV) practices, to inform an optimised information architecture and decision system, and the implementation of DHM analysis using RAMSIS. DHM is a Transfer of Innovation from the automotive industry, where it has demonstrated a reduction in development costs of more than 50%, through a reduction in vehicle development timeframes by a factor of 3 to 5

In order to obtain a better understanding of what offshore operations consist of, and in particular wind farm service operations, a hierarchical task analysis was conducted on a vessel crew, participating in this type of operation, primarily transporting technicians and cargo to and from the wind farm. A hierarchical task analysis was chosen since it was expected to give timely results, and would not interfere with the operation. There is an intrinsic limitation with this method: cognitive processes and the level of mental workload needed in each step of the process are not directly part of the analysis. Thus effort was put to record these in a different manner, but linked to the hierarchical task analysis. A HTA method was chosen and performed as follows:

1. Define the purpose of the analyse
2. Collect data by interviews and observation
3. Determine top level goals
4. Divide top level goals in sub goals

5. Divide sub goals
6. Outline the how the goals are achieved in relation to each other.

The on-board visit/observations took place on a CTV with 3 crew members transporting 11 technicians to a wind farm, 50 nautical miles from the coast. The Hierarchical Task Analysis (HTA) is a result of the observations, recordings and interviews during its operations in the Wind farm that day. Mainly the observation took place from the bridge of the concerned vessel, covering navigation to field, different approached to different turbines/floatels and substation, a cargo operation at a sub stations was also observed. The approach to wind turbine is shown in Figure 1, the position of the camera illustrates the visual view of the master. Visual confirmation is leading for action and control of the vessels position in relation the boat landing. Important aspects here are wave heights and direction also strength and direction of the current is important when evaluating approach direction. Preparation for technician transfer is shown in Figure 2, where a crew member is assisting with the safety line, with the technician transfer shown in Figure 3. The layout of bridge forward console (Figure 4) is always in the line of sight of the captain when navigating between turbines. Figure 5 shows the captain manoeuvring the vessel against the turbine, his left hand operates the main propulsion and his right the rudder, the bow thrusters are seldom used. The top level task of the HTA identifies four main tasks the crew is engaged in at the bridge which are:

1. Navigation in restricted water inshore
2. Navigation in open water
3. Navigation the approach to installations
4. Manoeuvring close to physical objects

The requirement for all those four tasks must be met without compromising the ability to perform another. Without a structured methodology like UCD this might not be considered and thus the system as a whole sub optimized with increased risks of accidents as a natural consequence.



Figure 1: Approach to wind turbine



Figure 2: Preparation for technician transfer



Figure 3: Technician transfer

To be able to operate the vessel in a safe and efficient manner, the vessel and its support systems should be designed according to a user centred design approach. To be able to operate the vessel in marginal conditions, this design approach has a very important role to play. Limitations in design might limit the vessel crew in interacting with systems and controls, which affects decision making. The system should provide good overview, both to an individual and a group of operators, as dictated by the task/s being performed. There should be support for team work, information sharing and communication. This approach does not only affect the vessel but also the turbine itself. Therefore, to design a system that supports the user and the different tasks in an offshore environment is a very complex task. For example, the majority of the boat-landing points on the turbine pylons are designed to meet the highest wave heights, but the main factor that affects the vessels approach is actually the ocean current. Stated in the interview by the captain, the bridge design on this vessel is supportive in the task he is undertaken in these types of operations.

Overall it is essential that Human Systems Integration (HSI) was embedded within the WFSV design process. Examples of this HSI process for HSC have been described by Dobbins et al. [2] and were incorporated within the design process described in this report. Within the HTA navigation was highlighted as essential for mission success. Previously navigation errors during wind farm support vessel operations have been highlighted within incident reports by the UK Maritime Accident Investigation Branch (MAIB) [3]. Navigation

best practice, known as Dynamic NAVigation (DYNAV) for HSC operations [4] has been adopted by numerous organisations worldwide. Being a simple methodology it provides the crew with a resilient system for delivering both performance and safety. The four phases of methodology; Plan, Communicate, Execute and Control provide a shared mental model for the crew, and provides the interoperability capability for organisations tasked with crewing WFSVs. The phases are graphically illustrated in Figure 6.



Figure 4: Layout of bridge forward console



Figure 5: Captain manoeuvres vessel



Figure 6: The four phases of the DYNAV methodology

RAMSIS is based on a highly accurate DHM (Digital Human Model) that can simulate occupants with a large variety of body dimensions from global anthropometry databases. A probability-based posture prediction model was developed through research on driver postures and

comfort. The assessment of comfort allows designers to optimize packages with respect to driver comfort early in the design process. Analysis tools include: reach and vision; force-based posture and comfort prediction model. Applying a DHM to assess a design with respect to ergonomic criteria consists of three steps in general. First a test sample is defined and second task specific postures of this test sample are predicted within the design. Finally these postures are analysed taking several ergonomic criteria into account.

In order to address a wide range of operators, a corresponding test sample is specified. In general medium and boundary manikins are created from anthropometric databases with focus on specific body dimensions. In many applications the stature is of major interest and hence a female manikin of the 5th percentile stature as well a male manikins of 50th and 95th percentile stature are used. In the next step these manikins are automatically positioned into the design. The posture prediction method is based on experimental posture knowledge and a user defined task description. Based on the manikin anthropometrics and the design dimensions a corresponding task specific postures are automatically calculated (see Figure 7).

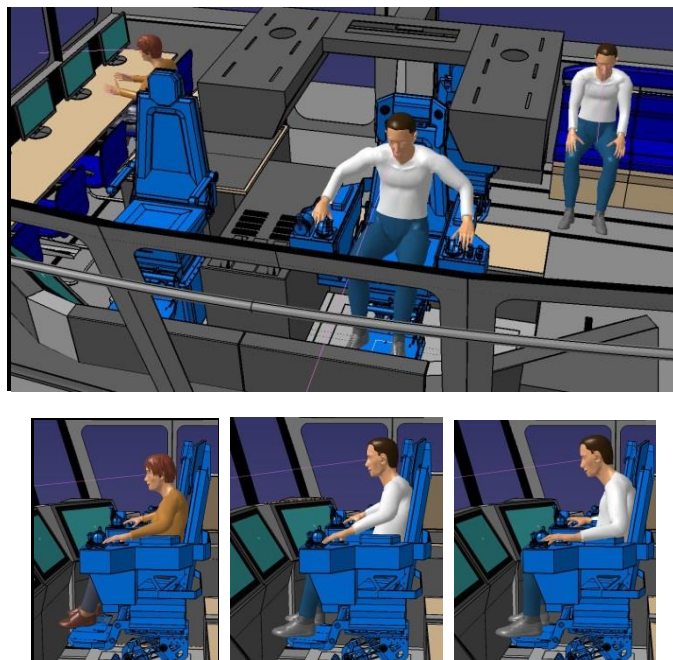


Figure 7: Task specific postures (e.g. operating with control balls and crew positions)

In a final step these postures are analyzed with respect to different ergonomic criteria like view, operating forces, comfort, reachability, perceptibility (see Figure 8).

The ergonomic analysis on the manikins gives feedback on the ergonomics of the design and helps the engineer to modify the design in order to get better ergonomic ratings. In the following subsections the ergonomic analysis are given in more detail. An initial analysis of the vision conditions for the operator is achieved through the manikin vision (see Figure 9). The designer looks at

the environment through the eyes of the simulated operator and can easily check view obstructions for different sizes of the operator (small female, tall male). Beside this qualitative analysis RAMSIS can predict different view areas like perception and gaze fields. They can be used to cluster the display areas for important and less important information devices (left image of Figure 8)



Figure 8: Ergonomic analysis on task specific postures (e.g. view, operating force)



Figure 9: Vision through eyes of the manikin in operation posture (left, middle, right display)

Another cluster method for display areas is to use vision shift time isochrones. Starting from the current operator's point of fixation the isochrones provides regions for vision shifts within the same required time (see Figure

10). Time critical displays should be placed within smaller isochrones. In designing and positioning optical displays in bridge configurations the optical display properties should be taken into account to ensure a decent perception from the operator's position.

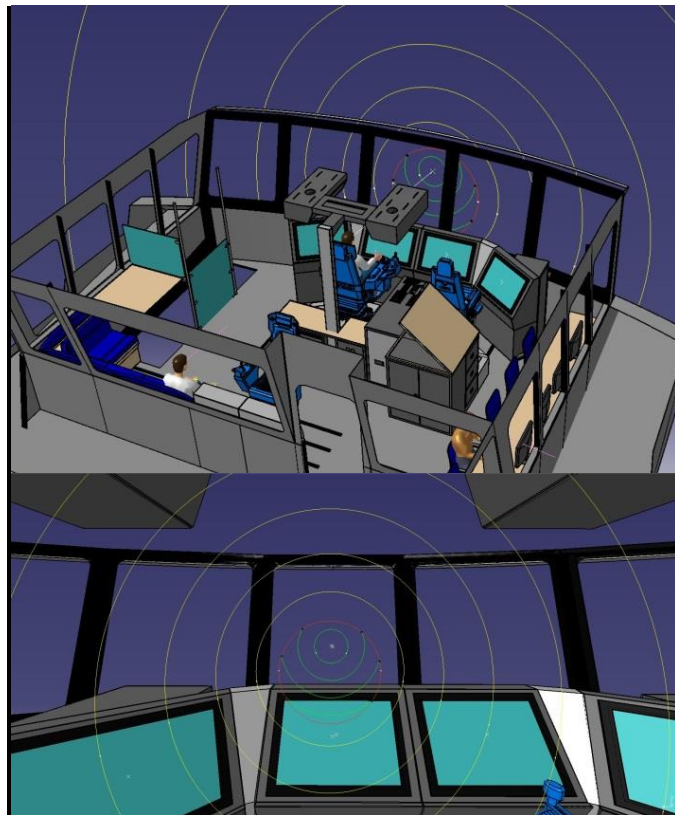


Figure 10: Vision shift time isochrones to cluster time critical display positions (Observer view upper, operator vision lower)

The ergonomics of displays are affected by the acuity of the display characters and symbols. This is depending on the visual capabilities of the operator, the size of the characters and symbols and on the distance between operator and display. The complete situation can be analyzed by RAMSIS through simulating the look on a specific character position of the display and generating corresponding test characters for different levels of recognition (minimum, optimal, recommended). These test sizes can be checked against the current display character sizes (Figure 11).

Building upon the design-driven field research model [5] the Marine Design approach utilises the Virtual Design Studio (VDS), a web based platform for file sharing and VOIP to minimise the cost of collaboration. Here the approach is to develop an optimised information architecture and decision system, through the use of 3D CAD systems and RAMSIS, informed by a dialogue between researchers and key stakeholders, based on the integration of Dynamic NAVigation (DYNNAV) practices. The resulting design proposals are then evaluated in a bridge simulator, with the best performing design uploaded to a WFSV bridge for field trials. The multidisciplinary team of researchers and stakeholders

includes: marine HF and HSC navigation consultancy (ST-Research); marine HF and HSC navigation researcher experts (Chalmers University); vessel operator (Mainprize Offshore); vessel interior and motion seat design and manufacture (KPM-Marine); vessel display system developer (Marine Automation Propulsion).

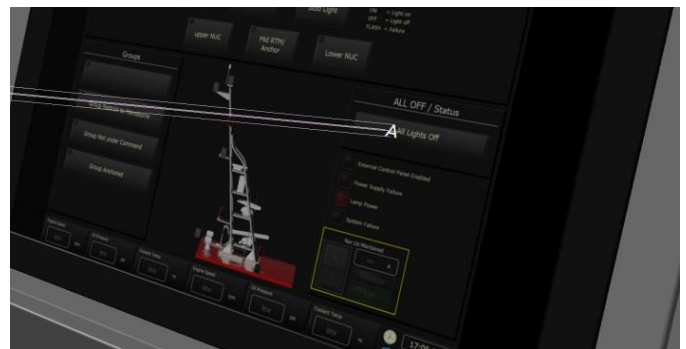


Figure 11: Simulation of look at display characters (upper) and comparison of recommended and current character and symbol sizes (lower)

The operation of a Wind Farm Support Vessel is a socio-technical system composed of people, equipment and organisational structures. Socio-technical systems regard organisations (in this case a vessel) as consisting of complex interactions between personnel and technology. This approach can also encompass the wider context to include the societal infrastructures and behaviours in the wider, shore-based management aspects of the organisation. These aspects are linked by functional processes (which are essential for transforming inputs into outputs) and social processes which are informal but which may serve to either facilitate or hinder the functional processes (McDonald, [6]).

In the Five 'M's system approach (Harris and Harris, [7]) WFSV navigation and crew transfer is not just about the integration of the crew (huMans) and ship (Machine) to undertake a particular voyage (or Mission) within the constraints imposed by the physical environment (Medium). It is also about the societal/cultural environment (a further aspect of the Medium). In shipping, the role of Management is crucial. The (hu)Man aspect of the five 'M's approach encompasses such issues as the size, personality, capabilities and training of the user, in this case the vessel's crewmembers. Taking a user-centred design approach, the crew are the ultimate design forcing function, as the design of the equipment and procedures on the vessel have to lie within the core abilities of the people involved. The (hu)Man and the Machine (ship) components come together to perform a Mission tasked by the Management. However, design solutions must not only work within the parameters (Human Factors) imposed by the crew, the ship's technology and the environment, and regulations governing the design, construction and operation of the ship and the wider norms of society. The owner's Management must also work within these rules. This prescribes performance standards through the selection and training of crew or the required technical performance of the ship. The Management is the key link between the (hu)Man, Machine, Mission and Medium. It plays the integrating role that ensures compliance with the regulations and promotes safe and efficient operations. The inter-relationships between the five 'M's are illustrated in Figure 12.

During the late 1990s the discipline of Human Systems Integration (HSI) began to appear, initially in military procurement programmes but subsequently in the oil and gas industries. HSI provides a through-life, integrative framework with the potential both to enhance safety and increase performance while reducing through life costs. HSI originally encompassed six domains [8]. These were Staffing (how many people are required to operate and maintain the system); Personnel (what are the aptitudes, experience and other human characteristics required to operate the system); Training (how can the requisite knowledge, skills and abilities to operate and maintain the system be developed and maintained); Human Factors Engineering (how can

human characteristics be integrated into system design to optimise performance within the human/machine system); Health Hazards (what are the short or long term hazards to health resulting from normal operation of the system) and System Safety (how can the safety risks which humans might cause when operating or maintaining the system be identified and eliminated, trapped or managed).

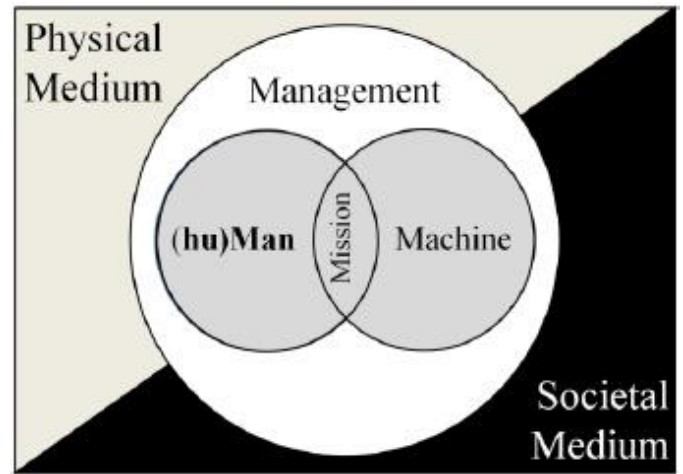


Figure 12: The Five 'M's Model [7]

Subsequently a seventh domain was added, the Organisational and Social domain, which encompasses issues such as culture, safety management, information sharing and interoperability. Taking a system-wide approach means that Human Factors can now 'add value'. Examples of this are already appearing in the military domain (Human Factors Integration Defence Technology Centre, [9]). For example, taking an end-to-end system perspective, good equipment design simplifies operating (and hence training) requirements, making training faster and cheaper (less time is spent in unproductive – not revenue producing – work). Training is better targeted to the operator's requirements and is more efficient. Simultaneously, better equipment design (e.g. interface design or design for maintainability) and better specified training produces superior, more error-free (safer) performance. Careful crew selection processes may be more expensive initially but they subsequently reduce the drop out and failure rate in training (also expensive). Analysis and modification of crew rostering practices can produce rotas which produce more efficient utilisation of crew, reduce fatigue, increase well-being and simultaneously enhance safety. Such efforts can also reduce stress and decrease employee turnover. At the same time a well-considered Human Factors aspect in a company's safety management system makes it cheaper to run and produces the information required to promote safer operations.

There is great potential for the application of virtual environment applications within the marine shipping industry as a design aid for subject matter experts to evaluate ship designs virtually prior to ship construction. Simulation-based prototyping has the potential to bring

attention to human factors and ergonomic concerns, highlighting the importance of integrating these issues into the design of the engine department. It also gives an opportunity to take into consideration technological developments and changes in work procedures. Employing human factors design considerations through simulation-based prototyping early in the ship design process can also facilitate constructive feedback from crew members and other stakeholders to ensure that the design of the ship meets and supports the needs of modern ships and its crew. Existing features of virtual environment technology can be exploited to include human factors into the design process and facilitate preliminary ship engine room design and evaluation. Such features include: accurate visualization, customization, flexibility, ease of use, realistic interaction and simple communication platform (Figure 13). [10]

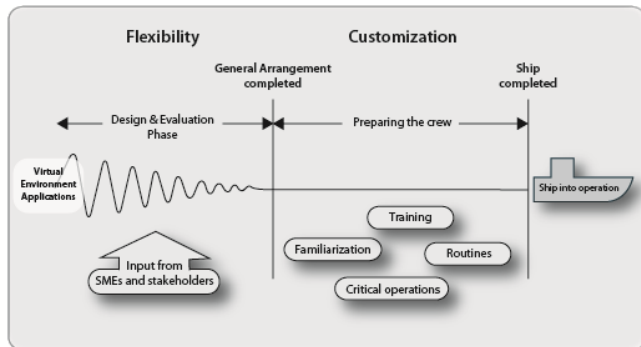


Figure 13: Features of virtual environment technology[10]

Human Factors approaches can significantly reduce through life design costs of vessel and systems. Ship design still focuses on technical solutions, neglecting human aspects associated with crewing and procedures until a very late phase in the design/engineering process. Manning issues are usually regarded as the responsibility of the end-user usually relating to accommodation and other associated facilities. In the maritime industry, incidents and accidents in the Maersk shipping company decreased by a third (from one major accident per 30 ship years in 1992, to one per 90 ship years in 1996) after the introduction of Bridge Resource Management (BRM) training. Furthermore, in 1998 insurance premiums were lowered by 15%. This reduction was directly attributed to the effects of enhances BRM and simulator training.[11]

Marine Design Methods and Techniques

Marine Design is an holistic design process with a strong focus on the end users as well as stakeholders in the design process, based on the principles of Industrial Design. In contrast to Industrial Design, Naval Architecture is about addressing a design specification. The most important part of the Marine Design (Industrial Design) process is reaching a well informed design specification. Effective Marine Design requires a multidisciplinary design team of Naval Architects, Industrial Designers, Human Factors specialists,

Environmental Psychologists and Interior Designers. The start of the marine Design process is understanding the personas and needs of the end user. The aim of Marine Design is to improve the aesthetics, human factors and functionality of a vessel or system, and its' marketability. The role of a Marine Designer is to create and execute design solutions for problems of form, usability, ergonomics, marketing, brand development, and sales. Based on the principles of Industrial Design, the objective of which is to study both function and form, and the connection between product (vessel or system), the user and the environment.[12]

Although the process of design may be considered 'creative', many analytical processes also take place. In fact, many industrial designers often use various design methodologies in their creative process. Some of the processes that are commonly used are user research, benchmarking, sketching, human factors evaluation and CAD visualisation. Marine Design may also have a focus on technical concepts, products and processes. It can also encompass the engineering of objects, usefulness as well as usability, market placement, and other concerns such as seduction, psychology, desire, and the emotional attachment of the user to the object. [12]

User Centred Design (UCD) is a process in which the needs, requirements, and capabilities of crew members as end users of a vessel or system, are given extensive consideration at each phase of the design process. UCD tools and methods characterised by two aspects, the design activities they support, and the role of end-users in these activities.

In 'traditional' UCD methods in which the roles of designers and users are quite distinct; designers generate solutions for users based on explicit knowledge. This knowledge can be gathered through ethnographic research such as interviews or surveys with the user, or by observing users during product use. Users are the objects of study and, during usability testing, the testers of solutions. These techniques are currently in common use in the product design industry. Analysis, design and evaluation activities as part of these methods are mostly conducted by professionals for or together with users. There are however several challenges in product development that cannot be addressed by these traditional UCD methods:

- Gathering rich user insights
- Acquiring experts knowledge
- Early validation of user requirements
- Obtaining a multi-perspective review

Active user involvement and participatory design methods have been developed to address these challenges. Participatory design had initially been used for the design of software and organisational structures with the goal of representing the interests of workers in the design process. Recently it has been applied to civic participation, healthcare design and architecture.[13]

Active user involvement methods help end users express and analyse their current user interaction behaviour with products and the context, allowing them to conceptualise and reflect on future use scenarios. Effective communication is required in order for end users to share their tacit and practical knowledge with a design team effectively and efficiently. However, communication between users and a multidisciplinary design team is challenging for both sides. As designers and engineers are trained to communicate in a multidisciplinary environment, but users are not. Therefore, it is difficult for members of the design team to identify appropriate questions for prospective users and construct them so that the answers reveal useful design insights, as end users are generally not able to translate their current habits and routines into user requirements. It is therefore necessary to employ a range of tools and techniques to facilitate communication between end users and the design team. They are often practical and action oriented, encouraging participants to describe and explain their actions. Designers can subsequently use this information to improve the product. Physical mockups or virtual prototypes are often used to reduce the threshold for users to engage with the tools. Generic groups of techniques include: task analysis; scenarios; virtual reality. [13]

Luras and Nordby [5] investigated the use of field research in multidisciplinary design process of a bridge for an offshore service vessel. The UBC (Ulstein Bridge Concept) was a design research project seeking to redefine current ship bridges on offshore service vessels including deck layout, workplace design and user interfaces. The project was carried out by a multidisciplinary team of researchers and designers from the fields of interaction, industrial, sound and graphic design, as well as experts in human factors and engineering. Informed by their experiences of these field studies for design processes they introduce the model of design-driven field research. The model has three pillars of field studies in design: data mapping; experiencing life at sea; on-site design reflection. Design-driven field research emphasises the need for designers to experience the on-board environment for themselves when designing for complex marine domains such as ships bridges. It also encourages the designer to engage in design reflection in the field, in order to accelerate the process of interpreting use situations, thus expediting the creation of appropriate designs

AESTHETICS AND EMOTIONAL DESIGN

In considering the relationship of commercial vessel exterior form language aesthetics and emotional design, it is useful to first consider the automotive industry where this relationship is firmly established. The first characteristic of a car that catches a potential customer's attention, engaging their emotional perception is the aesthetic appearance of its exterior styling [6]. Automotive form language has been developed in the superyacht industry for some time and in recent years it has been implemented in the commercial vessel

industry. Where brand specific styling features differentiate a vessel from its competitors, as is the case with the car industry. Both from the customer's and society's viewpoint, styling makes a statement about the vehicle's owner. For most customers, the message sent out by their vehicle's styling is as important as the performance of the vehicle, even if this statement is understatement. Ulstein, Damen, Royal IHC, and Vard have commercial vessels with distinctive but different messages. Exterior styling is responsible for that visceral response of 'love at first sight'. [14]

DESIGN-DRIVEN INNOVATION

To facilitate design innovation marine designers should consider implementing a Design-Driven Innovation strategy as is often employed within product design. People do not buy products but buy design meanings. People use things for profound emotional, psychological, and socio-cultural reasons as well as utilitarian ones. Analysts have shown that every product and service in consumer as well as industrial markets has a design meaning. Marine designers should therefore look beyond features, functions and performance, and understand the real design meanings users give to vessels.

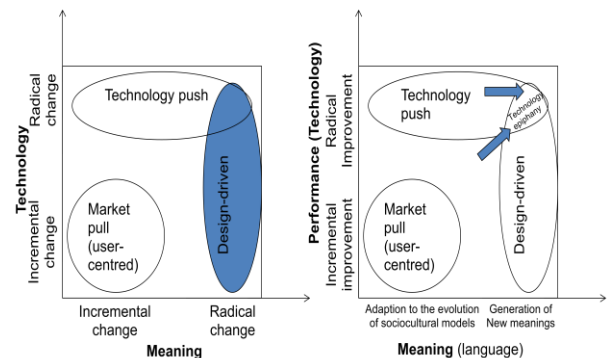


Figure 14: Design-Driven Innovation as research [15]

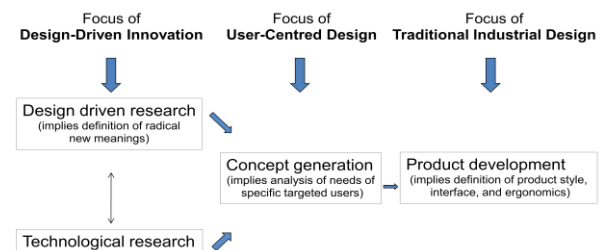


Figure 15: The strategy of design-driven innovation as a radical change of design meaning [15]

The process of Design-Driven Innovation is an exploratory research project, which aims to create an entirely new market sector for a given product through changing the design meaning the user has for the product. It occurs before product development, as shown in Figure 14, and is not the fast creative brainstorming sessions that are typical of concept generation but a design investigation similar to technological

research[13]. In essence, it is the development of a design scenario through engaging with a range of interpreters in technology and cultural production. Knowledge is generated from immersion with the design discourse of the interpreter's groups. The process can be structured or unstructured and is dependent upon the nature of the relationship of the client with the interpreters. The interaction between innovation of design meaning and technology innovation can transform the market within an industry and even create new market sectors. The successful interaction between design-driven and technology-push innovation is called a technology epiphany, shown in Figure 15, it creates a market leader and in some cases a completely new market sector. It is the basis for successful products such as the Apple iPod. [15]

PRELIMINARY DESIGN PROCESS OPTIMISATION

Decisions in the concept design phase of a vessel are critical as 90% of the major design decisions have been made when less than 10% of the design effort has been extended. These decisions have a direct influence on the quality of the resulting design. If improper or inferior decisions are taken, the resulting design can be suboptimal, or in the worst case, fail. Although design rationale occurs in multiple areas of concept design, it would be particularly valuable during the configuration design of complex vessels. The layout of spaces in complex vessels represents unique blend of experience, judgment and tradition. In addition, the decision knowledge required to identify and justify the relationships, i.e., interactions, between objects in the design is often tacit, qualitative and not explicitly available. For example, factors such as habitability, operability and convenience are difficult to describe quantitatively; but, without specific consideration, can result in difficulties for the ship and crew's overall functioning. Given a collection of objects in a design, there are two primary categories of rationales describing configuration: interactions and compromises. Interaction rationales describe the spatial proximities between objects in the design and the reasons, i.e., rationale, justifying such relationships. Compromise or trade-off rationale describes the preferred priority between competing or conflicting interactions. [16]

Identification of interaction rationale is important in ship design because it informs design analysis as the basis of compromise or trade-off decisions. Without knowledge of the interactions in the design, it is difficult to understand the consequences of compromises. Rationales can also provide an increase in the relative quality of knowledge in the ship design process. The "Knowledge- Cost-Freedom" curve shown in Figure 16 illustrates the benefits of increased knowledge during the early stages of design. As knowledge becomes obtainable earlier in the design process, design freedom increases, committed costs can be postponed to a later point in the design cycle and overall design time can be reduced. This is especially important during periods of reduced capital reinvestment in complex ships.

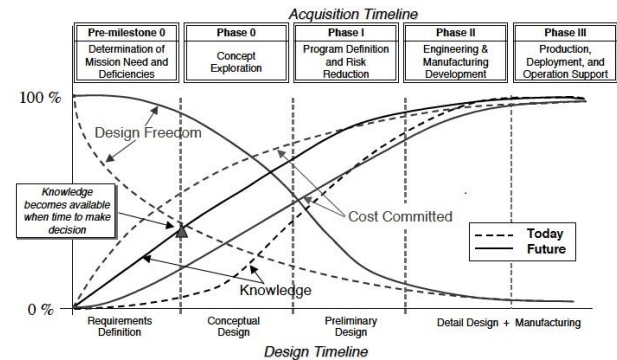


Figure 16: Distribution of cost, knowledge and design freedom during the early stages of design. [16]

A methodology for capturing configuration rationale in complex ship design [16], uses Reactive Knowledge Capturing to "trigger" the expression of design rationale. This arrangement also captures dependency structures between objects and relationships in the design. A dedicated feedback mechanism for expanding the knowledge (rationale) base is used. This methodology first identifies gaps present in the rationale database. Subsequently, it uses these gaps to instruct the design generation module to produce designs likely to trigger Marine Designers into expressing targeted rationale. At the same time, user expressed rationale is also incorporated into designs.

A simpler and faster version of a novel type of parametric ship description, based on mathematical packing problems has been developed [17]. This describes the ship configuration in three transverse 'slices', which helps to lower the computational effort by a factor of three to seven. Figure 17 shows three example designs from various studies performed with the packing-approach.

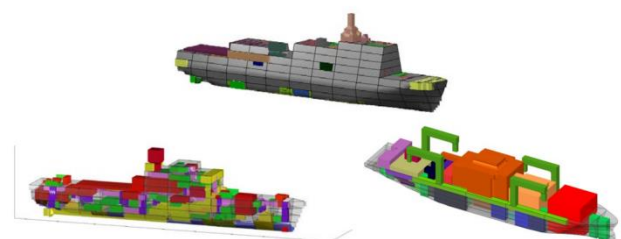


Figure 17: Three examples of feasible ship designs generated by the 2.5D and 3D packing approach: a frigate (left), a mine-counter-measures vessel (top), and a deepwater drillship (right). [17]

An interactive design exploration approach geared towards early stage ship design was proposed [18], which allows the Marine Designer to perform requirements elucidation better. The proposed approach provides the means to explore and assess a broad range of design options, which are integrated into coherent design solutions, thus covering a large area of the design space. This insight is then used to steer and control the design exploration process through a

feedback mechanism within the approach (Figure 18). This empowers the designer to not only identify, but also act upon the emerging relationships between requirements and the design, which can then either be avoided within the interactive approach or communicated to the stakeholders in support of a better requirements elucidation process.

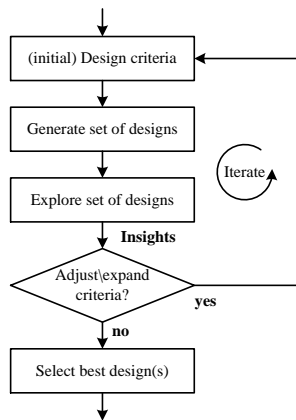


Figure 18: Workflow of the interactive design exploration approach proposed by Duchateau et al. [18]

In the examination of the initial development of a design and engineering strategy for complex ships in between incremental and radical innovation [17]. It was found that the majority of European ship-design industry concentrates on the development of complex, one-off 'specials' for the offshore industry. To control the complexity of these vessels the industry uses large and expansive knowledge bases that support the design, engineering and manufacturing activities. As current strategies are aimed at controlling the complexity, they leave very little room for more innovative developments. Based on case studies they proposed an alternative design strategy that leaves more space for innovation has been proposed, which focuses on the complex interactions between the different levels of decomposition in the complex structure of a ship.

Open Innovation

In order to facilitate transfer of technology into the Maritime sector EBDIG proposes the use of 'Open innovation' (OI). OI is a new paradigm for the management of innovation. It is defined as 'the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation, respectively.' It thus comprises both outside-in and inside-out movements of technologies and ideas, also referred to as 'technology exploration' and 'technology exploitation'. As a result, a growing number of MNEs have moved to an OI model in which they employ both internal and external pathways to exploit technologies and, concurrently, to acquire knowledge from external sources. In order to better profit from internal knowledge, enterprises may engage in three activities related to technology exploitation: venturing, outward licensing of

intellectual property (IP), and the involvement of non-R&D workers in innovation initiatives.

Venturing is defined as starting up new organisations drawing on internal knowledge, i.e. it implies spin-off and spin-out processes. The third practice to benefit from internal knowledge is to capitalize on the initiatives and knowledge of current employees, including those who are not employed in the internal R&D department. Several case studies illustrate that informal ties of employees with employees of other organizations are crucial to understand how new products are created and commercialized. Many practitioners and scientists, also outside the field of OI, endorse the view that innovation by individual employees is a means to foster organizational success. Work has become more knowledge-based and less rigidly defined. In this context, employees can be involved in innovation processes in multiple ways, for example by taking up their suggestions, exempting them to take initiatives beyond organizational boundaries, or introducing suggestion schemes such as idea boxes and internal competitions (van de Vrandea et al., [19]).

However, innovation in SMEs is hampered by lack of financial resources, scant opportunities to recruit specialized workers, and small innovation portfolios, so that risks associated with innovation cannot be spread. SMEs need to heavily draw on their networks to find missing innovation resources. External networking to acquire new or missing knowledge is therefore vital for European Maritime SMEs to remain competitive. OI is therefore highly relevant for both service and manufacturing organisations and is described in the following collaborative model (Figure 19). As the Maritime Sector is heavily populated by SMEs, the use of this model to efficiently transfer knowledge while engendering trust in a mutually beneficial relationship is both novel and ideal.

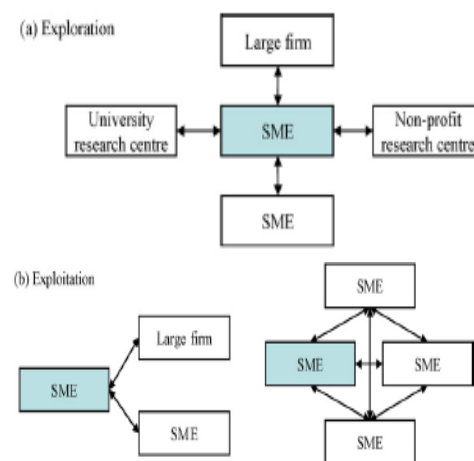


Figure 19: Possible models for open innovation with SMEs

Open Innovation enables an open business model for companies to "co-innovate" with their partners, suppliers, and customers in order to accelerate the rewards of

innovation. For example, a small or mid-sized company develops a game-changing new idea and works with a larger company to bring the product to market. It enables companies to leverage new ideas and products, and conduct experiments at lower risk levels. Given the maritime industry this would be beneficial to facilitate collaboration with smaller companies in and outside the industry and quickly develop new concepts and ideas.

OFFSHORE WIND INDUSTRY O&M TRENDS AND FUTURE PREDICTIONS

The offshore industry contributes to Europe's competitiveness and leadership in wind energy, provides employment in the EU, reduces Europe's import dependence and reinforces its security of supply. Key points:

- €4.2bn to €5.9bn annual investment
- 75,000 FTE (2014)
- 178,000 FTE in 2030 (75% of wind employment)

Advances in technology and industry maturity will make offshore wind an increasingly attractive investment. Bigger turbines utilising cutting-edge technology will increase yields and cut costs by as much as 17% by 2020, and a 39% reduction in costs could be achieved by 2023 in an optimum regulatory and competitive market. EU funded projects such as [LEANWIND](#), which is comprised of 31 members across industry and academia, work together to reduce costs within the offshore lifecycle. [20] The Offshore Wind Accelerator (OWA) is Carbon Trust's flagship collaborative RD&D programme. The OWA is a joint industry project which aims to reduce the cost of offshore wind by 10% in time for cost savings to be realised in UK Round 3. Cost reduction is achieved through innovation. In 2011 the OWA launched the access innovation competition addressing CTVs, access systems, and mothership solutions. Of particular note were the Umoe Mandal Surface Effect Ship CTV, the Holder TAS fitted to the BMT XSS CTV, and the LARS mothership CTV launch/recovery system. [21]

Operation and maintenance (O&M) costs make up 20-25% of the total lifetime costs of an offshore wind farm. In the UK the market for offshore wind O&M services is expected to grow to £1.2 billion/year by 2020 and almost £2 billion in 2025. This represents a 500% increase on today's market. By the end of the decade there will be up to 4,000 wind turbines and 50 offshore substations requiring O&M in the UK. The required O&M services are contracted by three main actors: project owners, wind turbine original equipment manufacturers (OEMs) and offshore transmission owners (OFTOs). These players are driving a wide range of contractual and strategic approaches to offshore wind O&M, underlining the need for commercial flexibility for contractors targeting this evolving and relatively fragmented market. Project owners are taking a range of different approaches to contracting O&M services both during the warranty period and beyond. These approaches vary from a "hands-on" approach, taking direct responsibility

for a wider range of activities, to a "hands-off" approach, relying on a few key contractors to look after the project. This is driven primarily by the strategic interests and corporate policy of the owner, where they see themselves adding value by reducing cost. The need to reduce O&M costs will encourage project owners to have a more direct involvement either hands-on or hybrid. Dong has been building and operating wind farms for more than 20 years with a hands on approach, owning and operating marine assets such as boats and providing technicians and other personnel to work under the management of the wind turbine manufacturers in the maintenance of offshore turbines. [22]

The broad strategic approaches to offshore logistics are as follows: work boat-based operating from a port base up to 12NM; heli-support workboats with support from helicopters between 12NM and 40NM; at 40NM offshore-based strategy with fixed or floating accommodation. Where it is critical to capability to achieve technician transfer in 2.5m Hs for acceptable level of turbine availability.[22] Catamarans typically achieve crew transfer in 1.5m Hs, with the following innovative platforms achieving crew transfer in up to 2.5m Hs: hydrofoil supported catamaran; semi-swath; SWATH; Surface Effect Ship. The SWATH hull form has excellent sea keeping and stability but is less capable for the transfer of cargo and heavy loads, and has a higher fuel consumption than the catamaran platform. BMT have developed the extreme semi-SWATH (XSS) to offer an improved level of sea keeping over existing designs without the performance and cost penalty exhibited by a full SWATH vessel. The Wave Craft CTV developed by Umoe Mandal, based on its military Surface Effect Ship (SES) technology, has been chartered by DONG Energy since March 2015 for O&M operation in the Borkum Riffgrund 1 wind farm in the North Sea. Using air cushion technology the vessel, with its top speed of above 40 knots, offers significantly higher speed than competing designs, and significant reduction in seasickness. The air cushion damps motions when accessing turbines, facilitating technician transfer in 2.5m Hs. [23]

O&M was a key research topic for offshore wind technology development proposed by TPWind [24]. Where the key issues are to investigate versatile service fleets and safe access, improve reliability and availability and research on full cycle cost models for optimisation of asset management. In order to enhance the market deployment of wind energy, one of the topics identified by TPWind was human resources. Which in this context is the need to quantify the need and level of O&M education in the EU and accession countries at national level and elaborate solutions for "skill and resource drain" towards high salary sectors such as oil and gas, review current wind energy masters programmes and encourage the creation of new programmes. The implication being that vessel for installation and O&M have to attract the digitally native generation to a new sector, that must compete with land based as well as other offshore careers.

The majority of CTVs have been specifically designed and built to work in the sector, with passenger comfort onboard a priority. As it is important that the technicians arrive in the field feeling well before transferring to the turbines. Vessels have individual suspension seats, designed to minimise travel fatigue and impact stress caused by the motion of the vessel. Other facilities on board normally include a small kitchen, television and entertainment systems. Whilst Naval Architects are qualified in the design of vessel hull and structures, the skill sets required for design for manufacture, interior design, fit out and Human Factors are a completely separate specialism and not available in most Naval Architect practices or Boat yard design departments, due to traditional business models. Therefore to achieve strategic advantage they should engage in the multidisciplinary holistic design practice of Marine Design. Before any design or manufacture can start on any product there needs to be a robust process for the determination of the specification. The wind farm industry is a good example of how the specifications have changed over a short period of time and increased the number of stakeholder interests. To the point that vessels less than 6 years old are technically redundant and being laid up. At the core of a model for vessel strategic advantage is the Design Value Proposition (DVP) for the charter company. Techno-economic forecasting facilitates strategic advantage requirements by specifying the vessels type and its position in both the current and future market. After which the competitive advantage has to be determined. Once the vessels size and type has been determined from the strategic point of view, the owner or designer needs to consider asset adaptability and how the asset life can be extended to deliver optimum payback.

The change in the business model of energy companies informing charter companies of the vessel specification that they wish to charter, is an opportunity for Marine Design, with the charter company directly dealing with both yard for the hull and an interior supplier. In the Marine Design of a modular CTV interior [25], the technological innovation was the use of a modular system to facilitate vessel flexibility through the innovative application of Design For Manufacture (DFM). The offshore wind farm and oil and gas future market challenges indicate market sensitivities which require higher technical standards and platform flexibility. The key issues are the need for offshore wind to recruit land based technicians, and the fact that the oil and gas sector will be replacing a high percentage of their work force over the next 10 years. The digital native generation have a need for connectivity to attract them to a work environment. The interior shown in Figure 20, where the front row of motion seats have tables and plug sockets, designed as an ergonomically resolved workspace for laptops. This type of informal interior designed workspace is defined as a 'fourth space', which is perceived to be of significant value to the productivity and creativity of employees. The use of the design language of luxury motoryacht interiors and luxury small

apartments engages the user in emotional design, creating a low stress positive environment, supporting well-being and morale.



Figure 20: Rear 3/4 view of WFSV interior render

The DDI design scenario identified the need for vessel flexibility when trying to raise finance and spread risk in the business plan, given the uncertain market of the offshore wind farm industry and the potential opportunity of oil & gas. The technology innovation was implementation of the DFM process with digital technology, which can reduce production costs by as much as 30% as well facilitating vessel flexibility for both offshore wind and oil & gas sectors. By the adoption of these new production methods, design and cost control, the UK boat building industry will be able to compete in global market which will come under greater cost and price pressure.

As offshore wind projects throughout Europe develop in size and complexity, there is a demand for more versatile vessels with higher capacity for both equipment and personnel. In response, the German flag state has recently adopted a national guidance notice to allow vessels to operate with more than 12 industrial personnel onboard in national waters. In response to this opportunity Seacat Services have recently launched the Seacat Courageous designed to accommodate up to 24 offshore wind personnel. The 26m catamaran, has a modular interior, which allows the client to specify the number of suspension seats between 0 and 24, dependant on the particular operational requirements for their project.[26] The requirements for industrial personnel include: transport or accommodated on board for offshore industrial activities; medical standard equivalent to STCW; appropriate offshore basic safety training; vessel familiarisation; appropriate PPE.[27]

The refit of existing vessel with a modular interior could support their longevity and hence enhance return on financial investment. The design challenge of interior spaces such as showering/changing facilities with the potential future increase in seating, could be addressed through the use of lightweight modular cabin habitation units, fitted to the fore and aft deck to increase interior volume for technicians and their equipment. Such as the recently launched KPM-Marine 2 CUBED CABIN, which is load tested and DNV approved. Lightweight modular

cabins offer the vessel operator significant fuel savings over tradition TEU based structures. Growth in vessel size is restricted by regulations on maximum fendering push-on load. This may be addressed in part by innovative fender designs to reduce the push-on load, such as the 'compensated' and 'smart' fenders. There has been a shift from vertical D fenders to custom built composite constructions, with varying depth and recesses/protrusions, that may be refitted for different sites. [27]

The majority of wind farms within the UK are within 60nm of the coast, so most CTV are MCA Cat 2 compliant. The implementation of motherships as a 'safe havens' in UK Round 3 would enable MCA Cat 2 vessels to operate at far shore projects within 60nm of a mother ship. The 90m SPS code compliant DP2 vessel, Atlantic Enterprise is a new class of offshore mothership or Service offshore vessel (SOV) designed to support UK Round 3 developments, with technician accommodation. It has up to 100 berths in mainly single ensuite cabins. The combination of daughter craft, walk-to work motion compensated system and the helipad, facilitates a wide range of flexible O&M strategies. The daughter craft consists of: 2x CTV; 2 x heavy duty work boats; 2 x high speed daughter craft; 1 x FRC. The CTVs are dry stored inside a stern garage. The vessel is currently on charter at Gode Wind 1 to support the construction of the 330MW site, with a potential to start work on UK Round 3 in 2016. Hence the SOV can be used in construction as well as O&M and has market sector adaptability as a flotel for Oil & Gas.[28]

Siemens have already implemented one of their fleet of SOVs on O&M duties at Dong's Westernmost Rough off northeast England. Four of the new vessels will enter service by the end of next year. The 90m motherships will reduce the cost of operating offshore wind farms at maximum output, with weather-related downtime expected to reduce from the current 40-45% to 10-15%. The effective integration of remote diagnostics into a planned maintenance strategy supported by daughter craft of the SOVs transferring technicians to individual turbines to carry out repairs, is predicted to reduce current O&M costs projections for wind farms located more than 70km from the coast by 20-30%. The vessel, with spare-parts storage, workshops and accommodation for 40 people, will be able to sail to projects through high waves and force 6 winds, where technician transfer would be achieved using a walk-to-work system. Two vessel will be built by Ulstein and chartered from ship owner Bernhard Schulte; and the other pair will be provided by Denmark's Esvagt. The Ulstein SX175 design will feature the new X-STERN hull line design as well as the proven X-BOW, making it capable of operating with stern or front towards wind, waves and current, increasing the operational window. It will be able to house 60 people in single cabins, 40 of whom will be technicians. The Esvagt vessels will be Havyard 832 SOV windmill service vessel, of length 83.7m and accommodation for 60 technicians and crew. The first SOV will operate at the 288MW Baltic 2 wind

farm off Germany, with the second vessel at the nearby 288MW Butendiek project. With the new SOVs, personnel will be able to stay offshore for four weeks, adding three hours of productive working time to each 12-hour shift. Whereas previously, five hours has been lost to transit to and from the site. Vattenfall have recently signed up for Siemens' combined service concept for their German North Sea Sandbank and DanTysk projects, where one SOV will operate between the two wind farms. An SOV is also under consideration for Gemini, the Netherlands' largest offshore wind development. [29]

The first consent order for offshore wind energy at Dogger Bank in the North Sea was granted on the 17th February 2015, making it the largest renewable energy development ever to receive planning consent in the UK and the largest offshore wind project to receive consent globally. It will be operated by the Forewind consortium: RWE; SSE; Statkraft; Statoil. Dogger Bank Creyke Beck is part of the Dogger Bank Zone, the largest of the UK Round 3 zones but one of the shallowest, with high wind speeds and seabed conditions ideally suited to offshore wind development. Dogger Bank Creyke Beck, which has a total generating capacity of 2.4GW, comprises two separate 1.2GW offshore wind farms, each with up to 200 turbines installed across an area of 500km². The wind farms will be located 131 kilometres from the UK coast. [30] Given the significant generating capacity of Dogger Bank Creyke Beck and the distance from shore, a significant number of SOVs will be required to facilitate both construction and the O&M strategy.

A major challenge is to meet the technician recruitment target this will require land based technicians to work at sea use of Environmental Psychology to optimize working living space for well being. The EBDIG-WFSV project has developed two SOV case studies at opposite ends of the spectrum of SOV design philosophy. The first is a an adapted OSV platform proposal with a focus on cost minimization. The second proposals is a purpose designed SWATH platform with a focus on technician well-being. Next generation motherships will need to address the user needs and aspirations of a new generation of technicians, who may not have previous marine experience.



Figure 21: OSV platform based mothership [30]

The OSV mothership concept design proposal[31], shown in Figure 21, challenges perceptions of the working and living environment on commercial vessels through the implementation of Design-Driven Innovation. An analysis of the offshore wind market identified the challenges of vessel financing compared to the oil & gas sector, as a unique opportunity for a common platform technology vessel. The concept has an innovative WFSV launch/recovery system enabling a conventional OSV platform to be adapted into a mothership role. Resulting in a more cost effective solution in terms of design and construction that benchmarked specialist vessels.

The Toyota Production System (TPS) is a continuous improvement philosophy. It became the basis for the LEAN and Six Sigma manufacturing philosophies. A significant element of TPS is automation, or “automation with a human touch”. In the same way that lean techniques have been applied to automotive manufacturing, the principles of automation can be applied to offshore wind farm maintenance practices to improve turbine availability. The SWATH mothership concept [32], shown in Figure 22, was designed to support an automation approach to offshore wind farm maintenance practices, developed through an implementation of the NetWork model of Environmental Psychology. The NetWork model [33] encompasses both how and where work is done and how workers, processes and places are supported. It differs from previous Environmental Psychology models by focusing on the work that is to be done and how to enable it to be done most effectively. This knowledge informs the specification of furnishings, technologies, equipment and infrastructure that enable workers to make the best of wherever they work, to develop effective work practices, and to continue to adapt. The design process was a Transfer of Innovation from interior architecture where environmental psychology is a well established approach to design highly productive low stress working environments. The potential of this Human Factors focused approach to reduce risk and increase crew productivity could reduce operational costs such as manning levels and insurance.



Figure 22: SWATH platform mothership [31]

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THE NEEDS ANALYSIS OF THE COMMERCIAL VESSEL INDUSTRY IN EUROPE

The EBDIG-WFSV partners developed a detailed online questionnaire to elucidate the potential needs of the European industry stakeholders in the context of this project and to profile their respective activities as actors within the marine industry sector. The responses to key questions relating to the impact and value of the EBDIG-WFSV project are shown below. As an integral part of the questionnaire key concepts were delineated to contextualise the questions.

Questions	UK	ES	IT	TR
How many days per year would you be able to engage in RINA online learning CPD activities? (days)	17	25	2.75	8.3
Are you aware of any European commercial vessel manufacturers or design consultancies applying the principles of Marine Design? (% yes)	66	50	50	50
Do you think Marine Design could offer your company a unique selling point for competitive advantage if clients became aware of the value of Marine Design? (% yes)	66	100	75	94
Would you be interested in free online RINA accredited CPD to further your understanding of Marine Design? (% yes)	100	100	75	100
Based on the above high return on investment for the small cost increase in implementation, do you think HSI would benefit your company if your clients became aware of the value of HSI to their operational costs? (% yes)	100	100	75	100
Would you be interested in free online RINA accredited CPD to further your understanding of Human Systems Integration? (% yes)	100	100	75	100
Do you think the transfer of innovation of Digital Human Modeling could be beneficial in enhancing bridge development while reducing design costs? (% yes)	100	100	25	94
Do you feel there is a need for the European commercial vessel industry to develop TOI (transfer of Innovation) from other industries on order to maintain a competitive edge in challenging and cost sensitive international markets? (% yes)	100	100	50	89
Do you feel your company would benefit from an online innovation portal and CPD material to support open innovation? (% yes)	100	100	75	88
Do you think the WFSV specialist market could be an opportunity for diversification for your company? (% yes)	66	50	25	94
Do you think the WFSV Mothership specialist market could be an opportunity for business diversification for your company? (% yes)	66	50	25	89

In summary the needs analysis supports the following key proposals of the EBDIG-WFSV project:

- Marine Design could offer competitive advantage if clients became aware of its' value
- Marine Design CPD accredited by RINA would be of significant interest to the sector
- DHM would be a TOI of significant interest to the industry
- Open Innovation and a support infrastructure would be of significant interest to the industry
- WFSV and motherships would be an opportunity for business diversification in UK, ES and TR.

This questionnaire will be repeated in a shorter format after the launch of the EBDIG-WFSV learning material to measure the impact of the online learning material and the Open Innovation portal on the EBDIG website (www.ebdig.eu). **Please join the EBDIG-WFSV group on LinkedIn for regular updates.**