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The State of Human Centred Design in e-Navigation; Investigating Drivers and Barriers in North-European Testbeds

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Abstract

e-Navigation has been launched by IMO as an overall strategy for increased maritime safety and efficiency, by stimulating and enhancing the innovation of user-friendly services and equipment for maritime customers. The purpose of this thesis is to investigate the level of user involvement in e-Navigation testbeds, along with the drivers and barriers, including external environment, to Human Centered Design in the projects. Through qualitative interviews with testbed participants and analysis of web reporting, e-Navigation was found to be user centered but not user driven, and meeting several barriers that constrains the effective utilization of Human Centered Design. The special features of some e-Navigation testbeds are the large funding by, and the active involvement of Authorities, which work as drivers counteracting the classic time-cost-quality dilemma of projects. The role of public institutions is highlighted, however challenges in the communication and cooperation between designers, users and HF/E experts show that there are possibilities for further improvement in gaining maximal outcome of user involvement practices. The results are discussed in light of existing theory on user involvement and practical implications within e-Navigation.

Keywords: e-Navigation, open innovation, living labs, human centered design, user centered design, co-design, maritime, testbed

TERMS and ABBREVATIONS

IMO – International Maritime Organization

IALA – International Association of Light House Authorities

HCD – Human Centered Design

UCD – User Centered Design

SQA – Software Quality Assurance

ICT – Information and Communication Technology

E-Commerce – buying or selling online

EHEA – Early Human Element Analysis

UT – Usability Testing

IEC – International Electrotechnical Commission

ISO – International Organization for Standardization

HF/E – Human Factors and Ergonomics

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Introduction

E-navigation Strategy is an IMO initiative to enhance maritime safety and efficiency at sea, by stimulating and harmonizing innovation in the maritime domain. The continuous growth of volume in international seaborne trade is increasing the pressure on congested waterways and ports. UNCTAD estimates that world seaborne trade has increased 2,5% the last two years despite of the downturn in general international trade (UNCTAD, n.d.). A raising number of tasks along with reduced manning on board vessels put further pressure on the officers on watch. According to IMO, around 60% of marine accidents occur as a consequence of direct human error (MSC 85/26/Add.1 Annex 20). Concurrently, *digitalization* of services is becoming a popular notion in the maritime world, where the moving from verbal to digital transfer of data is expected to replace human operations with automated functions. The industry is increasingly seeing opportunities and starting projects to enable safer and more efficient shipping worldwide. (DNVGL, 2017, NAVTOR, 2017).

IMO wish to take on the overall coordinating role of this development as they otherwise fear that innovations in e-Navigation will become diverse and incompatible with other systems. The e-Navigation Strategy Implementation Plan (SIP) approved in 2014, states the five main priorities for development in the period 2015-2020 (IMO, n.d.) to reduce errors made by humans operating in solitude and with unreliable navigational tools and information. The strategy lists user-friendly bridge-design, standardized and automated ship reporting, improved reliability of navigational information, integration of information on graphical displays, and improved communication of VTS service portfolio. By this framework IMO expect to provide the industry with the necessary information to start designing harmonized products and services for e-navigation solutions. 37 projects have been listed on IALA's web page for e-Navigation since

the start-up in 2008, aiming for the different tasks in the strategy. Those projects range from single-firm projects to large-scale million-euro projects including authorities, industry partners and academia (IALA, n.d.). IALA has been given a coordinating role in the *reporting* of testbed results in the e-Navigation strategy on behalf of IMO. To arrange for a common and standardized reporting, a separate guideline has been issued and a web site was established. (IALA Guideline No. 1107, 2013), which could simplify the task of getting an overview of discoveries made and potential that could be utilized for firms entering new projects.

Ship owners, represented through The International Chamber of Shipping (ICS) are watching e-Navigation with a concern for proven benefits to the maritime industry ("ICS | E-Navigation," n.d.). Urging for eased burdens on the Master and increased efficiency of ship operations, they provide a critical voice, questioning the useful outcome of e-Navigation initiatives.

A key point of e-Navigation SIP is *user friendly design*, further emphasized by the 2014 guideline for Software Quality and Human Centered Design (MSC.1/Circ.1512). The guideline is a voluntary tool meant to be used for providing a general understanding of the concepts in e-Navigation development, along with international standards such as ISO 9241 – 210:2010. To reach the IMO's goal of user friendly innovations in e-Navigation, an efficient utilization of user centered design processes including the HCD Guidelines could be beneficial. Successful implementation of such processes is dependent on internal and external drivers and barriers for user involvement and HCD. Which drivers and to what extent they are present, along with how they affect and coordinate the development of e-Navigation is sparingly researched. Furthermore; whether and to which extent user involvement is optimal and desirable seen from the practitioners' point of view is unknown.

e-Navigation bears with it the possibility for different levels of user involvement throughout the innovation cycle. Stakeholders' motives, knowledge and beliefs will determine the level of arranging for HCD in terms of ordering, planning and budgeting relevant actions. The thesis will identify the level of HCD implementation along with important barriers and drivers for HCD in e-Navigation. It may serve as a foundation for possible improvements to arrange for continued focus on Human Centered Design in e-Navigation.

Literature Review

This literature review will form the basic understanding of main concepts as they are used in the thesis. It will also form the basis for conceptual operationalization, which in turn is used to state the precise formulations of my research questions. The main theories surrounding user- and technology driven innovation are summarized before introducing the concept of Human Centered Design (HCD). Possible drivers and barriers to HCD is discussed in the text and later summarized in methods part.

User Centered Innovation

Users may take or be given various roles within open innovation (Nyström, Leminen, Westerlund, & Kortelainen, 2014). Examples of radical innovations where users have played the active part of realizing their ideas *(user driven innovation)* and actively sought out industry partners (Lettl, 2007, von Hippel, 1988) do exist, however theories on *User Centered Design (UCD)* and *Human Centered Design* usually illustrates the opposite. Companies seek out and activate users in the context and at the stages that they see feasible for their projects. Users' influence is ultimately governed by the willingness of project owners to include and cooperate with them, from the most heuristic forms to the formalized living labs where users are actively collaborating with designers as an equal partner for the benefit of both producer and user

(Baldwin & von Hippel, 2011; Følstad, 2008; Ji-Ye Mao, Vredenburg, Smith, & Carey, 2005; Nyström et al., 2014).

An alternative argument to user centered design is made in other innovation theories such as *design thinking.* The idea is that analysis of user needs will only result in incremental changes. Radical changes in meaning of products are achieved by taking a step back from the users and designing in diverse teams that look at the whole context of the user. The concern for user is still important, but in the role as informant and object of study (Denning, 2013). Ultimately it is said to concern how to *"…manage innovations that customers do not expect but that they eventually love…*" (Verganti & Öberg, 2013). Thus, active user involvement such as co-creation, could be seen by actors as limiting innovation potential also for e-Navigation. Customers as buyers of e-Navigation solutions are not likely to be the direct end users themselves (A. Costa, 2016). The interests of procurers will govern the final investment, and consequently the sales potential for radical and incremental user experiences for commercial end products in this domain is uncertain.

Authors use different numbers and names for innovation stages. (MSC.1/Circ.1512, 2015; Rocheska et al., 2014; Tidd & Bessant, 2013) For simplicity, three overall stages of innovation as illustrated by Rocheska et al. are used in this thesis; early, advanced and late stage. The boundaries of those stages are fluid and used in a heuristic way for the thesis.

There are various forms of user involvement in innovation. *User-driven* innovation posits that innovation is driven by users' needs, ideas and opinions, and is the result of a more or less close collaboration with users (Baldwin & von Hippel, 2011). In this thesis, being *user-driven* represents the highest level of user centeredness in innovation as shown in the framework of Leminen & Westerlund (2011), where users play an active role in the activities forming the

innovation, such as ideating, setting goals and objectives, co-designing, evaluating and validating products or services (Baldwin & von Hippel, 2011; Rocheska et al., 2014). The works of Leminen & Westerlund (2011) explain type of co-creation as a gradual scale from producer – to user driven as illustrated in Figure 2.

My introduction of *user centeredness* embrace also the concern for user outside what may take place within the formal framework of HCD. A cooperation where users have a less active role, may provide user centeredness without the process being actually driven by the users (Baldwin & von Hippel, 2011). Being *user centered* could still mean being concerned for the user, but users may be separated from designers by experts who collect user input and create reports for the designers, or they are gathered at the needs of the project and provide usability testing and feedback to designs already provided by others. Features of user centered innovation are summarized in table 1 and the attached table 11. Use of more specific or heuristic methods and more active encounters with users would imply a higher degree of user centeredness on the scale towards being fully user driven.

Open Innovation

In recent times two-thirds of award-winning innovations in U.S. come from partnerships between businesses and government. In 2006, 77 of 88 U.S. entities with award-winning innovations were beneficiaries of federal funding (Tidd & Bessant, 2013, p.267). Sources of innovations may be various, and such collaborations provide opportunities for more innovativeness, better customer satisfaction and financial success (Torvinen & Ulkuniemi, 2016). Public agencies as customers of the projects have a unique opportunity to influence innovation methods and deliveries, and they could promote utilization of users in the process if they desire.

Open Innovation comprises the idea that innovation cannot happen alone, and that more and better ideas and opportunities emerge in cooperation with others (Chesbrough, 2003). Various forms of openness is defined in literature, differing between inbound and outbound, pecuniary and non-pecuniary openness (Dahlander & Gann, 2010). User involvement implies an example of inbound, non-pecuniary openness by including people external to the firm into the innovation process. There are claims in literature that research on open innovation practices tend to focus one-sidedly on implementing and optimizing the processes, while not paying sufficient attention to the implicated challenges, such as practical implementation and capturing value (Tidd & Bessant, 2013). Motivation for keeping developments in-house tend to be desire for keeping business advantage by avoiding knowledge leaks. Such a strategy requires large in-house resources and bears with it the risk of missing out on ideas from external sources such as end user knowledge (Baldwin & von Hippel, 2011; Chesbrough, 2003; Tidd & Bessant, 2013). A closed, producer-driven organization stands in contrast to the open, collaborative open innovation, but in practice most firms represents something in between (Leminen & Westerlund, 2011). Open innovation between firms and institutions may not necessarily require user involvement, but where users external to firm are involved, some form of openness is evident.

Technology Driven Innovation

Early research on innovation places the producer in center of innovations, and claims that the producers take the lead in developing most important new products and processes (Baldwin & von Hippel, 2011). *Technology driven innovation* represents the theoretically opposite term of designing and producing products and services in collaboration with users. Though acknowledging the value of understanding customer's needs, there is little interaction with users, and any information collected from users might fail to flow into the firm's business and

operation (Leminen & Westerlund, 2011). Innovation is governed by the mere technological possibilities and the ideas of the designers themselves, also called *technology push* (Tidd & Bessant, 2013, p.75). By the ideas of technology driven innovation, producers are expected to be motivated to innovate by future profits from some sort of monopoly of their inventions. This has traditionally been dominating the view on innovation, thus promoting the protection of innovator's profit by granting of intellectual property rights or subsidies (Baldwin & von Hippel, 2011; Gallini, 2002).

Human Centered Design

IMO emphasizes that e-Navigation development should be user centered. *Human Centered Design* (HCD) as innovation concept has been developed over decades where an increasing focus has been put on users as center for design and even as co-partners in design (Sanders & Stappers, 2008). HCD has been chosen by IMO as concept for e-Navigation to emphasize the effect on *people* rather than their narrower role as direct *users* (MSC.1/Circ.1512). However; the concept of *User Centered Design* (UCD) is more commonly found in scientific articles and is to a large degree overlapping the field of HCD.

HCD may comprise several approaches for involving the user, such as *participatory design*, *ethnography, the lead user approach, contextual design, co-design* and *empathic design,* (Steen, 2012). Steen (2012) sees HCD as a "fragile encounter" where HF/E experts need to be aware of their own tendency to steer development and limit openness by being too focused on primary goals. The unique possibilities of HCD is to "learn the things you didn't know you need to know", by embracing unanticipated input from users. IMO MSC.1/Circ.1512 emphasize that HCD should be an iterative user focused process at all stages of the generic lifecycle of a service or product, driving a feedback loop in each design stage to ensure usability and safety of

a product. Consequently, *Usability testing (UT)* should be carried out iteratively at all stages and provide input for further development and future versions of the systems. Only a limited number of articles are addressing the topic of HCD in the maritime domain, however some case studies have been made investigating barriers and benefits of HCD in navigational developments, (A. Costa, 2016; Costa, Holder, & MacKinnon, 2017) identifying anticipated benefits from a human-centered and participatory approach to ship design, and prerequisites for successful user participation. The study was conducted by eliciting the expectations of user representatives only, as an attempt to outweigh the perceived resistance in the maritime community towards HCD principles. HCD has tended to be seen, especially by designers, as a research-driven approach rather than design driven (A. Costa, 2016; Costa et al., 2017). Findings from these studies indicate that HCD is an academic product that lacks the bridging towards the industry in terms of practical guidance and texts that are, ironically enough, user friendly and easy to use by people who are not academic experts in HCD.

Studies made in other domains such as IT and health care are more provident. The mining industry is also a high-risk business as is the maritime, where similar attempts to validate HCD into the industry have been made (Horberry, 2015). Studies on UCD in these domains also found that "*major obstacles to creating greater strategic impact included resource constraints, development and management doubts about the value of UCD or usability engineering, and deficiency in usability knowledge*." (Ji-Ye Mao et al., 2005).

Mao et al. (2005) found that in other industries the positive attitude, implementation level and expectations towards future use of UCD had been increasing among UCD practitioners themselves. In general, UCD was perceived to have a positive impact on product usefulness, however concerns were raised regarding lack of effectiveness measurements and unclarity if

there were any savings effect on time and cost. In terms of practical implementation, divergence was found between the methods considered most important and those that were most widely used, probably due to the cost-benefit trade-off. The most valued UCD measures, such as *field studies* and *user requirements analysis* tended to be less used to due to the cost involved, while *heuristic* and more *informal approaches* were more popular due to the relatively easy performance and lower cost. Kujala (2003) concluded that user involvement, in early phase particularly, is beneficial for getting better user requirements and higher user satisfaction with the end product. However, challenges were found towards users' understanding of design process, increased time spent on development and resolving issues between designers and user, and users demanding changes late in the development.

Living Labs as User Centered Innovation

Living labs is a user centered network type that has developed within the field of open innovation the last decades (Følstad, 2008; Leminen & Westerlund, 2011; Rocheska, Kostoska, Angeleski, Mancheski, 2014; Turkama, 2010). In Living Labs, the collaborating parties are deliberately put together to boost innovation, and the user involvement as an equal part to the other parties is a key aspect. Research made on user roles in living labs, claim that users should have an active and included role in the innovations, in order to distinguish the users in living labs from the traditional object of study (Nyström, Leminen, Westerlund and Kortelainen, 2014). Users may act as informants, testers, contributors and co-creators in a living lab, with co-creators being the most active form. Here users engage with designers or alone to solve their user needs (Nyström et al. 2014). The type and level of co-creation between customer and producer are seen as a factor determining the level of producer or user driven innovation, from closed- and producer driven to open- and user driven (Leminen & Westerlund, 2011). Various levels of

openness and user involvement are identified in former research however no companies being fully open and user driven. Leminen & Westerlund (2011) provide a framework in four steps between closed – and producer led companies to open – and user led innovation companies, based on the type and level of co-creation taking place in the innovation process.

The use of concepts within open innovation and innovation networks are not uniform and consistent. Different conceptual frameworks for test -and experiment platforms (TEP) have been developed (Ballon, Pierson, & Delaere, 2005). The term Living Lab is generally used to indicate two different functions (Følstad, 2008):

1. Living Labs as open and user-driven innovation structures

2. A testbed for exposing applications to user

The concept of "Living Labs" has been formalizing in the Nordic Countries the recent years, being actively promoted and researched by interest organizations within innovation (Turkama, 2010). Nyström et al. (2014), characterize Living Labs as "(…) *public-private-people partnerships (4Ps) formed by stakeholders from companies, universities, public agencies and users may collaborate to design, prototype and test technologies, services, products and systems in real-life contexts."* Research on living labs and user driven innovation are mainly found on ICT and e-commerce (Ji-Ye Mao et al., 2005; Turkama, 2010) which by nature have a wider resource base of direct users, and possibilities for crowd sourcing and direct feedback from users over Internet than what is feasible in the maritime domain.

Research Model

To answer the research questions, the extent of implementing HCD methods and principles for user centered innovation is explored by interviews and secondary sources as articles and web reporting, as a tentative benchmarking of the level of user involvement in e-

Navigation. Drivers and barriers to HCD in e-Navigation testbeds are identified in existing literature on HCD and user centered innovation and compared with qualitative interviews with different testbed and stakeholder representatives. Finally, the subjective experienced effect of external factors to e-Navigation is explored by gathering the views of testbed respondents.

Conceptual Definition

The Phenomena of study in this thesis is the degree of user centeredness, and the drivers and barriers to Human Centered Design in the context of e-Navigation as stage for innovation. *User involvement* is an important factor for successful HCD as encouraged by IMO. Living labs emphasize a high level of user involvement with the objective of meeting user needs and boosting innovation. Features of Living Labs as well as User Centered Design and Human Centered Design are therefore used to find indicators of what I called *user centeredness*, and drivers and barriers to Human Centered Design in e-Navigation. This produces the following concepts for research:

1. User centeredness in e-Navigation
2. Drivers and barriers to HCD
3. External factors to e-Navigation

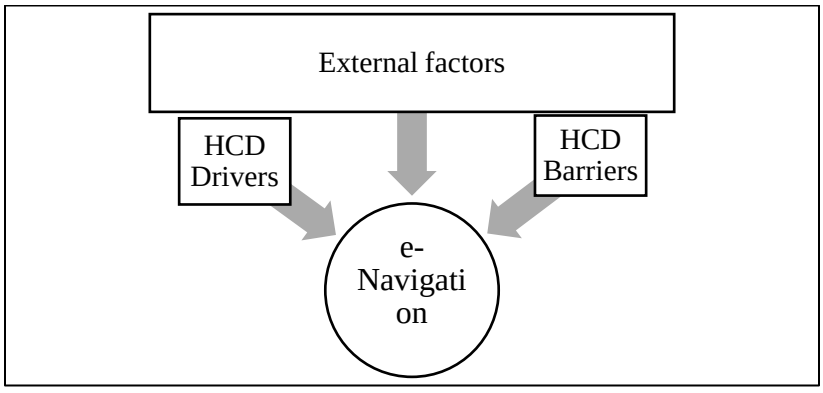

Figure 1. *Research Model*

Research Questions

The research question of this thesis is:

- *How user centred is e-Navigation as innovation platform today?*

Two Sub questions are included:

- *Which are the main drivers and barriers to HCD in e-Navigation?*
- *How do external factors influence the performance of e-Navigation as user centered innovation?*

Operational Definition

User centeredness is characterized by different sets of identifiers as stated in research on user driven innovation, living labs, User Centered Design and Human Centered Design. The existence and level of user involvement is investigated by interviews with participants in e-Navigation projects and information on web resources, seeking information on user involvement phases, user roles and co-creation, methods and number and types of users. Drivers and barriers to user involvement as experienced by the individuals involved in the processes are investigated by interviews focusing on the representatives' attitudes, beliefs and experiences within the e-Navigation developments. This is further supported or challenged by existing literature and information found in secondary sources regarding e-Navigation and user driven innovation. Drivers and barriers to HCD in e-Navigation is derived from existing literature in maritime and other domains, and used as framework for interview guide and deductive codes, as well as an iterative adjustment of interview guide to cover new factors that emerged underway. Inductive codes were found after interviews to fill the exploratory part of study.

Deductive codes are listed in table 1.

Table 1. *Drivers and Barriers to HCD*

HCD Drivers	
DU: Desire for product usefulness	Mao et al. (2005)
DB: Beliefs & expectations	Leminen & Westerlund (2011), Niitamo et al. (2006)
DAU: Active User Roles	Baldwin & von Hippel (2011), Costa et al. (2017)
DRR: Rules and regulations	**
DGS: Guidelines and standards	**
DCD: Customer Demand	**
DOS: Driver Official Stakeholders	**
HCD Barriers	
BMR: Management Resistance	Costa (2016), Mao et al. (2005), Turkama (2010) Horberry (2015)
BC: Cost	Mao et al. (2005)
BT: Time	Mao et al. (2005)
BK: Lack of Knowledge	Costa (2016), Mao et al. (2005), Horberry (2015)
BBP: Missing Business Propositions	Turkama (2010), Mao et al. (2005), Horberry (2015)
BR: Missing clear responsible	Turkama (2010)
BCO: Coordination	A. Costa (2016)
BTB: Trust building	A. Costa (2016)
BUA: User availability	A. Costa (2016)

Note. ** In addition, I wanted to investigate if the official stakeholder such as IMO and IALA, and relevant guidelines and standards has any impact on the HCD implementation, as well as any possible customers demands or expectations. These are added to the deductive codes for creation of interview guide and initial coding.

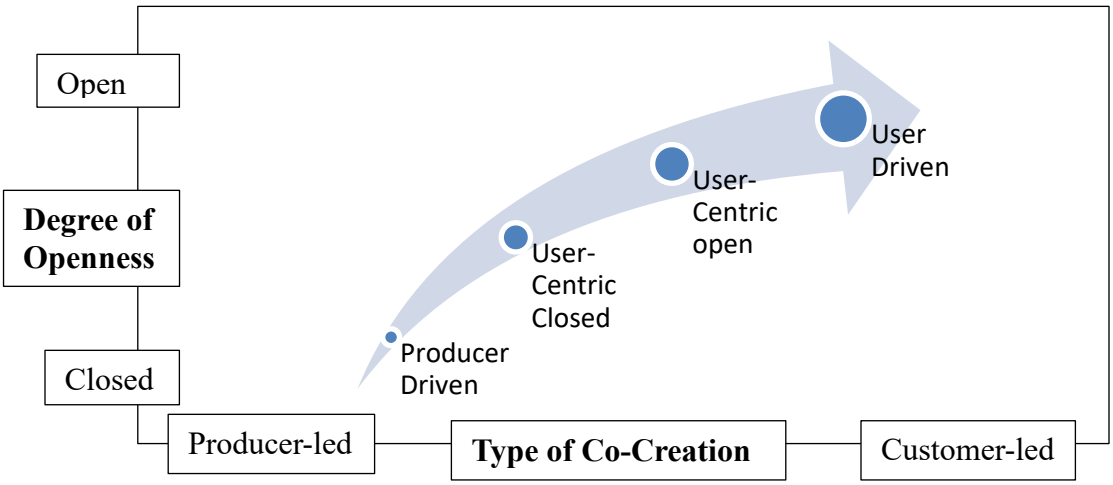

Figure 2 *Illustration of User vs Producer Led Innovation Firms by Degree of Openness* (Leminen & Westerlund, 2011)

Levels of user driven innovation per Leminen and Westerlund (2011) are summarized in Table 2. By identifying features of the sample testbeds an indication of user centeredness for

each testbed evolved and further indicate the state of user centeredness in e-Navigation today. Five themes were derived from this framework to provide a basis for deductive analysis of interview data, shown in Table 3. Attached table 11 shows identifiers for user centeredness derived from table 2 and other sources.

Table 2. *Characteristics of User-Centeredness*

Type of innovation	Characteristics
Producer-led	innovation led by producer
	producer's ideas and patents
	policy to keep assets in-house
	little interaction with users
	intermediaries perform market research on behalf of firm
	lack of skills and resources for valuable user involvement
User-centric closed	innovation led by producer
	more visible user role
	systematic user surveys and studies at company premises
	different users at different stages
	pilot testing
	no general instruction and practices for user involvement
	spend resources to keep intellectual property in-house
User-centric open	users considered important source of information
	relevant procedures are widespread
	users are only involved in certain phases, discharged as they learn the new products and give less critical feedback
User Driven	development is open and led by users
	firm enters intense, long-term cooperation with users
	well-established procedures for user involvement
	value co-creation across organization

The Second Part of the interview and thesis regards the IMO and its guidelines, the IALA reporting and guidelines, and e-Navigation development in general. I used purely inductive codes for this part due to its specificity where earlier research was not found.

Research Methodology

Research design is the logical sequence that connects a study's empirical data to the initial research questions and ultimately to its conclusions (Bennett, Glatter, & Levašič, 1994). This chapter is meant to serve as an explanation to the linkage between my research questions,

the chosen method and samples for data collection, and analysis. My research question regards e-Navigation testbeds in general. The desired research design was to obtain respondents representing different testbeds or testbeds within larger projects, in order to obtain larger credibility if there is any consistency across cases (Rubin & Rubin, 1995). This would also align for comparison between cases if differences occur. Different types of informants would be beneficial to see how they perceive a situation (Dalen, 2013). If informants are too homogenous, they could give answers that reflect only the view of their group, and give a too narrow frame for the exploration of views to user involvement in e-Navigation in general.

Research Strategy

As a main strategy of this thesis, a qualitative approach has been chosen to facilitate a wider understanding of the interrelated factors in e-Navigation as user driven innovation. An alignment between existing theory on user centered innovation and e-Navigation was made to assess the fit between theory and practice, and at the same time identify the main drivers, barriers and the improvement potential in terms of reaching a higher level of user involvement in e-Navigation. The framework is used to set the boundaries of research.

User Centered Innovation Theory	e-Navigation Case	Alignment
Producer driven innovation User Centric innovation, HCD/UCD User driven innovation	e-Navigation Features	Level of User Centered Innovation and HCD implementation
HCD Drivers HCD Barriers	HCD Drivers HCD Barriers	Drivers and Barriers for HCD in e-Navigation

Improvement potential

The theoretical framework is structured by the following rationale:

1. Assessing the level of user centeredness in testbeds by accessible web sources and various testbed participants' experience. The level of user centeredness is a starting point for discussing drivers and barriers to the implementation of HCD in e-Navigation.

2. Identifying drivers and barriers to performing HCD in e-Navigation internally and externally to the e-Navigation projects. Identification of the main drivers and barriers to HCD is essential for the recognition of factors that promote or hinder a holistic performance of HCD in e-Navigation.

3. Identifying the effect of external factors surrounding the e-Navigation development by the perspectives of test participants. The perceived influence of external factors provides a mirror view of perceived impact compared to the intentions of official stakeholders and serves as a feedback if those intentions are achieved.

Qualitative studies

Qualitative studies provide a possibility to understand how and why the parameters in question are fulfilled or not by using open-ended questions and words rather than statistical numbers (Creswell, 2014). This study seeks to understand the context of implementing HCD and user participation in e-Navigation, by a combination of interviews and analysis of web reporting. This falls within what Creswell (2014) explains as a constructivist worldview, by inductively developing a theory or pattern of meaning from the meanings that others have about the world. To follow this process, I allowed emerging questions to be added to the interview guide underway, for further interpreting and making meaning of the data (Creswell, 2014, p.4). The study deals with words and concepts rather than statistics, while data points are used for

indication of context only. It provides counting and summary tables meant to serve an easier projection of findings and relationships, but with no statistical significance.

The research strategy is inspired by the approach suggested by Flick et al. (2007) for qualitative studies. The use of axial coding is an element collected from Grounded Theory which I found useful to connect codes to higher categories. According to Creswell (2014), a qualitative study involves analysis in two levels: a) the general analysis of data and b) the steps embedded within the specific research design, which has been described previously. Though seeking to gain emerging findings through open-ended methods, the benefits of framing the research through preset theory and tentative categories is highlighted by both Yin (2012), Creswell (2014) and Marshall & Rossman (2016), especially for novice researchers who might become overwhelmed by data from open research strategies. Therefore, the literature review was used to create the interview guide and identify tentative, deductive codes and categories to search for in the first cycle of analysis.

Data Collection

Semi-Structured Interviews

Semi-structured interviews allow for open-ended questions and probing, but is centralized around themes already chosen by the researcher (Dalen, 2013). The answers to the interviews make up the data material of the study and as such the questions should encourage rich and detailed answers (Dalen, 2013). The aim was to create good questions that were clear, not leading, required special knowledge, were too sensitive and still allowed for original answers (Dalen, 2013). The questions were created based on the research questions and what was found in the literature review. In this study, the relations to special knowledge such as the HCD principles and guideline as well as major stakeholders are of interest, as that would indicate the

actual drivers and barriers to HCD in e-Navigation. An answer of little or no knowledge of such information is still regarded as valuable information. The Interview guide was created with themes and features from living labs and open innovation, the guidelines for HCD and reporting on IALA web page, and external stakeholders.

The semi-structured interview provides the possibility to ensure the interviewer understand the answers correctly, and to ask follow-up questions to cover the topic sufficiently. The interviewees could speak freely on their thoughts of each question, which provided widespread information and experiences regarding the topics.

Qualitative research cycles may be built by adding questions to the interviews to test out ideas underway (Dalen, 2013). An initial interview guide seeking out the main themes, as well as practical information such as age, gender, nationality and experience, was developed before data collection started. The interview guide was tested with a colleague before performing the first interview; however, the specificity of the domain meant that still some irrelevant questions were removed between the interviews, and some were reframed or added to better capture the themes of interest (Dalen, 2013). The last version of interview guide is attached in Appendix A.

Interviews lasted approximately one hour and were performed face-to-face at college campus, on the premises of the informants, and on Skype for the more remotely located informants. Notes were taken during the interviews for backup of information storage. Interviews were recorded and transcribed within a week of completion.

Web Reporting

IALA testbed reporting site was initially analyzed for a mapping of reporting level, indication of user involvement and use of HCD methods. It was later analyzed again for indication of user involvement, methodology and findings for a possible triangulation with

results from qualitative interviews. The reporting on IALAs web site indicates the level and type of user involvement for a testbed, and IALA's potential role as driver in e-Navigation. Most testbeds provide links to own websites for more detailed information on the projects. User involvement could be indicated here if reporting on IALA is limited. To investigate the accessibility of information on user involvement, presence directly on IALA site was the first part of the analysis, while number of actions to find relevant information on separate web page formed the second part. The search function on the web pages were utilized as well as the "word search" function on the screen. Search words were; user, operator, methodology, findings. User, methodology and findings are word used by IALA in their guideline and example page (IALA Guideline No. 1107, 2013). The term "Operator" was discovered on one testbed site, but provides also several hits that are not directly relevant to user involvement due to its various meanings in the maritime domain.

Sampling

Sampling strategy was decided based on the research questions and literature review. IALA e-Navigation web pages was used for the initial identification of testbeds and finding possible representatives for interviews as it should contain most of the important testbeds. Testbeds not being identified as direct e-Navigation testbeds (www.IALA.org) were disregarded to keep the focus on those projects that will affect maritime end users directly on land and on board. To capture feedback that was still relatively fresh, testbeds completed before 2015 were disregarded in the first run of approaching the research field.

An invitation email was sent to responsible persons listed on the testbeds that fit the preset limits of relevance, to get a small group that was representable of the population of e-Navigation participants (Marshall & Rossman, 2016). The collection would then be convenience

based, in that the ones who responded positively would be chosen for interview. The study would also be feasible for snowball sampling, as the participants would suggest other people with rich information on the case (Marshall & Rossman, 2016). Out of 15 approached testbeds, three responded positively and provided two respondents each for the interviews.

As interviews progressed it became apparent that e-Navigation communities are built up by individuals who are attached to several testbeds, often related to or in continuum of each other. Hence; they do not only represent one testbed, but up two seven completed or ongoing testbeds. The study then progressed to focus on the individuals and their experiences within e-Navigation as belonging to networks that emerged; the "Nordic Community", the "Norwegian Community" and "German Community". Analysis is done on the individual level and community level.

Table 4. *Overview of Study Participants*

Community no	Interview	Role	Partner type	Testbed Type
Comm 1	Interview 1	HFE expert	Academy	EU / Nordic
	Interview 2	WP leader	Authority	EU / Nordic
Comm 2	Interview 3	Developer	Industry/Academy	EU / German sub proj
	Interview 4	HFE/coordinator	Industry/Academy	EU / German sub proj
Comm 3	Interview 5	WP leader	Industry	Norwegian
	Interview 6	Project Manager	Industry	Norwegian

The sampling for the analysis of the reporting page is done differently, as I wanted a higher number of testbeds for a realistic analysis of the page itself and the display of user centeredness. I also wanted to provide a view outside the sample testbeds to mitigate the possible bias in only interviewing testbeds being interested in HCD. Reporting seems to be done late in projects and the same selection criteria as for interviews would result in sparingly interesting data for analysis. All testbeds were put on a numbered list and numbers picked randomly by a digital number generator. Initially five testbeds were chosen, but as the results

were scarce and seemed not representative, three more batches of 5 testbeds each were added until 20 were included in the simple analysis. This accounts for 44% of all 45 testbeds listed on IALA. The sample was drawn at random from all testbeds at all completion stages. Here analysis is done on testbed level due to the nature of available data. The analysis of web reporting must be seen as complementary to the analysis of interviews.

Data Analysis

Analyzing went parallel to the collection of data (Creswell, 2014; Marshall & Rossman, 2016 p.208). Already when transcribing the first interview, I started dealing cognitively with the data, interpreting and considering the relevance of questions and response, and possibly missing information by transforming data from spoken to the written word (Marshall & Rossman, 2016). The process was a dynamic one, going back and forth between categories, codes and transcripts, checking consistency and searching for further literature to support the findings. Doing manual analysis is time-consuming as Creswell (2014) points out, but due to the relatively low number of interviews it was manageable.

As first cycle of coding, relevant parts of interviews were summarized and grouped into categories as suggested by Creswell (2014). The summary was then used to identify the preset theory-generated codes (Marshall and Rossman, 2016) in table 1 and 2 in "Operational Definition", to assess the fit towards existing literature. Some factors specific to e-Navigation were also added for the sake of this research. New codes emerged inductively from the real-life data to cover drivers and barriers relevant to e-Navigation, which were not found in the literature review. This was done by performing what is commonly referred to as "open coding" (Marshall & Rossman, 2016), using chunks of text to generate categories and codes by what is experienced as the meaning of text. I first marked text parts in the line numbered texts, and gave it a category

name and a shortened text containing the main message. This was pasted into a common table for all the interviews, where shortened text parts falling into the same categories were put together for comparison. The reference to line numbers made the findings traceable back to the raw transcripts. Each category could contain several codes, summarized in the columns and margins. All codes were then listed in a new, common document for easier review and comparison of which interviews provided which codes. This approach was inspired by web resources from educational institutes, and the works of Creswell (2014), Marshall and Rossman (2016), and Miles, Huberman And Saldaña (2014).

Two approaches are used in analyzing the interviews for indicators of user centeredness; the existing framework of Leminen and Westerlund (2011), and a setup of factors found in existing literature including ISO 9241-210 and IMO MSC.1/Circ.1512. The interviews were analyzed for information matching deductive and inductive codes and categories, including utilization of methods and users, view on users and user roles. The list in Table 6 shows the main indicators, summarized for each respondent and community as a tentative benchmark of the level of user centeredness.

The main categories and codes were summarized in Appendix F and G for further analysis and discussion. Reporting on IALA and own web pages were summarized in Appendix H and summarized graphically in Figure 3.

Validity, Reliability and Generalizability

Validity is one of the strengths of qualitative research as it concerns whether the findings are accurate from the standpoint of the researcher, the participant or the readers of an account (Creswell & Miller, 2011). The ability to assess accuracy of findings in qualitative research is achieved by applying appropriate procedures to research design. Findings in this study are

supported through secondary sources on the Internet, and converging the perspectives of several participants from different testbed communities. The sampling from several communities strengthens the possibility to say something about e-Navigation in general by including both producer- and authority led testbeds, and testbeds outside and within EU. A rich, thick description of findings (Creswell, 2014) is attempted to strengthen the validity of findings. Spending a prolonged time in the field is also advised by practitioners (Creswell, 2014; Marshall & Rossman, 2016), however this was not feasible in his study. Minimizing researcher bias by identifying one's own preconceptions is essential (Creswell, 2014; Dalen, 2013). My own background from the maritime industry at sea and on shore, may well give some preconceptions towards the user centeredness of maritime products. To minimize researcher bias I aimed to stay aware of my own preconceptions, and open minded to earlier research and emerging data, without favoring any of the data found throughout the study. Interview guide was created with as neutral and open questions as possible, based on literature review and personal perceptions of the field. I also looked for and present in the thesis some diverging findings to themes to reflect the realism of the study (Creswell, 2014).

Qualitative reliability indicates a consistent approach across research (Flick et al., 2007). The transcripts were checked for obvious mistakes, and codes were checked for drifting by going back and forth between codes and data (Creswell, 2014). A simple "code book" was kept to gather the meaning of codes. As there was only one researcher, "inter-coder" agreement was not a relevant challenge.

In contrast to quantitative studies the aim of qualitative studies is not to generalize findings to individuals, sites or places outside of those under study (Creswell, 2014), but rather to understand a phenomenon from the participant's perspectives. This study involves different

respondent types from different testbeds, from which general abstractions are made within the field of e-Navigation, as a form of transferability (Marshall & Rossman, 2016).

The nature of this study demanded authorization from the Norwegian Center for Research Data (NSD), which was granted. All recordings and note takings were anonymized and recordings were deleted at end of the project. No information in the study will be traceable back to any informant. The study followed the norms of *informed consent* where informants agreed that the interview be tape recorded and were informed of the right to withdraw at any time.

Limitations

Only testbeds in Northern Europe responded to the interview invitation, which means the study is representative of e-Navigation as it is performed in Northern Europe. Furthermore, the convenience based sampling bears with it a risk that those who responded positively to the invitation, are the projects with the highest interest in and knowledge about HCD. More producer-led testbeds might have been missed out, and if so, their views to barriers and drivers are missed out. The limited number of interviewees are a limitation in that a higher number of respondents would provide more empirical converging or disconfirming data, thus increasing validity of the study.

Findings

This part presents the findings from data analysis in the following structure; firstly, the level of user centeredness, then the identified drivers and barriers to HCD in e-Navigation, and finally, a separate part is granted the external factors to e-Navigation and their role in promoting Human Centered Design. The narratives of interviews are attached in Appendixes B to E. As a way of systematizing the findings, drivers and barriers are grouped into higher categories as

resources, operational aspects, human aspects and external factors in figures 4, 5 and 6. Some factors found in academic literature, were not identified in this thesis.

User Centeredness

User centeredness is extracted from two sources; web sites, and the interviews with representatives. I will first present the findings from web reporting, and then the analysis of interviews.

Analysis of Web Reporting

The analysis of IALA's reporting web page for e-Navigation testbeds showed that out of 20 randomly chosen testbeds listed, 7 reported more than a short description and link on the web page. Out those seven, all reported directly on the page that user representatives had been or would be involved, 2 mentioned the methods and 3 also described their findings.

Out of the 7 separate web pages that were found, accessible and readable, 4 pages mentioned user involvement, 3 also mentioned methodology and findings. Two of these were the same testbeds that reported positively on the IALA reporting page. See also the attached table 10.

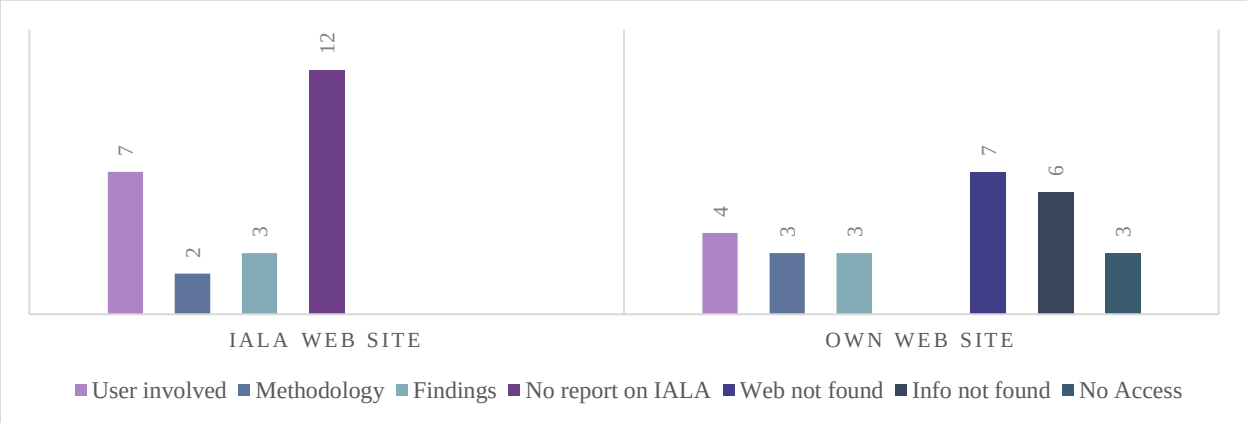

Figure 3. *Reporting of User Involvement on IALA and Separate Web Pages*

Analysis of Interviews

Analysis of interviews provided indicators of user centeredness as summarized in Table 6. The main differentiators between communities are number of HCD methods mentioned, resources and identification of user needs. View on user as co-designers and idea generators are the identifiers lowering the score on user centeredness. The result of analyzing testbeds towards the existing framework of Leminen & Westerlund (2011) is shown in table 3.

Table 6. *Indicators of User Centeredness in e-Navigation Testbeds*

	Comm 1		Comm 2		Comm 3		Possible total
Indicator	Int 1	Int 2	Int 3	Int 4	Int 5	Int 6	
No of Methods	5	4	2	5	1	1	9
Involvement Stages	3	3	1	3	2	2	3
No of user experience types	2	2	1	1	1	1	2
Identified User needs	1	1	1	1	0	0	1
Co-design	0	0	0	1	0	0	1
Informant	1	1	1	1	1	1	1
Test and validation	1	1	1	1	1	1	1
User Idea generation	0	0	0	0	0	0	1
Iterative loop	1	1	0	1	1	0	1
Clear responsible for HCD	1	1	1	1	1	1	1
Resources for HCD	1	1	1	1	0	0	1
Interview sum	17	15	9	16	8	7	22
Comm Average	16		12,5		7,5		

Table 3. *Themes and Indicators of User Centeredness Derived From Leminen and Westerlund (2011)*

Comm 1 (2) ((3)) / Theme	User Driven	User Centric Open	User Centric Closed	Technology/ Producer Driven
Cooperation	Long-term	Users involved in certain Phases 2 (2)	Pilot-test, systematic surveys and test at company Different users at different phases. 2 (2) ((2))	None
Procedures	Well-established	Widespread 1	No general instructions 1 (2) ((2))	No general instructions 1 (2) ((2))

User Roles	User Driven Influence objectives, design, milestones	Important source of information 2 (2)	Visible Role ((2))	No direct contact Third Party perform user survey.
Policy for Intellectual Property	Open collaboration	Open collaboration	IP's to keep knowledge in-house	IP's to keep knowledge in-house. Producer's ideas and Patents (1)
Skills & resources for user involvement practice	Sufficient 2 (2)	Sufficient 2 (2)	Sufficient 2 (2)	Missing ((2))

Note. Cases are numbered 1, 2 and 3 as in other tables. Within the table, numbers 1 or 2 show if one or both representatives in a case provided the information. Cases are indicated by plain number for case 1, simple parenthesis (2) and double parenthesis ((3)). Categories may be valid for several levels of user centeredness.

Drivers for HCD in e-Navigation

Drivers related to human aspects; beliefs, desires and increased consciousness towards HCD and its prospected gains in usefulness and marketing were most often mentioned in interviews. Funding that allows wider cost frame, and project demand from project owners are followed by economic regions' technological competition and desire to "be first". Finally, the role of HCD enthusiast emerged, meaning a person that drives and encourages the HCD processes in the testbeds.

Table 7. *Drivers for HCD in e-Navigation*

Variable	Occurrence	Factor type
Beliefs (marketing, use)	6	human
Desire Product usefulness	5	human
Increased Consciousness	5	human
Funding	4	resource, external
Project Demand	3	external
Official stakeholders	3	external
Regional Competition	2	external
Enthusiast	2	human, operational

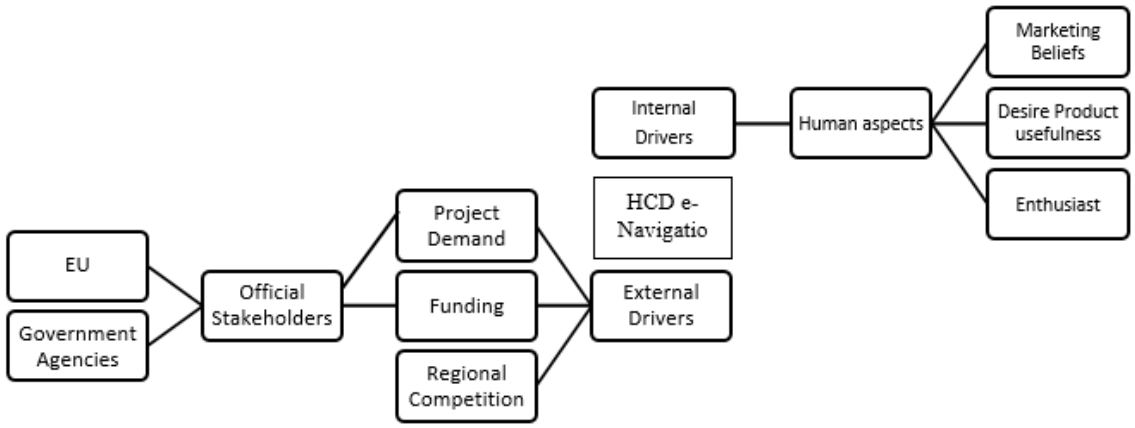

Figure 4. *Relationship Between Internal and External Drivers to HCD in e-Navigation*

Barriers for HCD in e-Navigation

Various barriers to HCD were identified in interviews and summarized in Table 8. The most frequently mentioned barriers were time and cost, followed by the perceived resistance among ship owners related to missing business cases and unknown outcome versus cost frame. Reluctance was identified in three groups; industry as presented by producers, ship owners as buyers ending up with cost, and users as being skeptical to change status quo and test unfamiliar solutions. Availability of valuable user was mentioned as an essential challenge to planning and performing HCD activities. More detailed description of barriers found in interviews is attached in Appendix D.

Table 8. *Barriers to HCD in e-Navigation*

Variable	Occurrence	Factor type
Time	6	resource
Cost	5	resource
Owner reluctance	4	external
Missing business case	3	operational
User availability	3	resource
Planning	3	operational
User reluctance	3	human
Uncertain result	3	operational

Industry reluctance	2	internal
Trust building, communication	2	human
Time Coordination	2	operational
Knowledge	2	resource
Rules and Regulations	2	external
Contracting and budgeting	1	operational
Physical Distance	1	operational

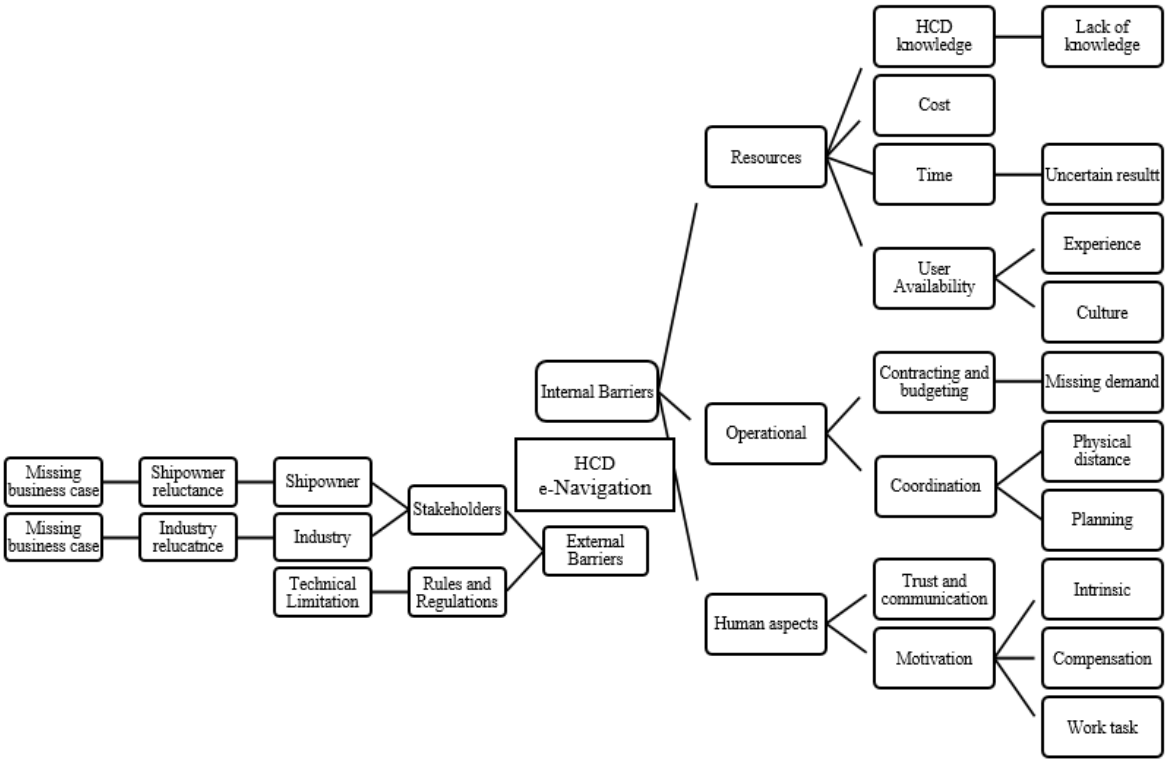

Figure 5. *Relationship Between Internal and External Barriers to HCD in e-Navigation*

External Factors in e-Navigation

Findings on external factors are described in appendix E. An overview of internal and external factors influencing on the utilization of HCD in e-Navigation is suggested in figure 6, summarizing drivers and barriers provided in figure 4 and figure 5. The factors may have features as both driver and barrier, for example *contracting* will signify a demand for HCD,

while the lack of specifying HCD in contracts forms a barrier to such. The frequency of occurrence in interviews are illustrated in the figure by font size.

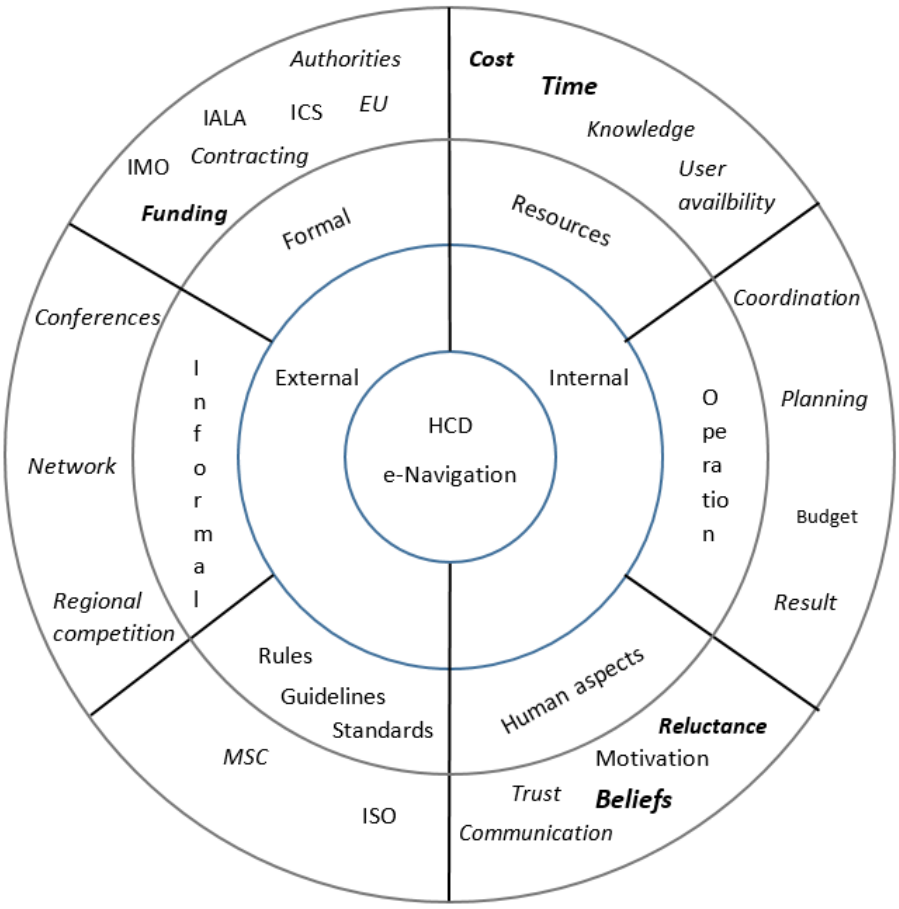

Figure 6. *Overview Factors Influencing Human Centered Design in e-Navigation*

Discussion

This part will discuss the findings and possible underlying explanations in the context of existing theory. Convergences, conflicting and new findings are discussed in the same structure as provided before; user centeredness, drivers and barriers, and external factors influencing human centered design in the field of e-Navigation. Table 9 Summarizes the main findings and the supporting existing research.

User centeredness

e-Navigation projects consist of private-public-people partnerships as described by Leminen and Westerlund (2011), however the way users are attracted to and given influence in the projects indicate that the projects tend to be user centered without being user-driven. The driving role in the cases are filled by either manufacturer or Authority, who attach users to the projects in the phases and to the extent they see feasible. Analysis of web sources indicate that those testbeds that follow the incentives for reporting, also follow incentives to involve users in the projects. Other testbeds listed on the page provided no information on testbed or user involvement, which makes it unrealistic to claim anything about their user centeredness. By looking at the testbeds that do report on IALA and own web pages, user involvement, methods and findings are reported to an extent that indicates some user centeredness.

The interviews provided more data on user centeredness than open innovation. By aligning the analyzed data and existing framework, the case testbeds fall into the categories of User Centric Open/Closed with one trending towards Producer Driven Closed. However, the identifiers of open or closed innovation is sparingly and not significant for the result (See Table3). None of them matched the features of user driven innovation in the framework of Leminen and Westerlund (2011), which corresponds with their original findings where no cases were fully user- or producer-driven. A modified model of user centered innovation in e-Navigation is suggested in figure 7.

The empirical summary of indicators for user-driven innovation show that the majority of testbeds are unison in not having users in active roles as leading or co-designing in the testbeds. Users do however, play an essential role in the testbeds as they are involved in different phases and by different HCD activities. The testbeds run by authority or academia, and being strongly

connected to HFE experts, expressed a more cognizant use of formal methods than the manufacturer driven testbed. This supports the findings of Costa (2016) arguing that HCD is seen as complicated for non-experts, and Mao et al. (2005) that heuristically methods tend to dominate, combined with lack of knowledge and lack of planning.

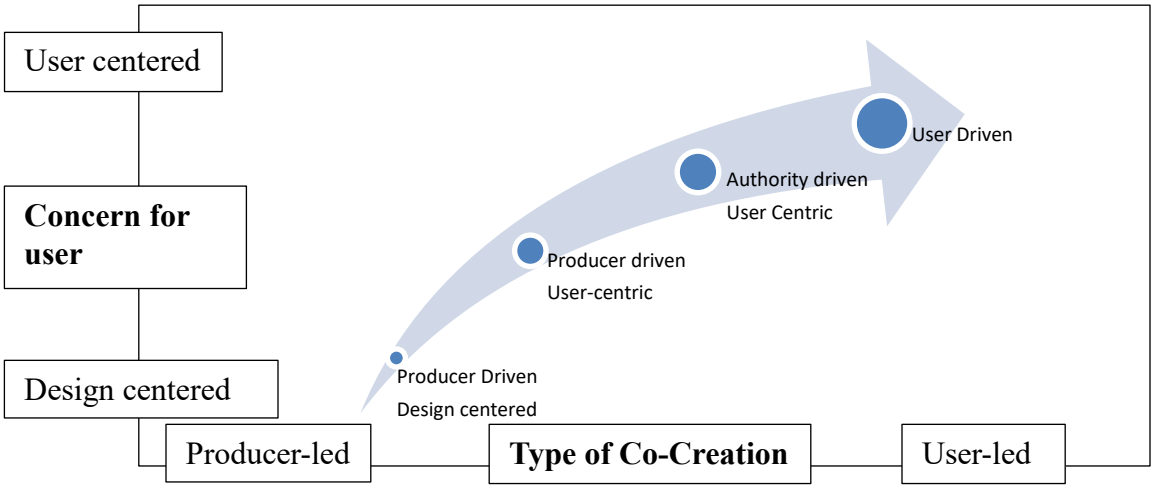

Figure 7. Modified Illustration of Producer – or User driven innovation by partner roles and concern for user in e-Navigation

Drivers, Barriers and External Factors to HCD in e-Navigation

The analyzed data of this thesis provided numerous drivers and barriers to HCD in e-Navigation. Drivers and barriers as found by analysis and supported by literature is displayed in Table 9.

HCD is performed with various levels of cognition in the cases, depending on the role of HF/E experts and the knowledge about HCD in the projects. Costa et al. (2017) suggests that an HCD educated project manager in close cooperation with a HF/E specialist could lead designers to perform HCD activities more efficiently. As shown also in this case, HCD process and terminology are not common skills and needs to be guided and translated into practical tasks for the design team. In practice, HF/E experts are connected to the projects on a remote basis, where

they give tasks and advice at occasions. Consistent access to HF/E or HCD experts would facilitate shaping of plans and methods to the project's needs at beginning of the process (Costa, 2017). This is consistent with statements of the producers, who would have liked to include the HF/E expert more.

Cost, time and user availability are the most frequently found resource-related hindrances to HCD in this study, which is also a common barrier identified in existing literature (Mao et al. 2005, Horberry et al. 2015, Costa 2016, Kujala, 2003). Physical testing and iterations are resource demanding and must be planned for. The need for business cases and cost-benefit figures for HCD have been addressed by researchers in other domains (Mao et al. 2015, Horberry et al. 2015, Turkama 2010, Kujala, 2003) to overcome reluctance from the producer industry and buyers. This corresponds with the perceptions of informants for the e-Navigation Case. User availability and attraction is a challenge also in other domains (Kujala, 2003), and sailing schedules of active officers increases the problem for maritime (Costa, 2016). The interviews confirmed this to be a returning issue.

Turkama (2010) theorizes that lack of clear responsible is a barrier to the running of living labs, however this was not found in the e-Navigation cases. Rather, planning and budgeting HCD activities from the beginning was missing, when it was not part of the formal order from the customer. When not part of the contract, HCD received a lower priority despite the producer's positive beliefs and expectations that HCD would provide better alignments between user requirement and delivery, as was also found by Kujala (2003). The lack of contracting signifies a lack of formal demand, an issue that was found also by Horberry et al. (2015). The increased positive consciousness and recognition that HCD is perceived to have

gained the recent years could counteract this tendency and alter the prioritizations and demand for HCD in the future.

In terms of internal operation of the projects Kujala (2003) found that user involvement is not without challenges. User motivation and willingness to test and provide useful feedback is essential for success, however some users could turn out quite unwilling. This was expressed also by some of the respondents in this case, where especially senior officers were perceived to be somewhat reluctant towards new solutions. Kujala (2003) further brings forward that designers and users often have problems in communication. Users are not educated in design process and HF/E terms, which complicates communication and understanding of goals, tasks and objectives of activities. In this study, it was pointed out that designers feel uncomfortable in getting feedback from users and questions from HF/E experts. Users might also feel uncomfortable testing unfamiliar products where they feel revealed as less competent. This shows the need for *trust building* and better communication as also shown by Costa (2016). A conscious translator standing between the designers, users and HF/E expert could remedy this, as mentioned in the interviews and supported by Kujala (2003). The time spent on resolving issues between users and designers must be weighed against the gain in better user requirements and better products. This study also found that HCD activities tend to gain a lower priority than other objectives, and that a *HCD enthusiast* is necessary to drive the user centered innovation cycle. This corresponds with the findings of Costa et al. (2016) that a proactive HF/E expert was desired by the design team.

Coordination of resources is essential to the outcome of HCD (Costa et al. (2016). Interviewees experienced that physical distance between design team and programmers resulted in a loss of common creation phase, and that lack of planning and coordination meant that HF/E

expert was not properly utilized. HCD was not seen as something the firms would carry out on their own or as an integrated way of working for the firm, as promoted by Costa et al. (2016), and as such relied heavily on the HF/E expert as responsible for user involvement. This is a natural consequence of the lack of knowledge about HCD practice in the production company.

Rules and regulations was experienced more as a barrier than driver, in opposite to my original expectations. Existing mandatory standards such as performance standard for ECDIS limit the possibilities for adjustments and stand in direct opposite to HCD according to the informants. Baldwin & von Hippel supports the view that rules and regulation decrease the value of innovation opportunities. For HCD itself there are no mandatory rules, and the guidelines have little impact for the time being.

The identified drivers for HCD in e-Navigation today are less than the barriers, which might explain the more occasional use of HCD as innovation process. The drivers exist on a more overall level than the practical barriers. In the end, it boils down to the beliefs of decision makers, leading to formal demand and informal expectations to HCD implementation. The expectations that user involvement may provide better products based on better user requirements, thus being a good marketing argument, is generally found in literature. (Mao et al. 2015, Kujala 2003, Niitamo et al. 2006, Costa 2016). Costa et al. (2016) also supports the finding that the funding in e-Navigation allows design teams to spend more time and resources on performing HCD. Project demand exist in some cases, while in others not. The result of missing demand has already been discussed. Official stakeholders as IMO and IALA acts more as a distant push, where the influence acts through other stakeholders as partners in projects. EU and coastal authorities as direct partners in projects received credits by the interviewees for their active role-taking in projects.

Seeing opportunities for future business and for influencing standards for solutions in e-Navigation, a state of competition between technologically leading regions were suggested by the informants. Consequently, new projects are publicly funded with the objectives of staying in the lead of development. Following IMO incentives and partner's expectations to the positive effect of HCD, this is a possibility for increased level of user centered projects in the maritime domain.

Table 9. *Drivers and Barriers to HCD by Analysis and Supporting Literature*

Drivers	Supported by literature
Beliefs (marketing, use, alignment)	Mao et al. (2005), Kujala (2003)
Desire Product usefulness	Mao et al. (2005) Niitamo et al., (2006)
Increased Consciousness	New
Funding	Costa (2016)
Project Demand	New
Official stakeholders	New
Regional Competition	New
Enthusiast	New
Barriers	
Time	Mao et al. (2005) Horberry et al. (2015) Costa (2016)
Cost	Mao et al. (2005) Horberry et al. (2015) Costa (2016)
Owner Resistance	Horberry et al. (2015)
Missing business case	Turkama (2010), Mao et al. (2005), Horberry (2015)
User availability	Costa (2016) Kujala (2003)
Industry (Designer) reluctance	Horberry et al. (2015)
User Resistance	Kujala (2003)
Uncertain result	New
Lack of Planning	New
Trust building, communication	Costa (2016) (Kujala 2003)
Coordination	Costa (2016)
Knowledge	Costa (2016), Mao et al. (2005), Horberry et al. (2015)
Rules and Regulations	New
Contracting and budgeting	Horberry et al. (2015)
Physical Distance	Costa (2016)

Conclusion

This study set out to explore the level of user centeredness in e-Navigation, its drivers and barriers to Human Centered Design, and the role of external factors. By comparing with

existing frameworks and derived indicators, I found that the e-Navigation cases are user centered but not user-driven. There is still room for more user involvement by demanding, budgeting, planning and coordinating user involving activities and HF/E experts throughout the innovation cycle.

The drivers for HCD are less numerous than the barriers, the main factor being the beliefs and expectations of project owners for increased benefits during the design process and to the end product itself. e-Navigation is in a unique position for implementing and performing HCD as innovation platform, due to the large official funding and conscious prescriptions set by certain stakeholders in the domain, which might outweigh some of the identified barriers.

More challenging barriers to overcome, in addition to the well-known cost-time perspective, are the challenges related to interpersonal factors. Reluctance are experienced from both designers, users and ship-owners. HCD is demanding for the involved parties, who might lack the know-how, practical tools, common language and necessary confidence in each other. More specific contracts could serve to increase the focus on HCD, and a closer cooperation between designers, HF/E experts and core users could improve the common understanding and trust between involved parties.

With missing business cases and success stories in the background, HCD suffers challenges to perform and convince cost sensitive buyers of the benefits involved. Until HCD becomes common industry practice, external stakeholders will continue to pay an important role in highlighting, encouraging and demanding user involvement in their tenders for further projects in e-Navigation.

Suggestions for Further Studies

Future studies could consider how to provide success stories, supporting numbers and business cases for HCD in e-Navigation, which was highlighted as a need in this study. Another issue to explore is how the relationship, including trust and communication, affect or could be improved between HF/E experts, designers and users in e-Navigation projects, to bridge the knowledge and terminology between the parties.

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APPENDIX A. Interview Guide

Testbeds features

1) Testbed:
2) Firstly, could you please explain type of partner do you represent in the testbed; (public, private, educational, designer, manufacturer or user)?
3) Could you briefly describe your testbed, size, its participants and objectives?
4) How is/was your testbed coordinated?
5) How would you describe your role in the testbed(s)?

User involvement / Living Labs features

Do you know if any user representatives have been involved in the developments of your testbed?

a) What were their role? (active contributors/passive objects of study)
b) At which stages in the process were the users involved?
c) Did the users contribute to develop any of the testbed's ideas or solutions? (who, when, how)
d) Which HCD methods have been used in your project?

HCD Driver / Barrier

6) In your opinion, which HCD methods are most valuable in e-Navigation?
   a) Do you see any benefits by involving users in the innovation process?
      (1) Could you give an example?
   b) Are there any challenges with involving the users?
   c) How do management and designers relate to HCD methods?
      (1) Do they see the benefits of HCD?
   d) Do you have the time and resources you need to perform proper HCD cycles in the project?
7) Do you know how users are found and connected to the project?
   a) Are they hard/easy to find and engage in the project?
   b) What is their benefit of participating? (their motivation)
8) Who is/was responsible for the HCD activities in your project?
9) How firm are the testbeds objectives and budgets?
   a) Are goals and milestones firmly set from the beginning or may they be adjusted underway?
   b) Are you able to benefit from unexpected discoveries underway?

External incentives, stakeholders and guidelines as driver / barrier

10) How well do you know IMO's Strategy for implementation, the SIP, for e-Navigation?
    a) Which role does it play in e-Navigation in general and the testbed?
11) IMO has developed a guideline for SQA and Human centered design for e-Navigation. Could you please describe if this has any impact on the work of the project you are involved in?
12) How well do you know IALA's reporting page and guideline for reporting of testbed results in e-Navigation?
    a) Is there a fixed responsible person for the reporting?
    b) How does that guideline fit the work of your testbed?
    c) Which benefits or challenges do you see in that common reporting page?

d) Have you used any discoveries already reported on the common web page?

13) How is your project's connection with IALA as coordinator of reporting results in e-Navigation?
14) Are there other stakeholders that are more important to the work in your project? (who; government, buyers, EU)
    a) Do they require or encourage any human centered design focus or documentation of such activities?
    b) If there was documentation that HCD methods were used for a design, do you think that would affect the customer's willingness to buy the product?
15) What would you say is the main motivation behind user involvement in e-Navigation?
    a) Is it because of external expectations or internal motivations
16) How do the new ideas develop?
17) FOR AUTHORITIES and BUYERS: As "customer" of e-Navigation, do you require or encourage HCD in any way?

Drivers in e-Navigation, coordination and open innovation

18) Does your project have any relationship with other testbeds?
    a) Have you utilized discoveries or methods already made and reported by other testbeds?
19) The guidelines that I have mentioned regarding testbeds reporting and HCD are voluntary, how do you perceive the objective of them? (valuable, important, unnecessary)
    a) Do you think that they should be mandatory, and why/why not?
    b) How do you feel that regulations affect innovation in the maritime domain?
    c) How do you perceive the interest for user involvement and HCD in the maritime research environment?
    d) Has there been any change in attitudes towards HCD from start until now?
20) Do you have any thoughts on the IMO's e-Navigation initiative in an overall perspective compared to your work?
    a) What/who is the main drivers behind the e-Navigation developments? (IMO, IALA, EU, authorities, technologists, educational institutions.)
    b) Do you believe that the e-Navigation development will be possible to harmonize and standardize as intended?
21) Do you have any other comments or useful information that I missed?
22) May I contact you if I have further questions?
23) Are there any informants you would recommend me to contact?

APPENDIX B. Interview narrative on User Centeredness

Users play an important role in all the testbeds investigated in this study. The interviewees acknowledge the value that users bring as informants about the innovation field, and for finding user needs for further development. They also highlighted the need for productive face-to-face interaction to gain a wide understanding of users' environment and needs,

the product would not be the same without asking them. And if you only do a questionnaire or observe you will not get the explanations that fill in the picture. So, it is good to talk to them to get the better result.

Another respondent made a comment that also promotes the value of distant observation of real behavior of the users,

The biggest gap that we can close is the difference between, how they should work, by local procedures or what they were taught in school or by procedures, and how they actually perform. Also, sometimes people think they act in a certain way, which is different from what they actually do. Which is interesting to see from the outside, also.

There are however, some differences in the practicalities in exploiting this value.

The main differentiators are the utilization and knowledge of different HCD *methods*, and available *resources* for HCD. While two cases experienced that they possessed the necessary resources to perform proper HCD cycles, one reported that they did not. They expressed that user needs had been found late in the process and by coincidence as in opposite to the other cases, who would name the specific methods by jargon. Though all respondents agreed that early involvement of users is important for an optimal outcome of projects, this part was not planned for in the last case, and was generally skipped to keep time frame and budget,

We skipped the sketch and paper and all that. We went straight to «here, we made something, what do you think about it? And then it is like they realize «OK, it is already made, maybe you can change that font over there and redo that table. » (...) So that is what we miss. The alignment of expectations comes too late, and the gap becomes bigger.

Interviewees pointed out that the earlier users are given the possibility to comment on the product, the larger the possibility to make changes to a lower cost and with less effort. If the input comes too late, it might not be possible to integrate the comments at all, and the users respect the product that is presented to them.

User types involved in the projects varies with the type of product or service being developed, including students, novice and experienced seafarers, pilots and VTS operators. The value of utilizing users with various level of experience was mentioned by several, although also reminding that the involvement of users is not motivated by finding the most popular solutions rather than eliminating design flaws and save development by avoiding unnecessary functions. There was also the concern that users "learn" the scenarios and the flaws in the systems, and as such provide less authentic feedback on the testing with time. All interviewees involved at least one type of user in terms of experience, and chose from students and operators as it fit the product.

In terms of resources, all responded that the responsibilities for performing HCD was clear. Each testbed was connected to a form of "expert" person or firm, that would shape or carry out the activities related to HCD. The variation between cases lies in the role and priority that was given to the HCD responsible throughout the process as illustrated by an industry partner,

... so no there was not a formal process. And the project was not budgeted to have Human Centered Design Processes throughout, so ... we did not have..., we have done Human Centric Design with some of our software, with some of it and it is an expensive process. So (...) we would have liked to have given him more hours, so that he could do all the things that he wanted to do, but unfortunately.

The majority of respondents claimed to be truly dedicated to the HCD process and had also been involved in the development of the HCD Guideline for IMO. One HFE expert expressed a sense of disappointment to the general interest in HCD within e-Navigation,

Something that I feel has happened lately is that the industry has become more interested in participating in the testbeds, that is interesting and then it changes. In the beginning, it is mostly enthusiasts and then the interest for performing HCD is greater, now it is more a question of... when the industry is a partner they are more interested in developing their own little bot and think maybe HCD is, it becomes a burden you know, so that is my impression (...) that I do not perceive the interest that I wanted to see from the beginning in this user involvement.

The features related to *user driven innovation*; *co-design* and *idea generation* were not found in the cases. Examples of such were mentioned as diverging examples not being typical of the dynamics in the testbed,

As soon as a user starts thinking in terms of «how could this look in a different way? », then he leaves his role as user somehow, and it is clear that it becomes a kind of «participant design» or something (...) we have had a pilot who has been heavily involved even in design and been very interested, but then you cannot view them as users any more, in my opinion."

The interviews perceived that more of the project ideas came from themselves, as natural development in time and as a response to user needs, but not developed by users themselves. The general perception is that user needs is to be elicited by project partners, answered by designers, and then tested and validated.

Users are seen by the informants as important sources of information in the early phases and as useful tools for test and validation in the later phases. All testbeds involved users in some form of pilot test and usability testing when the projects were well established, and reached at least one iteration. The industry representatives seemed more positive in theory to active user involvement and user ideas than those testbeds heavily influenced by academia, but struggle to perform in practice,

... Well, yeah, we probably could but that would actually involve quite a bit of development to do that. And at that point our development hours were pretty much used up, so by the time we had gotten to the testbed site, the way the project was the designed, by the time we got to the testbed phase we were at the end. So, it was really not the time nor the resources for further development.

Although some disappointment from the HFE expert, all interviewees sensed a positive change in the consciousness in HCD in the maritime industry, which might be underscored by this last quote from the industry partner,

One of the things we plan to do in the next project is to have the testbed activities going on over a period of time (...) and if XX joins us, I would actually like to get him to (...) a few times and to go through and to test certain things as we go along, instead of it all coming together right at the end. So, that's what we would like to see and hopefully that will be the way it works. And that is how it has to work if we are going to use human centered design process,

because we can't have, you know, an iterative process when we test right at the very end. You know, we can't do it that way.

APPENDIX C. Interview narrative on Drivers to HCD in e-Navigation

The expectations to HCD as a tool for designing better products are high among the interviewees. Academics as well as producer representatives see the process as a possibility to deliver products that are wanted, necessary and useful. Producers also see possibilities for cost saving in terms of avoiding to spend time on designing functions that are unnecessary and unwanted. Finally, it is also perceived as a benefit for marketing purposes,

...and doing it also is working is good marketing for us as well. You know to say that we are following human centered design processes. And results are generally something you can see. You can tell that it's made by an engineer on his own.

The role of official funders in e-Navigation is highlighted by the interviewees. EU is perceived as a major driver in the process, providing large scale funding that demands and allows for human centered design to a higher degree than what would be the case in a purely business motivated innovation project,

... but I would say that the advantage with the EU projects is that we can get money to perform sound simulator testing.

Another informant states,

If EU had not done what they did with STM (...) They have invited us, given us access to all documents, we are invited to meetings even though we are not partner. And that shows how little they are governed by kind of a producer community, I mean they represent the users, while (...) project organization is governed by the producers. (...) And they think standardization. (...) What EU care about is if you are willing to test it.

The Norwegian Coastal Administration was also mentioned as an important driver in e-Navigation, both financial wise and providing a project push, however not so much on the HCD

part. The partners expressed that they were encouraged to engage designers to improve product. Project Demand for HCD is higher in EU projects, specifying testing with users and requiring detailed reporting,

It is written in the projects that they shall be tested those services with the right users, and that has been some of the primary output, this user experience. So, these reports have played a central role in the delivery from the project. The delivery has not been only to deliver proof of concept; it has been to gain a user feedback as well.

Regional competition between Europe and Asia is motivating EU and other stakeholders to invest resources in e-Navigation and HCD. e-Navigation is seen by the industry as a new market, where the final solutions lie somewhere in the future and the ones who take part in shaping solutions and standards are the possible future technology winners,

Owners have the money, and they want it to be cheap. It cost a lot with HCD, which is probably why EU is pushing a lot of money in it. To get it done. It cost a lot, but somehow the manufacturers need the technology advantage.

Another informant stated;

They fund research projects, development projects. And it is just as much to ground the EU and the European countries in that field. Korea granted 115 mill dollars to e-Navigation and they have some large industries there, they have Hyundai and Samsung and LG and all the other techno firms and that is a support to them. If they become good in e-Navigation they will take market shares. So, they have spat a lot of money in it.

HCD requires skills and particular knowledge about methods to perform well. It is often seen as time and resource consuming as discussed in next part on barriers. The need for a

dedicated enthusiast was brought up, both for HCD but also to drive the e-Navigation projects further

We willingly come out and talk about these different methods, how to perform a focus group and other things, but the interest is not burning somehow. Apart from that it always, needs someone to drive that idea. Otherwise it ends as it often does, that if you have an idea you sit down and calculate, and then it is not that person's responsibility to see to it that the product is usable. That is someone else (...) But I think there is need for an... enthusiast that drives this with HCD, and someone on the economy side who believes that it can give a better product that sells better, because that is what it is all about, in the end.

APPENDIX D. Interview narrative on Barriers to HCD in e-Navigation

The issue of time and cost versus product quality is the most frequently mentioned barrier to HCD in the interviews. All respondents claimed that HCD takes time and "cost a lot of money",

...time and money, that is the big thing. You know Human Centered Design processes really takes time. And it is much more expensive. It is not just a little bit more expensive, it is very much more expensive. Because we do and... it is more expensive both for us and the end user. Eh, because the end user has to pay their end users. To their operators to participate. And after we made something we have to develop scenarios and test procedures for it. Eh, then make a test environment. And then spend the time of going through the test and after going through the test, then you have to actually look at the results and talk to the end users and then take those into another iteration. You know, so and if we were not doing human centered design process, the test would be very, you know left-click - right-click, "pushbuttony", "Click here - does it do this? Yes, it does that". "Go to next one", you know, "If I scroll the mouse over this thing, does it...?" So, you know the testing is much more easier if it is not human centered design.

The maritime industry is a price sensitive business. The interviewees had no information on official figures showing the cost-benefit of following Human Centered Design processes in short or long term perspectives, but the need for educating end users and buyers in the benefits of HCD was a returning issue. If raising their development cost by following HCD, producers see the need to forward much of this cost to their buyers, as they do not want to "swallow it alone". As HCD brings uncertainties to cost, time frame and what and when the final product will be, interviewees experienced resistance from ship owners and their interest organizations,

Then the ship owner association has ICS, but they rather think it is too expensive. It is not an official withdrawal from them, they too have an interest in that the safer their equipment become, the safer sailing becomes, generally. But it is a little, we had a meeting in the start of the project where we had a human design workshop on how to apply it in the project, then it was repeatedly that this takes time and cost money. But hopefully one could make a business case which shows that money become earnings again by avoiding accidents or make ship operations more effective or what. Because otherwise HCD is out of the question.

The technical firms in the industry also impose some barriers to HCD, as the process does not fit the traditional "waterfall" production line where products are ordered by customer, designed, implemented, verified and entered in to operation without the iterative adjustments typical of HCD. The academic partners had experienced that some producers did not possess the willingness to "program as you want", and left an e-Navigation project due to the gap in working procedures. The producer representatives confirmed that this is a challenge compared to their normal working environment, where they design the systems on their own and then make updates taking customer feedback into account each 6th months. In what they call "research projects" they recognized benefit of keeping users close to align the delivery expectations and maximize the outcome of funding.

User representatives themselves impose barriers. Finding the right users with the desired level of experience, mindset and skills, and motivating them to participate in their spare time proves a challenge to the testbeds. Active seafarers have schedules that might not fit into the testbed plan. Often, students are used due to easier access and a more open mindset to new solutions. It was claimed that often users are reluctant to changes and want to keep status quo, and do not necessarily want to play along. The motivation to participate varies from personal

interest, monetary compensation, or being built into the daily work by the employer. The maritime industry is an international one, and user representatives do not have the same perspectives all over. One testbed experienced cultural barriers in cooperation and user perceptions,

... even what we did here towards the customer, and they thought that was OK, but when we showed it in (...), they thought it was way too... not at all OK, they didn't understand what we had done and more importantly, why we did what they didn't understand we did. So that required some... but they communicate in another way and they more demonstratively resist if they feel lack of attention in a period so… we talked it through with the customer and partner, you could say.

The testbed that did not plan for early user involvement and had a more heuristic strategy for user involvement, pointed to a lack of contracting and budgeting of HCD as reason for the low priority given to the HCD activities. If not specified by customer, the resources tend to be spent on other activities than HCD. The operational aspects of the testbed include contract management, budgeting, planning and coordination. Coordination in time and distance were also seen as barriers, as programmers in some cases are placed somewhere in eastern Europe. Due to the physical distance, the programmers are missing in the common creative phase, and more difficult to communicate with regarding changes and updates. The respondent favored active user involvement through placing users, designers and programmers in the same room,

An important part in our project was that the government invested and hired several programmers who made (...) and it was kind of a development platform. (...) Without that we would never have come as far as we did. And then it was still possible to change something because he sat there and if it was anything then we could change and run one more time.

When cooperating with HCD experts and users, producers are challenged towards their accustomed ways of working and their products. They must tolerate critique and questions towards their own work. In addition, they must justify their reactions to users' suggestions, if they are considered or not. These physical encounters bring issues towards communication and interpersonal trust that are specific to HCD projects,

The challenge is of course that we are challenged ourselves, *you know… with questions and we need to answer why we don't think that the user brings a good idea. In research projects, there is much more openness than in a delivery project, but I would say that it is for the common better both for us and those who has the needs and wishes.*

Another respondent pointed out that the HFE experts and designers have different expectations to working methods and could need a person leverage their worlds,

The human factors experts they ask a lot of questions that developers are not so comfortable to answer. And it needs, what I have seen is that there needs… there is the developers and then there needs to be a person, one of our people that stands between the developers and the HFE experts, so like project manager or product manager, who can eh… translate. and can take some stances in certain areas. And make decisions about approaches because developers are used to sort of doing things in a certain way. And if we are going to do things in another way, they have to be told "this is the way we are going to do it now". And they are not going to do that themselves, they need a manager to tell them to do it that way. So for us that is bit of a challenge.

Trust and the fear of being outside one's comfort zone was also mentioned regarding user representatives. Some are reluctant to participating in testing as they feel that they appear as not competent in the system.

APPENDIX E. Interview narrative on External Factors in e-Navigation

Various factors might provide an external push to facilitate Human Centered Design in e-Navigation. *IMO* as the overall governing body within the maritime regime, has issued their strategy and guidelines to stimulate and guide the direction of innovation. The knowledge about and recognition of IMO and its related documents varied significantly between the respondents, from the ones having been involved in writing them, through those with a brief recognition to those having no relationship with the documents at all. Those located closer to the management of main projects, projected a higher cognition of the governing bodies and documents. Only the case that had been involved in the making of the guideline, used it actively. The general perception of IMO's role is that it is distant, slow moving and technologically lagging, which could be a challenge in keeping up with developments in terms of having updated documents and standards that sets the appropriate level of boundaries around innovation without limiting the possibilities too much. MSC.1 1512 for Software Quality and Human Centered Design in e-Navigation is a voluntary guideline, and the question if the interviewees would see it mandatory provided diverging answers. Three of the respondents were positive to the push it would provide, while the other three expressed that the product quality itself should be the selling point, and pointed out that even by following a guideline one could still end up with a bad product. As external driver for HCD at the present, EU requirements were seen to have a higher impact.

IALA hosts the web site for common reporting of testbeds and results, and arranges the annual "e-Navigation Underway" conferences where stakeholders may exchange views and experiences for the progress of e-Navigation. Only those that had been involved in making the guideline for reporting and had been contributing the web page on behalf of IALA, had any knowledge of the page and guideline. Three respondent had no knowledge of the page and no

intention to visit it. The results from screening of the web page in Table 2 further indicates that this page is used by few people and sparingly reported on by testbeds. None of the respondents had used the page for input to their own projects, ratherthe reporting was seen as a necessary duty withing the research projects. One informant who had been working on the page stated,

Some of them, eh… there is no requirement that we report into the IALA testbed portal, but the testbeds that are Authority driven, these are MONALISA, EFFICIENSEA, ACCEAS, STM, the big ones, the ones with 10-30 mill EURO budgets, they have a whole lot of resources and time to report and in fact that is mostly what they do is they generate paper. Whereas this project is sort of on the other, we generate technology and very little paper. And so reporting is actually something we find to be really unreason, something we don't normally do, and but I do it because I have to for the Research Council. So… complicated answer, some of it is that if it is manufacturer driven they don't really want it, they don't see much value, especially if there is some trade secrets they don't want to reveal.

On the other side, the page was also believed to have unused potential. It was suggested by some of the respondents that the page could be used for connecting interested partners to new projects and as such be a facilitator for cooperation. Although the web page did not play an important role to the interviewees, they honored the good intentions of harmonization and effectivization of e-Navigation. They also showed good knowledge about other testbeds and projects. Informal networks, conferences and committees were mentioned as alternative ways where information flows within the community.

The European Union and single governments play a role in e-Navigation where they fund relevant research projects. There was a perception of technological competition and desire to be first between countries who engage in e-Navigation projects. However, not all authorities

demand HCD in this perspective. EU was the authority that was mentioned to demand HCD through requirements and reporting, while single authorities encourage it but leave the practicalities to the project management.

The role of the Academic partners is essential, as those are either referred to as the experts of human factors and HCD, or presenting the project themselves. All cases were attached to an academic partner possessing knowledge within the field and having some responsibility towards HCD activities.

Ship-owners and their associations were mentioned as a bystander in e-Navigation, perceived to be primarily concerned about possible additional costs in forms of new requirements to ship equipment. One respondent, however also acknowledged the differences in ship owner's safety culture. If the ship owner is concerned for safety in the long term, he might be more positive to improved and safer equipment and services. As to overcome the reluctance towards HCD, the need for business cases and numbers showing the long – and short term benefits was highlighted by the interviewees. Some of them informed that they are working on providing such numbers, as an attempt to outweigh the reluctance they experience from stakeholders in the industry.

APPENDIX F. Main statements - most relevant themes and categories - of the thesis

	BP: Planning
User Motivation	Personal interest
	Pay
	Work task
Challenge user involvement	
	Cultural differences
	User Variety
	Right users
IALA reporting site	knowledge
	Unused potential
	Burdon
	Competition
	Informal knowledge sharing
IALA Role	Passive collector
	Coordination
	Research ethics
HCD Guideline	Low impact
	All involved knows it
	No knowledge
	General knowledge
	Should be mandatory
	Increases consciousness
	EU Rules prevail
IMO	Little innovation impact
	Pay attention to
	Technological lagging
Other external drivers	Partners
	Informal network
	Committees
	Conferences
HCD Documentation	No belief
Procedures	Workpackage
	Project requirement
	Random
	No Plan

Table 10. Testbed reporting *on http://www.iala-aism.org/ and dedicated web pages*

Testbed	Year Completed	Reported on IALA, user related			No. of actions to find on own page		
Testbed	Year Completed	User involved	Methodology	Findings	User involved	Methodology	Findings
1. Arctic Web	2017	No report	No report	No report	No access	No access	No access
2. E-ATON JTCD	Preparation	Yes	No info	No info	No web	No web	No web
3. ESABALT	Ongoing	No report	No report	No report	1	1	1
4. e-Yangshan Port	2016	Yes	No info	No info	No access	No access	No access
5. MEH	2012	No report	No report	No report	In Chinese	In Chinese	In Chinese
6. AVANTI PRONTO	2016	No report	No report	No report	Web not found	Web not found	Web not found
7. EMSI	2017	No report	No report	No report	Web not found	Web not found	Web not found
8. Hermitage	Ongoing	No report	No report	No report	Web not ready	Web not ready	Web not ready
9. Torres Straits/GBR	Ongoing	No report	No report	No report	Web not found	Web not found	Web not found
10. ACCSEAS	2015	Yes	No info	Yes	1	1	1
11. Ariadna	2013	Yes	No info	No info	No access	No access	No access
12. EfficienSea	2012	Yes	Yes	Yes	2	2	2
13. FLAGSHIP	2011	No report	No report	No report	Info not found	Info not found	Info not found
14. Norsat 2		Pure Technical					
15. Winmos	2017	No report	No report	No report	Info not found	Info not found	Info not found
16. Dublin Bay Digital Diamond	2015	Yes	Yes	Yes	1	Info not found	Info not found
17. E-Freight	No report	No report	No report	No report	Web not found	Web not found	Web not found
18. ENSI	No report	No report	No report	No report	Info not found	Info not found	Info not found
19. FAROS	2015	No report	No report	No report	Info not found	Info not found	Info not found
20. Tianjin Port e-Navigation	2017	Yes	No info	No info	Web not found	Web not found	Web not found
User related info in total		7	2	3	4	3	3

Note. One testbed is disregarded as the delivery is purely technical.
“No info” means there was no information on that data.
“No report” means there was no reporting on the web site except short description.
“Web not found” means there was either no link provided, the link malfunctioned or pointed to a general site which provided no further track of the project.
“Info not found” means the web page exists but I did not manage to find information on the relevant data.
“No access” means the directed web page was restricted by login and password.

Table 11. *Codes for user Centeredness in innovation projects*

User Centered Innovation	Literature Reference
LL: Living Labs	Nyström et al. (2014) Leminen & Westerlund (2011)
LLP: Public-private-people partners	
LLO: Adjustable Objectives	Rocheska et al. (2014) Niitamo et al. (2006)
LAU: Active user role	
UI: User involvement	
UEU: Experienced users	
UUE: Unexperienced users	
UP: Pilots	
UE: Early stage	
UA: Advanced Stage	
UL: Late Stage	MSC.1/1512, ISO 9241 – 210,
M: Methods	Mao et al. (2005)
ME: EHEA	Nyström et al. (2014), Leminen & Westerlund (2011)
MI: Interview	
MFG: Focus Group	
MFS: Field study	
MS: Surveys	
MO: Observation	
MUT: Usability Testing	
MER: Expert Review	Mao et al. (2005)
MH: Heuristic and informal	MSC.1/1512
IF: Iterative feedback loop	MSC.1/1512, Tidd & Bessant (2013)
IU: Identification of user needs	
UDL: Innovation led by users	Leminen & Westerlund (2011)
UDLT: Long term cooperation	
UDWP: Well established procedures	
UDCC: Co-creation across organization	
USR: Sufficient skills and resources for user involvement	
UCI: User important source of information	
UCWP: Widespread procedures	
UCP: User involved in certain phases	
USR: Sufficient skills and resources for user involvement	
PL: innovation led by producer	
UCVU: visible user role	
UCSS: systematic user surveys and studies at company premises	
UCP: different users at different phases	
UCPT: pilot testing	
UCNI: no general instruction and practices for user involvement	

IP: spend resources to keep intellectual property in-house
PL: innovation led by producer, PI: producer's ideas and patents IP: policy to keep assets in-house PLU: little interaction with users PMR: intermediaries perform market research on behalf of firm PSR: lack of skills and resources for valuable user involvement