Digitalizing Maritime Industry: A case study of technology acquisition and enabling advanced manufacturing technology

Abstract

The need to reduce time-to-market and reduce cost-of-non-quality drives organizations operating within the advanced manufacturing industry to explore, and source technology externally. This paper reports on a case study of enabling technology for advanced manufacturing and strategies for technology acquisition. The data is collected through in-depth structured interviews with five global technology experts. The interview guide is developed based in a dataset collected in the Norwegian maritime industry. An industry delivering vessels to global markets and a high-level adopter of advanced manufacturing technology. The interviews were analyzed in the qualitative software tool Nvivo. The results are presented and discussed related to three modes of technology acquisition, namely alliances & licensing, monitor, acquire & merger, and coopetition.

Keywords: technology acquisition; advanced manufacturing; Industry 4.0; enabling technologies; case study

JEL: L60; O14; O33

1 Introduction

Today in the private and public sector there is a lot of discussion regarding the digitalization of products, processes and services. Digitalization of traditional sectors, such as manufacturing, places challenging requirements on organizations to change and adapt accordingly. Germany Trade & Invest has labelled this 'the fourth industrial revolution' and introduced it with the terminology *Industrie 4.0*, where the first revolution was the introduction of mechanical production facilities with the help of water and steam power. The second revolution was the introduction of division of labor and mass production with the help of electrical energy, and the third revolution was the use of electronic and IT systems that further automated production. The fourth industrial revolution, which is currently taking place, involves the utilization of cyber-physical systems at its core (Kagermann et al., 2013).

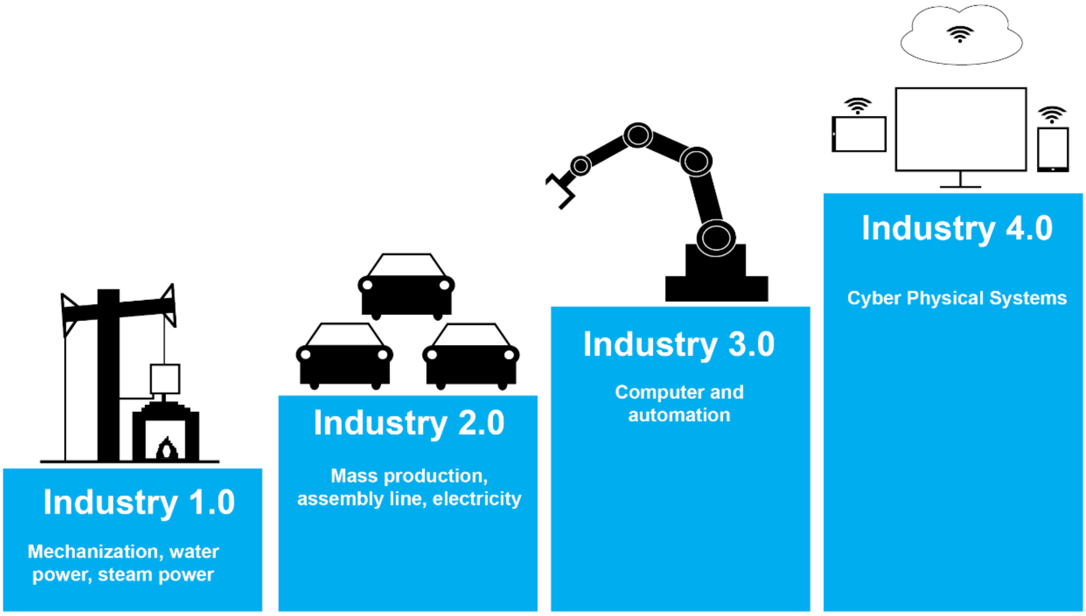

Figure 1: Industry 4.0 and its four industrial revolutions

In England, the government has also initiated a program to direct the attention towards digitalization, namely the *Catapult Programme* (https://catapult.org.uk/). The underlying motivation for such initiatives posits that there has been an underinvestment in infrastructure for test and validation of these new digital technologies. The aim is to re-industrialize national manufacturing capabilities. This argument is not new as Naik and Chakravarty in 1992, conclude that the US manufacturing industry had lost reputation due to short-term financial orientation resulting in underinvestment in new equipment, technology, and research and development (R&D). In the US today you find strategic initiatives with similar reasoning, one such example is the Digital and Manufacturing Design Innovation Institute (DMDII) (http://dmdii.uilabs.org/). More and more countries such as Norway (Siva, 2015) follow this trend, elucidating its importance.

High initial capital expenditures are denoted as moderators and hurdles for why traditional manufacturing industries are conservative in adopting the new technologies and systems (Koren and Shpitalni, 2010; Wang et al., 2015). Therefore, achieving short time-to-market and time-to-value (reduction of cost of non-quality) have become crucial for organizations in a time when the velocity of developments in new technologies and systems, and environmental dynamism is higher than previously seen; like the case of

Moore’s law. One constraint for exploring more flexibility and responsiveness in manufacturing technologies is the asymmetry in resource allocation to early design phases of the manufacturing process. Youssef et al. (1998) underpin that the most commonly used advanced manufacturing technologies are used in design and planning phase, hence it appears to be an untapped potential in exploring advanced manufacturing technologies that reallocate resources to later stages in the process shown in figure 2, or to source new strategies for reducing the high initial capital expenditures.

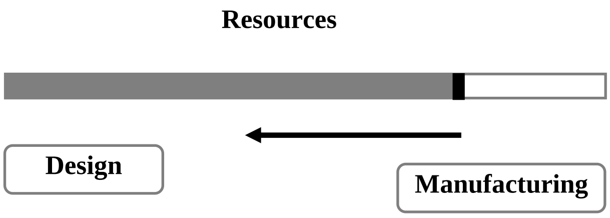

Figure 2: Resource reallocation between the design and manufacturing phase

Therefore, the motivation of this study is to better understand the developments represented by enabling technologies for advanced manufacturing within the maritime industry. Further, identify strategies for how organizations can acquire the capabilities and technologies needed to successfully transition into a digitalized manufacturing environment. By understanding this, organizations may more effectively utilize their resourced, providing slack resources or higher rates of financial return.

2 Literature review

2.1 Advanced manufacturing technology

Advanced manufacturing is not a new term for either practitioners or scholars, and has been given extensive attention due to its role in providing competitive advantage (Sambasivarao and Deshmukh, 1995; Pagell et al., 2000; Karsak and Tolga, 2001). However, the definition and a clear taxonomy has proven to be difficult to agree upon, and given its complexity, diverse and fast developing nature – that may not be such an issue. Noteworthy, this study do not intend to extend these attempts. Thus, previous attempt to define the term can serve as an origin for scholars new to the term, in search of better understanding. In their extensive review of advanced manufacturing Esmaeilian et al. (2016) emphasize the inclusion of management and leadership methods. Table 1 present definitions of advanced manufacturing technology.

Table 1: Definitions of advanced manufacturing technology

Authors (year)	Advanced manufacturing technology
Voss (1986)	… is considered to include all aspects of computer aided manufacturing and design.
Small & Chen (1995)	… represents a wide variety of modern computer-based or numerical control-based systems devoted to the improvement of manufacturing operations.
Boyer, Leong, Ward & Krajewski (1997)	… an umbrella term to describe a variety of technologies which primarily utilize computers to control, track, or monitor manufacturing activities, either directly or indirectly.
Small & Yasin (1997)	... represents a wide variety of modern mainly computer-based systems devoted to the improvement of manufacturing operations and thereby enhancement of firm competitiveness.
Youssef et al. (1998)	… may be defined as a group of integrated hardware-based and software-based technologies, which if properly implemented, monitored, and evaluated, will lead to improving the efficiency and effectiveness of the firm in manufacturing a product or providing a service.
McDermott & Stock (1999)	… can be broadly defined as ‘‘an automated production system of people, machines, and tools for the planning and control of the production process, including the procurement of raw materials, parts, and components, and the shipment and service of finished products’’ (Pennings, 1987, p. 198).
Kotha & Swamidass (2000)	… are viewed as tools that enable firms to increase their information processing capability.
Pagell, Handfield & Barber (2000)	… is a term that covers a broad spectrum of computer-controlled automated process technologies, including standalone robots, flexible manufacturing systems (FMS), and computer-integrated manufacturing (CIM) systems.
Chan, Chan, Lau & Ip (2001)	… refers to computer-aided technologies in design, manufacturing, transportation and testing, etc.
Ordoobadi & Mulvaney (2001)	… can be defined as any type of advanced technology that, when incorporated into a manufacturing operation, has a significant impact on the product, process, and informational aspects of the system.
Dangayach & Deshmukh (2005)	… is an umbrella term that refers to manufacturing processes that use components to store and manipulate data and covers a broad spectrum of computer-controlled automated process technologies, which have emerged as a consequence of developments in information technology.
Kulak & Kahraman (2005)	… is broadly defined to include any automated (usually computer oriented) technology used in design, manufacturing/service, and decision support.
Hutchins et al.	… “a family of activities that depend on the use and coordination of information, automation, computation, software, sensing, and network”

(2015)	(PCAST, 2011).
Esmaeilian, Behdad & Wang (2016)	… should be extended to include not only the process aspect, but also the management and leadership methods.

Evident in the definitions that has evolved, is a development that coincides with the industrial revolutions. What the later definition have in common is that they acknowledges the complex nature of the implications and the connectivity the digitalized technology represent. These later definitions contrary to the earliest also emphasize that the fourth industrial revolution viewed from a manufacturing perspective also affects the entire organization and cannot be fully separated, despite a technology's direct influence and implementation in manufacturing. Further, some of the benefits associated with advanced manufacturing technologies are non-quantifiable or challenging to calculate (Ordoobadi and Mulvaney, 2001), therefore the benefits are classified as intangible or tangible (Chan et al., 2001; Dangayach and Deshmukh, 2005; Schenkal, et al., 2015).

The objective is to increase the competitiveness of the organization through increased product and process flexibility, quality, and efficiency measures such as delivery, lead-time, inventory, return on equity, set-up-time, consistency and reliability (Voss, 1988; Voss 1995; Boyer et al., 1997; Small and Yasin, 1997; Youssef et al., 1998; Chan et al., 2001; Ordoobadi and Mulvaney, 2001; Koren and Shpitalni, 2010). Further, it increases responsiveness by reduced time-to-market and access to market entrance and response to change in customer requirement and environmental dynamism (Small and Yasin, 1997; Youssef et al., 1998; McDermott and Stock, 1999; Chan et al., 2001; Ordoobadi and Mulvaney, 2001; Koren and Shpitalni, 2010). Example of environmental dynamism are sudden and sustained drop in oil price for markets dependent on oil price, entry of new competitors, disruptive business models, or new technology radically improving (or reducing costs of) existing products or processes or dramatically.

When introducing new advanced manufacturing technology the barriers for acquiring these are related to uncertainty and risk. Solely focusing on monetary value and inconsistent governance processes (information, metrics and decision support tools) also introduce barriers for successful technology acquisition. There are several specific issuers related to advanced manufacturing technologies that needs to be mitigated. These can be classified as internal and external and include; lack of standardization (Wang et al., 2015), risk of 'islands of automation' (Small and Yasin, 1997), challenging quality management (Esmaeilian et al., 2016), human factors (such as interaction with machines and systems, empowerment and skills) (Pagell et al., 2000; Wang et al., 2015), competitors behavior and environmental dynamism (Boyer et al., 1997; Koren and Shpitalni, 2010). In summary the potential value added and issues related to new advanced manufacturing technologies can be reviewed in two dimensions: tangible and intangible, and internal and external as shown in figure 3.

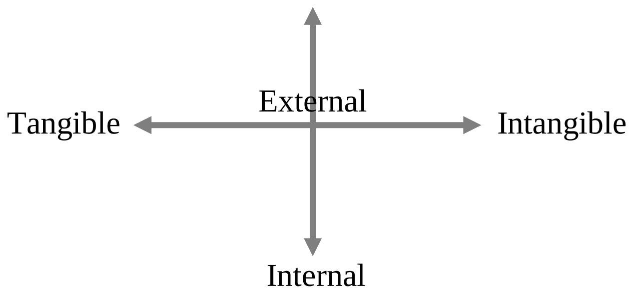

Figure 3: Dimensions of new advanced manufacturing technology

2.2 Enabling technologies

The specific advanced manufacturing technologies include a spectrum of technologies and can according to Small and Chen (1995) be classified in three types of technology. First, stand-alone systems, includes design and engineering technologies (e.g. computer-aided design and process planning) as well as manufacturing and assembly technologies (e.g. computer numerical controlled (CNC) - machining, lasers and robots). Second, intermediate systems, includes intermediate systems (e.g. automatic storage, retrieval and material handling systems) and automated inspection and testing systems. Third, integrated systems, includes flexible manufacturing technologies, computer-integrated manufacturing systems and logistic related systems. Ordoobadi and Mulvaney (2001) also use the classification of stand-alone, intermediate, and integrated systems. Kotha and Swamidass (2000) use a similar classification of product design, process, and logistic technologies and expand with the information exchange technologies. Whereas (Dangayach and Deshmukh, 2005) classify the advanced manufacturing technologies into direct, indirect and administrative technologies.

In later years the opportunities emphasized from advanced manufacturing technologies has been stemming from new capabilities for generating and processing large amount of data, e.g. collected through sensors. There is a wide range of application of big data-knowledge such as machine learning, artificial intelligence, visualization, simulation and augmented/virtual reality (Lee et al., 2014). These techniques can be classified into discovery and predictive techniques (Wang, 2007). One example of utilizing discovery and predictive techniques is combining analytics of sensor data with additive manufacturing and visualization. This opens a new paradigm of designing engineer-to-order products where you are free from constraints of traditional manufacturing - operating within a 'manufacturing-the-design' versus the traditional 'design-for-manufacturing' paradigm (Esmaeilian et al., 2016).

Big data has revitalized systems interconnectedness and communication abilities. As most interconnectedness in systems is based on internet, cyber security becomes decisive, which has given rise for a stream of research on cyber-physical systems. In their study, Wang et al. (2005) conceptualize and define cyber-physical systems as deeply embedded systems of computation and communication interacting with physical processes, which in combination provide new capabilities to the original physical system. Further, Hutchins et al. (2015) stresses that although the opportunities of harnessing the power of big data, the risk is substantial as the cyber threats can potentially affect confidentiality, integrity and availability in a manufacturing system – ultimately reducing competitiveness. One such example is the malicious computer worm 'Stuxnet', designed collaboratively by US and Israel to damage Iran's nuclear program, which spun out of control and spread beyond its intended target. Moreover, Hutchins et al. (2015) conceptualize data that can be compromised in a manufacturing system into five categories: high-level digital data, low-level digital data, financial data, physical data and user data. Hence, organizations' ability to stay protected will become decisive in the years to come.

2.3 Justification and implementation of advanced manufacturing technology

When organizations want to explore and invest in new capabilities for advanced manufacturing they face the justification challenge due to the high initial investment cost and strong emphasis on purely financial considerations (like return on investments and payback time) not taking into account the non-financial and long term strategic benefits

(Naik and Chakravarty, 1992). There are mainly three general classification of justification techniques: economic, strategic and analytic as referred to Meredith and Suresh (1986) by Naik and Chakravarty (1992) and Karsak and Tolga (2001). Swamidass and Kotha (1998) state that organizations need to pay attention to three factors when evaluating the benefit of advanced manufacturing technology; the organization's (1) competitive strategy, (2) vendor relationship and (3) ability to integrate advanced manufacturing technologies, and find an indirect relationship between use of such technology and performance.

Since advanced manufacturing technologies are often sought to be a panacea for re-industrializing manufacturing capabilities, organizations fall the risk of solely viewing it as the 'holy grail', demonstrating one-upmanship or grandstanding; underestimating the hard work needed for successful acquisition and positive outcomes. The promises of advanced manufacturing technologies does not always reconcile with the harsh reality after implementation (McDermott and Stock, 1999). The *integration* or implementation can be defined as: "the user's process that leads to the successful adaption of an innovation of new technology" (Voss, 1988). Voss (1988) further divides the implementation process into three phases; pre-installation, installation and commissioning, and post-commissioning and argues that there are four factors leading to successful implementation: organizational, technical, and business strategy & management. Dangayach and Deshmukh (2005) further divide the pre-installation phase into planning, concept development, requirement analysis, cost/benefit analysis and technology assessment, and the installation and commissioning phase into development and implementation, and training.

Many of the issues in adopting advanced manufacturing technologies are related to the implementation procedures. These include identification of specific objectives (viewed in short, medium and long term) and its strategic fit; the involvement, training and motivation of key employees; development of strategic programs, its procedures, governance structure, and time-line; and specific standards, information and resources and their availability, flexibility and adaptability (Sambasivarao and Deshmukh, 1995). Small and Yasin (1997) finds that the human factors are significant and the most important in providing positive performance from the implementation efforts. In line with this, Boyer et al. (1997) also stresses the importance of investments in human factors to secure a successful implementation and postulate that the efforts needed resembles quantum leaps and require concurrent integration. On a different note, Koren and Shpitalni (2010) suggest that there is a modification of the high-skill assumption as a prerequisite for performance; instead, there should be a fit between skill and given task. Thus, better understanding the strategic choice of how organizations acquiring advanced manufacturing technology serve as an enticing opportunity to contribute to this research.

2.4 Technology acquisition

When organizations decide to acquire new advanced manufacturing capabilities they have the strategic choice of sourcing in-house through R&D, or through alliances (including collaboration, licensing agreement, consulting), acquiring other firms or do a combination of these internal and external make-buy strategies (Veugelers and Cassiman, 1999). Acquisition through alliances have the advantage of avoiding high initial investment, achieving fast growth, access state-of-the-art technology, and access knowledge from outside organizational boundaries (Tsai and Wang, 2008). Moreover, according to Tsai and Wang (2008) research on external technology acquisition can be categorized into three streams of inquiry. First, focusing on institutional factors influencing technology acquisition performance, second on factors influencing the decision-making process and third examining the relationship between external technology and firm performance. In their study, Sen and Rubenstein (1990) organize the acquisition process into ten steps: need, focus, evaluate, make/buy, negotiate, receive, construct, start-up, improve and retool/redesign. Chan et al. (2001) allocate the acquisition process into four distinct but not mutually exclusive steps: strategic planning, justification, training and installation, and implementation of the selected technology. Furthermore, they underpin the uncertain nature of the acquisition process, of not only negative character, but also unexpected areas of application and benefits for organizations. Managers often ignore intangible benefits much larger than the direct savings they concentrate on (Ordoobadi and Mulvaney, 2001; Kulak and Kahraman, 2005).

Kotha and Swamidass (2000) argue that organizations are open social systems that must cope with environmental and organizational uncertainty, and to effectively do so, there is a need to develop information-processing mechanisms that deal with this uncertainty.

Where uncertainty is defined as the discrepancy between the amount of required information and already possessed by an organization. The viewpoint of an information-processing mechanism acknowledges that accessing new information and technology *per se* is not sufficient. Cohen and Levinthal (1990) state that the level of new knowledge acquired by an organization depends on its *absorptive capacity*, the “ability to recognize the value of new information, assimilate it, and apply it to commercial ends” (1990: 128), implying that some organizations are more successful than others in utilizing the same amount and type of information and technology. Sen and Rubenstein (1990) suggest that involvement of R&D capabilities in external technology acquisition processes and the negotiation process may increase bargaining power of focal organizations. Veugelers and Cassiman (1999) reason that R&D is important when acquiring new capabilities since being a good `buyer´ is challenging without being a sound `maker´. Further, that R&D can overcome the `not invented here´ syndrome explaining innovativeness. In line with this argumentation, Tsai and Wang (2008) find that positive impact of external technology acquisition on firm performance increases with levels of internal R&D efforts. Hence, understanding organizational integration and information-processing mechanisms are important in ensuring successful acquisition of advanced manufacturing technology holding opportunities to advance current understanding.

2.5 Strategies and modes of technology acquisition

The reasoning for acquiring advanced manufacturing technologies concerns the ability to achieve both cost leadership and product differentiation, put differently, both efficiency and flexibility. In the literature on strategic management of alliances, this distinction is found in the categorization of *exploitation* and *exploration*. Lavie and Rosenkopf (2006) find that organizations achieve balance between exploration and exploitation through alliances by domain separation and over time. This combination of both efficiency and flexibility contradicts traditional paradigm of operations and manufacturing strategy. The traditional viewpoint is that efficiency is associated with high-volume series, and that flexibility is associated with low-volume series (McDermott and Stock, 1999). Achieving both efficiency and flexibility requires new and refined acquisition strategies within manufacturing, emphasizing combinations of internal R&D and alliances. Ellingsen (2017) found that incumbent organizations need refinement and alignment between such strategies at different levels within an organization – in order to successfully commercialize new technology through such inter-organizational relationships.

In this literature, there is a stream of research devoted to organizations simultaneously collaborating and competing; this strategy is given the name *coopetition* (Nalebuff and Brandenburger, 1996). Drivers of such collaboration and joint ventures is seeking common goals and mutual benefits through accessing information and expertise all involved parties otherwise could not achieve (Wu et al., 2013). Coopetition offers win-win situations within the advanced manufacturing and maritime industry, by mitigating costly competitive learning races (Hamel, 1991), offers exchange of resources, knowledge, skills and capabilities (Cassiman et al., 2009), and achieving economy of scale (Bengtsson and Knock, 2000). Fallah et al. (2015) also note the change in the competition field from independent and individual, to supply chain vs. supply chain. Not to be misguided, coopetition is fraught with issues related to the vital tension of the competitive element, and the risk of unintended knowledge leakage, opportunism and difference in appropriation regime (Gnyawali and Park, 2011; Bouncken and Fredrich, 2012; Tidström, 2014; Ritala et al., 2015).

New business models extracting actual value from advanced manufacturing technologies will be determining for organizations (Esmaeilian et al., 2016). Wu et al. (2013) state that the new initiatives utilizing internet have led to new types of collaboration resulting in a power-shift away from very hierarchical business models. In the domain of advanced manufacturing, initiatives encompassing coopetition have emerged like the case of Apple and Samsung (Mathias, 2012); however, there is little attention to these aspects of the strategic decisions and acquisition policies. In summary, coopetition as a strategic choice holds important contributions to the literature on advanced manufacturing and successful adaption of enabling technologies, such as digitalization represent.

Future research

Based on the literature review, previous studies on advanced manufacturing technology acquisition call for research on; exploring the effect of environmental factors (Boyer et al., 1997) such as the competitive context (Kotha and Swamidass, 2000). Factors related to successful implementation (Voss, 1988; Sambasivarao and Deshmukh, 1995;

McDermott and Stock, 1999) and negative factors (Tsai and Wang, 2008). The interplay between internal and external resources and representative acquisition strategies (Sen and Rubenstein, 1990; Veugelers and Cassiman, 1999; Tsai and Wang, 2008). Establishing practical guidelines for technology acquisition (Small and Yasin, 1997) and new business models capturing true value and demonstrating best practice (Esmaeilian et al., 2016) explored as scenarios (Naik and Chakravarty, 1992). Moreover, creating palette of strategies with different profiles with regard to value adding properties (Schenkal et al., 2015). Finally, suggesting how the new collaboration forms should be formalized including immaterial property rights (Wu et al., 2013). This article aim to address the current gaps in the literature by providing better understanding of barriers of acquiring enabling technologies, emphasizing strategic choice. Hence, the research question guiding this study is "what are the barriers and strategic choice faced by incumbent industries in adopting enabling technology for digitalization and advanced manufacturing". This article employs an explorative and qualitative approach answering this question through a case study research design with structures interviews. Answering this question will improve our understanding of how advanced manufacturing technology can be acquired, consequently improving the change capacity and competitive advantage of traditional industries, such as the Norwegian maritime industry, challenged by high pressure to adapt and digitalize products and services. Such finding are expected to hold valuable insights for both scholars and practitioners.

3 Research design

The nature of digitalization and technology acquisition is contemporary, social, and ongoing and therefor performing case study and collecting data through interviews holds a good fit in regards to research design (Yin, 2013). Yin (2013) also call for case study design when the aim is to contribute to theory in fields of inquiry where there exists less defined frameworks and lack of coherent theory and definitions, asking *how* and *why* questions – seeking several answers. In addition to Yin (2013), Eisenhardt (1989) has pioneered qualitative research providing well-defined frameworks and procedures for conducting case study, and serves as an inspiration for this study's research design. Case study design is discrepant from quantitative methodology and techniques in the way that it is not a strict mechanical or technological exercise. Rather it is a dynamic, intuitive and creative process of inductive reasoning, thinking and theorizing that requires the researcher to be alert, flexible and positively interacting with the data collected and throughout the life cycle of the project (Basit, 2003; Hilal and Alabri, 2013). Most importantly, qualitative research relies on extensive interactions (most often) with people being studied and given a status as informants, allowing the researcher to uncover unexpected or unanticipated information (Wong, 2008). Rigor in qualitative research in introduced in the preparation of data collection and in the data analysis e.g. prior to the interviews developing interview guides and procedures for carrying out the interview (Zamawe, 2015).

The general and central process of qualitative data analysis is the pursuit of relationships between categories and themes in the data, seeking to increase the understanding of a given phenomenon. Put in Basit's (2003) own words "what coding does, above all, is to allow the researcher to communicate and connect with the data to facilitate the comprehension of the emerging phenomena and to generate theory grounded in the data." This process of categorizing is referred to as coding, and is the identification of a passage of text or specific words that exemplifies an ideas or concept that in the coding process is represented by a node that link the related text and its location, where one project often holds a list or set of nodes. Utilizing the developments within software technology, electronical techniques of coding data has gradually increased and been employed to achieve rigor in dealing with qualitative data (Leech and Onwuegbuzie, 2011; Hilal and Alabri, 2013).

3.1 Qualitative analysis – the software tool NVivo

Nvivo is a qualitative software tool, and once (for example) interviews have been transcribed, they can be uploaded and coded in NVivo before the dataset can be analyzed. The node structure in NVivo allows for several structuring regimes of the nodes. For example, it allows subdividing a dataset hierarchy with mother, child and sibling nodes. What is important to acknowledge is that coding and data analysis are not synonymous, though coding is a crucial aspect of the qualitative data analysis process (Wong, 2008) and the software tools have to be viewed as an aid in this process supporting the researcher (Zamawe, 2015).

Using NVivo (or similar software) in the qualitative analysis process has several advantages like storing the complete dataset. NVivo is flexible and enables efficient ways of recoding and un-coding of a text and restructuring, renaming, merging or removal of nodes at any given stage in the process. All these actions are stored and can be reported on, thereby increasing transparency of the research conducted (Crowley et al., 2002). Further, NVivo is independent of research design and methodology and coding can be mutually exclusive or allow several nodes for coded text. Moreover, NVivo can export several reports, making the process of further analyzing the text more accessible and intelligibly. Finally, NVivo support and facilitate that several researchers can work (code) on the same project simultaneously, allowing greater methodological pluralism (Piekkari et al., 2009; Urquhart et al., 2010).

Possible limitations of NVivo is that it may distance the researcher from the data or introduce too much rigor, where one of the hallmarks of qualitative research is that the researchers associations or whims is part of the creative analytical process and abstraction of ideas (Crowley et al., 2002). Therefor researchers should reflect and report on their node development and coding process. Further, software tools such as NVivo has some downsides in regards to the efforts needed in learning to use them. Once overcome Houghton et al. (2016) conclude that NVivo is a pragmatic way of managing complexity in qualitative research and that it provide robustness and reliability.

3.2 Data collection

The interview guide for the data collected in this study was developed based in on insights from a separate dataset that was collected prior to this study's data collection. The data for the first dataset was collected in the period between fall 2015 and fall 2016 as part of a collaborative data collection, where on is the corresponding author of this article.

The dataset the interview guide was developed from consists of semi-structured interviews of 31 informants from the top management team in organizations located on the west coast of Norway. This is organizations located within a limited geographical area delivering services and products to the global maritime market, and maritime industry in Norway is noted to be a high-level adopter of advanced technologies. This cluster of organizations with its more then 22 000 employees, and in 2014 a revenue of approximately 2% of Norway's GDP, is one of the most vertically complete and competitive maritime clusters globally (Mellbye et al, 2016). The informants represented all actors (ship owner, ship designer, shipyards, equipment suppliers, and research institutes) in the cluster and their organizations approximately 65% of the revenue generated in 2014. The semi-structured interview guide included a combination of broad and open themes and selected theoretical constructs.

For the study reported on in this paper the interview guide was developed based on preliminary insights from the first dataset on five specific nodes, out of thirty-four, which were identified as applicable for advanced manufacturing industry within the maritime industry. Table 2 present the five nodes that found the basis for this study.

Table 2: Applicable nodes for advanced manufacturing from the first data-set

Cluster Past (node 13) and Future Success (12)	**Advanced Manufacturing (4)**
o Past: joint learning and competence building, low hierarchy, relations, sense of shared identity, end clients present, customer involvement, experienced-based knowledge o Future: risk of losing multilateral collaboration and knowledge sharing, need to retain some local ownership, knowledge of processes, modularization, diversity	o Drivers: competitive advantage, speed of technology development, experience-based knowledge, customers and market needs o Barriers: new knowledge, lack of expertise, lack of financial means to invest, outsourcing
Coopetition (8)	**Sharing Economy (34)**
o Drivers: joint initiative and influencing authorities and regulators, access to skilled and competent work force, 'a rising tide lifts all boats' (cooperate locally to compete globally), 'pay it forward' (share and you will receive in return later), access to resources, diversity, spin-offs o Barriers: afraid that competitors become too close, knowledge leakage, opportunistic behavior	o Drivers: shared capex, access to resources (space, new facilities, new equipment, new machinery and manufacturing and process methodology), external funding, external lending schemes o Barriers: competitive elements, IPR, prioritization/ownership

[The following including table 3-5 could be moved to appendix] The informants in the semi-structured interview provide the motivation for the development of the interview guide in this study. The motivation is presented in table 3-5 arranged according to the three topics (1) enabling technology and its drivers, (2) challenges of adopting, and (3) coopetition in practice.

Table 3: Enabling technology and its drivers

	Statement	Implications
Informant 22	*"Due to the market, what we now have to do to increase our competitive advantage is to see if we can utilize robotics here and to mill in sand* [a new technique for casting metal] *instead of cumbersome logistics. This also apply for labor-intensive work such as cutting and chopping of materials that require precision and are time consuming. You can say that we might be able to do this in more simple way* [utilizing robotics]."	○ A need for continuously improving efficiency result in seeking enabling technology
Informant 27	Reflect on old strategic choice for cost leadership: *"I do not believe that we can fix this by only reviewing the cost issue in the old fashion way of moving activity to countries with lower cost bases. We need technology and we need to invest.* […] *And if you do not master manufacturing technology, then you are not able to know what is possible to design either."*	○ Stagnation in regional productivity development
Informant 28	*"What we soon discovered when we started with robot welding ten year ago, was that despite that we had confidence in our ability to code and make control programs for CNC* [computer numerical controlled] *machinery, making control programs for a welding robot was something completely different.* […] *Some of the perils and pitfalls is that you want to know exactly how profitable an investment will be. Then you end up buying too 'low' technology. Because you will say* […] - *let's buy the least expensive one. But the* [expensive] *machine have some capabilities that you do not understand. I believe we are relatively unique in regard to our eagerness to pick up new technology that we not quite understand."*	○ Enabling technology requires new skillsets ○ Opportunities for unintended positive results
Informant 11	*"I believe in being curious and staying in the forefront. The developments are now so fast, both when it comes to systems and digitalization and generally, so you can no longer make one deterministic strategy. The risk increases with this. Because you can no longer be certain you are doing the right thing. This is evident on the IT side of things, the system side. We are running several projects that are tied to systems and which we don't know where we end up, but we are certain that we are on the track that we need to be."*	○ Speed of technological development ○ Importance of embracing the unknown
Informant 13	"Look at remote access, this will become imperative. At the same time, the responsibility is removed from the bridge on the vessel. One solution is to run it in the same way as power plans are run, from off-sites in other countries where you monitor the engines and give instructions to what a remote operator should do. I do not think this solution will work; we need to be able to do things ourselves. The crew need both ownership and responsibility to what is going on. One have to be careful not to remove ownership."	○ Digitalization: Importance of sense of ownership, responsibility and ability ○ Address the empowerment barriers of adopting advanced manufacturing technology described in the literature

Table 4: Challenges of adopting

	Statement	Implications
Informant 10	*"We have had a strategy that for the last 15-20 years have been a success. A fantastic history. And we know that this strategy, that we have had for the last 15-20 years, no longer will work.* […] *We need to figure out what we believe in, what do we have to make a quantum leap in regards to, which shifts, what disruptions do we need to make in order to be an important actor within the industry for the next 15-20 years."*	○ Increased technological development speed in the industry requires new more flexible strategies
Informant 27	*"I have said this in various settings, that is was in the nick of time that this downturn came, although it didn't have to be this hard as it has turned out to be."*	○ Crisis in not only negative, ensuring survival and competitive advantage over time

Table 5: Coopetition in practice

	Statement	Implications
Informant 11	*"Much of what have been created here* [within the region] *have often been a result of us being a cluster. A cluster that compete, and at the same time collaborate"*	○ Defining coopetition which enhance regional competitiveness
Informant 17	"[Talking about a specific project aimed at technology development] ... *the American delegations was very sceptic to this being a cluster project – that's collusion, I am not allowed to work with my competitors. But you know, the local competition is very strong, so the value are these mutual benefits.* […] *Thus, you do not share, and now I go back to basic strategy, you do not share strategic resources. However, if you are able to define some mutual benefits, training centers, a simulator, and such…* […] *and when the companies have the knife against their throat things begin to happen, that is the benefit of crisis – you do new things."*	○ Informant 17 gives an example of how the more traditionally view of this form of working together might miss the value of mutual benefit and competitive pressure.
Informant 27	*"We realized early on that competence is something that is harmless to share, because it is your ability to convert this knowledge into a concrete project and your ability to use it into development, as entrepreneurs, this is what becomes your competitive advantage."*	○ Enable local collaboration between competitors

What is evident from the informant's statement is an ongoing change and new dynamics in the industry resulting in a need for new strategies and type of collaboration in order to ensure the right skillset and technology. They also tell a story of regional responsibility taken by the 'in-group' organizations, how coopetition is an established practice and a need to share capital expenditures creating mutual benefits.

Since the first dataset was broad in its coverage of topics and semi-structured by design, the interview guide developed for this study specifically addressed the advanced manufacturing industry, as part of the maritime industry, and therefore structured and in-depth by design. The structured interview guide was developed based on iterations between insights from the first dataset and the literature review conducted, and is found in appendix 1.

The interview guide together with an invitation for interview was sent to five carefully selected technology experts within the domain of enabling technology (digitalization) for advanced manufacturing relevant for maritime industry. The process of selecting the technology experts started with a mapping and grouping of key enabling technologies derived from the literature review, presented in figure 5. Further, the experts were identified by consulting senior management in the Norwegian maritime industry, which holds expertise within its domain, and by reviewing resent key speakers at conferences on the subject of digitalization, Industry 4.0, and advanced manufacturing and maritime industry.

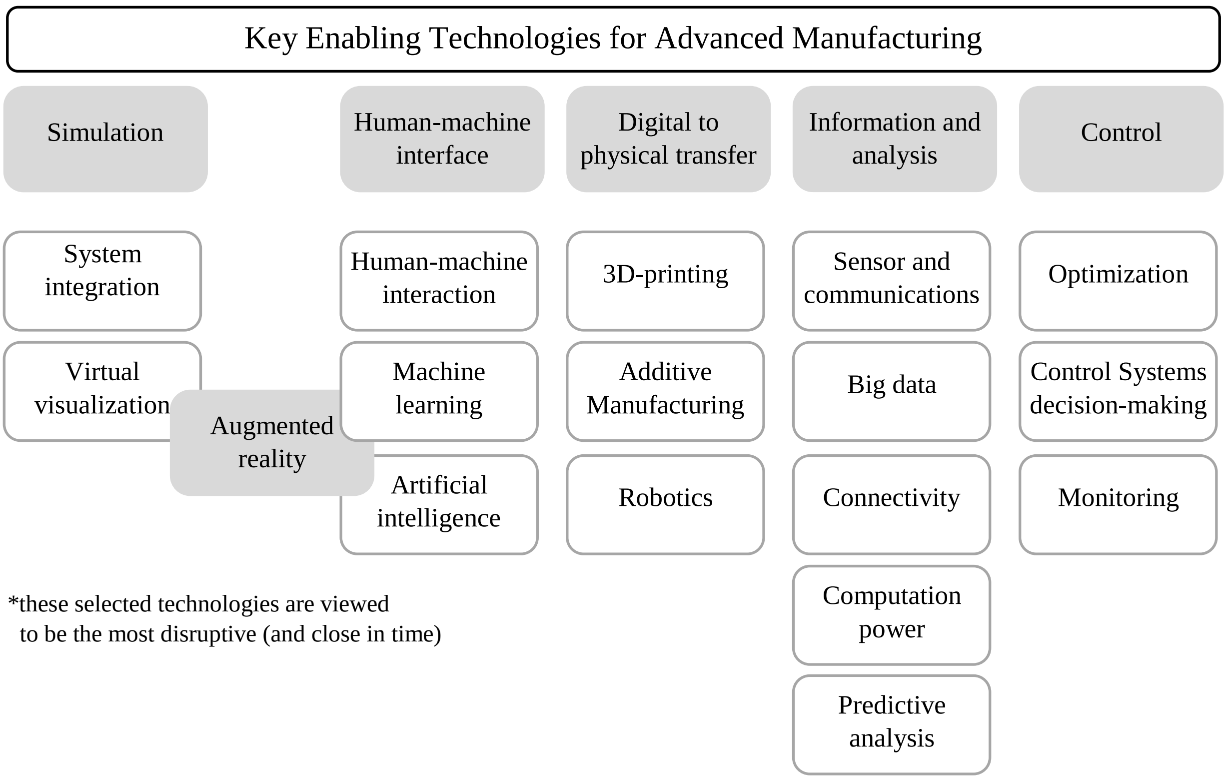

Figure 5: Key enabling technology for advanced manufacturing

Since the experts was situated around the world, all five interviews were performed over Skype from Stanford University campus during November and December 2016, since the corresponding author of this article was located there at the time as a visiting scholar. All interviews were transcribed and lasted longer than the original booked interview-time, which is considered to be positive as it was a result of the informants enthusiasm for the topics addressed. The five technology experts are presented in table 6.

Table 6: Characteristics of the technology experts

Technology expert	**Human-Machine interface**	**Simulation & Augmented Reality**	**Control & Cyber Security**	**Information and Analysis**	**Digital to physical transfer & Data collection**
Type of organization	Center for Autonomous Operations	Simulator Center	Center for Cyber Security	Software and sensor provider (technology development phase)	Software and digital solution provider (operations phase)
Role in org.	Director	CEO	Director	VP Strategy	SVP
Gender	M	M	M	M	M
Educational level	Professor	BSc hons	Professor	PhD summa cum laude	EMBA

3.3 Analysis

The coding and analysis of the data was done through several iterations, first developing a preliminary code structure based on the interview guide. While reading the transcripts, the process of abstracting ideas began making notes, comments and associations on the prints, in line with Crowley et al. (2002) note on the associative cognitive process. Further, the preliminary structures were discussed with the co-author further developing the final structure increasing the level of abstraction, in line with Miles and Huberman (1994) description of methods to generate codes e.g. based on the informants' introduction of key concepts or undiscovered ideas. The final coding structure used in NVivo with its child and sibling nodes were as shown in table 7.

Table 7: Final code structure

1 Industry 4.0		
	1.1 Definitions	
	1.2 Enabling technologies	
		1.2.1 Autonomy, sensor, monitoring, & big data generation
		1.2.2 Safety, optimization & environment
		1.2.3 Simulation & visualization
		1.2.4 3D-printing & additive manufacturing
		1.2.5 Robotics & automation
	1.3 Implications for advanced/smart manufacturing (AM)	
	1.4 New capabilities for AM	
2 Issues & barriers		
	2.1 Balancing exploration and exploitation	
	2.2 Communication & common language	
	2.3 Cyber-security, Transparency, & Privacy	
	2.4 Data Ownership	
	2.5 Existing customers	
	2.6 Ignorance & arrogance	
	2.7 Over dimensional, low capacity utilization, legacy systems & standardization	
	2.8 Political agreement	
	2.9 Shorter lifetime	
	2.10 Third party verification	
3 Disruption		
4 New business models		
	4.1 Big data	
	4.2 Monitoring arenas & corporate venturing	
	4.3 Selling safety & reliability	
	4.4 Shorter lifetime	
	4.5 Supplying for customer assembly	
5 Investments		
6 Uncertainty distribution		
7 Coopetition		
8 Acquisition mode		

Several of the codes were not directly relevant for the topics discussed in this paper, however they were included as several of the informants introduced the topics. However, what became evident from analyzing the reports from each code was the importance of understanding the drivers, issues and barriers for successful acquisition of enabling technology for advanced manufacturing. The results from the analysis is presented in the following section.

4 Results and findings from the analysis

The statements presented in this section is based on the analysis and agglomeration of the informant's statements – and not the authors.

Digitalization of traditional industry and sectors, such as manufacturing, and in society in general is not a new phenomenon and the terminology is myriad. The informants emphasize that digitalization has been an incremental and continuous development from back in late 1950-60s when the transition from the mechanical analogue to digital began. An example given by Informant 3 is the first numerical controlled (NC) and computer numerical controlled (CNC) machinery. Informant 3 views digitalization as the Industrial Internet of Things (I-IoT).

A significant change and driver for the attention that has been given to the developments and importance of utilizing such technologies, is initiatives such as the German government´s Industrie 4.0, which all the informants discuss.

The results of the analysis reveals that having concepts, and the attention such concepts receive, is important for industry in order to gather around a common ground and goal, especially from a political and conceptual perspective. Informant 2 underpin and illustrates this in the following quote. Where the silver lining is that implicit factors such as regional collaboration, takes an defining role over explicit factors such as emphasize of one specific technology over another, in line with discussion in the literature.

> "Y*ou need the new industry standard* [for communication protocols between digital models]. […] *There need to be a common understanding and then agreement, it cannot be done on their own and everybody needs to agree to do it together* […] *but it also go back to the political side of people agreeing, not just externally but also internally within companies*. […] A*nd that is what I said earlier, the political side is just as complicated - if not more complicated - than the technical side of it.*" – Informant 2.

As addressed in the literature the lack of a common taxonomy may misguide organizations and Informant 5 stresses the need to brake these initiatives down to tangible steps in order for value to materialize. Hence, it is first when the application and integration is successfully completed that investments generate value. Informant 4 agrees and elaborate on this explaining digitalization of the manufacturing industry in the following:

> "*Aircraft engines have a very elaborate design and increasingly change more towards embedded software, they have more sensors than ever before, but they also supervise the engine. Generating a lot of information when the aircraft engine is*

actually in operation, and by the way, today far more information is generated, than used. […] *So the idea of Industry 4.0 is really to utilize those data and somehow make sense of them and bring them back to make the product a better product, right?*" – Informant 4.

4.1 Enabling technology and drivers of digitalization

Understanding how digitalization influences existing business model and products, and how this can – and will have to – change in order to enter the fully digital era becomes decisive. As informant 1 stresses this is a tough task for organizations, in the following.

> "*And the biggest threat to* [the company] *is that you are not brutal enough in what we call cannibalization to drive those changes themselves and actually be willing to kill their own existing business models. This is always a threat to big companies. It is not easy to know how to do such transformations*" – Informant 1.

Organizations need to either survive disruptive business models or be the developers of the new business models, and the informants in this data collection posits that organizations can to some extent make a distinctive strategic decision between the two standpoints.

The analysis of the informants reflections on the drivers of the development and digitalization within advanced manufacturing have been organized into four main drivers, presented in table 8.

Table 8: Enabling technologies drivers

	Time-to-market	Cost reduction	Efficiency	Security and reliability
Driven by	○ High pace in developments ○ Increase in processing capacity	○ Less effect of outsourcing ○ Global competition ○ Low component cost and global pricing ○ Competence need ○ Optimization of resources	○ Optimization of resources and capacity ○ Need for slack resources	○ Increased complexity ○ More distributed risk and responsibility

4.2 Challenges of acquiring enabling technology

Table nine present the result of the analysis of issues and barriers addressed by the informants related to acquiring enabling technology for advanced manufacturing and digitalization of maritime industry.

Table 9: Issues and barriers of acquiring enabling technology

Issues	Barriers
1. Legacy system and shorter lifetime	
○ New technology requires constantly upgrading ○ New technology have shorter lifetime horizon ○ Legacy systems are not designed to be connected to internet – resulting in vulnerable systems	○ Legacy systems may have committed investments ○ Legacy systems have been designed to last long
2. Balancing exploration and exploitation	
○ Killing existing capabilities, products or turning their back on existing customers "*Kodak is the prime example of an organization holding the insights but lacking the ability to change and adapt to digitalization*." – Informant 1	○ Investing in and adapting new technologies ○ Delivery on daily operations ○ Ignoring important developments or being too confident in existing capabilities
3. Political agreement	
○ Difference operational guidelines, tax systems or ethical standards "*The political challenge might prove to be more difficult than some of the technological issues*." – Informant 3	○ Political agreement on directions
4. Communication and common language	
○ Lack of industry standards and protocols for interface between systems	○ Common language and standardized communication ○ Need the app-store concept for communication like the functional mock-up interface (FMI) used in the car industry
5. Cyber-security, transparency, and privacy	
○ New requirements to security, transparency and privacy ○ Dependence on cloud storage ○ Risks of malware, loss of data and other cyber threats ○ Cyber insurance	○ Creating secure links between inherently insecure systems (machinery and components not designed with cyber security in mind) ○ Physical protection not sufficient ○ Open sharing of information ○ Guaranteeing privacy and legal rights
6. Data ownership	
○ Who owns the data, and for what purposes can it be used? ○ What are the role of government and policy makers? ○ Creating customer value for cloud solutions	○ Arriving at general solution (similar to the political agreement issue) ○ Risk of prohibiting and not promoting good solutions
7. Standardization and low capacity utilization	
○ Optimizing with 'new' safety margins when humans is not in the loop ○ Moves from 'as much as possible' production capacity to 'lower' or 'enough' capacity	○ 'Unlimited' design opportunities requires new design standards limiting variation ○ Need new standards for digitalized systems ○ Transitioning and bridging current standards
8. Third Party Verification	
○ Software systems will still require third party verification	○ Setting requirements when there is no physical facility to inspect

4.3 The incumbents role in industrializing new technology

Based on the analysis of the informants´ description of the relevant technologies and its implication for advanced manufacturing, four digitalization scenarios emerged and was developed answering to Naik and Chakravarty (1992). The following sections review these four scenarios and present the informants viewpoints on enabling technologies implications, which are illustrated in figure 6.

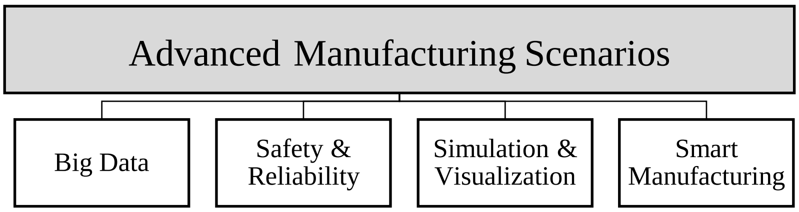

Figure 6: "Four digitalization scenarios for advanced manufacturing"

4.3.1 Scenario "Big Data" – data generation, capturing and analysis

Sensor and data generation - Sensors and their ability to generate data and communicate is the first important enabling technology for digitalization and advanced manufacturing. Sensor technology has become smaller, cheaper, smarter, and more accurate, have better processing capacity and wireless transfer to cloud solutions. Sensors can record knowledge and data about operations, processing, manufacturing, assembly and control for observational data. Drone and satellite technology are also important enabling technologies in providing what is referred to as cyber-physical systems. In this way, the data generated from the sensor devices can be recorded and stored as big data sets. Cyber physical systems become important as they represent the integration and smart interconnections between the physical and digital assets in order to control and monitor systems.

Data capture, analytic and autonomy – Advanced software enables processing and analytics of big data sets. This will affect advanced manufacturing in the form of freeing human capacity by providing better data for decision making and enables operations with increased reliability and automated evaluation of the data collected. This is often referred to as machine learning, and for advanced manufacturing this could be exemplified by a machine autonomously evaluating if it has the correct parts, tools or instruction to perform its given task. The potential of these new capabilities represent disruptions in the way of operating and creates new value propositions. Elaborate design and complex processes can be recalculated and optimized based on sensor data and providing feedback loops back into the design process and improving the product. The possibility of combining historic and real-time data also provides opportunities to improve the decision-making and risk evaluation processes. Remote access and control will also play an important role in the developments of the next generation factories.

4.3.2 Scenario "Safety & Reliability" – optimization and environment

Being able to make use of more automation and apply autonomy to systems will influence and improve safety. Monotonous and repetitive manufacturing tasks can be automated and remove tear and wear on operators, and autonomous systems require other safety margins than traditional manufacturing. The human operator will not be superfluous, but rather freed to perform other tasks that require creativity and combination of unrelated skills that only humans can make sense of. These systems require a high degree of integrity and need to be able to detect failure, especially failures in its own system. The ability to easily upgrade the equipment and systems will also be important. Since organizations possessing these capabilities can be regarded as pure software-based companies, the need for cyber security is vital. Third party verification will also become important. Technologies providing security management systems will be enabling for the developments. Satellite technology holds opportunities as security enabling technologies, where inexpensive satellite technology enables ownership of the satellite by a single company.

4.3.3 Scenario "Simulation & Visualization" – augmented reality

In earlier times, you had to decide if you wanted to perform a graphical simulation or a simulation based on real time data. Today the computational power has improved allowing live, real time physical solutions within simulation. The benefit of being able to perform such live real time simulations is having the human in the loop and playing around with creativity and operational experience. You can also simulate with humans in the loop in the simulations and understand the potentials for human errors that can influence the designed solutions. Virtual prototyping will increase the innovation speed by allowing more and faster iterations.

One example of utilizing simulation capabilities is within fluid dynamics. When designing electrical component heat management is important, visualization and analysis enables optimization of heat flow for very small and compact components. Traditionally this has been very difficult to perform. The analogy to manufacturing is a visualized factory layout that can be evaluated before any construction work has been done or any capital committed. Simulation and visualization technologies will have enabling capabilities for design of component, product, system, manufacturing cell, manufacturing line, the factory as a whole and its interconnected systems, as well as the products or systems in operation in real environments or in interaction with other systems.

4.3.4 Scenario "Smart Manufacturing" – automation, robotics, additive and hybrid

Additive and hybrid manufacturing – 3D-printing has the potential to completely transform manufacturing, and is in certain areas already doing so. It has a huge impact on logistics. Hybrid manufacturing that combines additive (techniques such as 3D-printing) and subtractive (techniques like milling and turning) provide possibilities for material optimization, and utilization the materials' full capabilities. Printing parts locally or printing on demand will compete with mass manufacturing's one-trick-pony of economy of scale, where the cost of transportation will hold a new and decisive post in the equation of a products lifecycle cost. Green stakeholders will force new business models for manufacturing. Amazons drone delivery of customer orders, is one example of enabling technology radically disrupting existing business models for transportation.

Robotics and automation – Recent developments in robotics have made them more diverse, intelligent, cheaper and they able to cooperate with humans. The introduction of co-bots utilizing machine learning is one example. More and more tasks will be automated like automated assembly and flexible assembly cells. Therefore, understanding the human factors of human-machine interactions becomes important for advanced manufacturing. One example of how new digitalized capabilities can further utilize automation within manufacturing is within CNC programming. Previously the efforts, both engineering hours and monetary, spent on developing a program controlling a CNC machine was immense and could take weeks and even months. Therefore, the improvements being made, either to product design or developments in hard metal tools had to be very large to surpass the fixed costs of reprogramming the CNC machine.

Whereas today software enables easy upgrading of a CNC program, and the thresholds of the improvement made is lowered, whilst the frequency of upgrading is increased. Being able to generate CNC programs from a 3D-model is also a capability that will be enabled by digitalization. This capability can be further developed, that already in the visualization phase of the product development process all resources requirements, cost, manufacturing availability and delivery can be calculated.

5 Discussion and implications

This study explores enabling technologies and strategy choice related to required investments, and technology acquisition – within the context of the advanced manufacturing industry, part of the maritime industry. An important implication of digitalization of the industry, addressed by the informants, is the fact that outsourcing production to far-off sites do not serve as a long-term strategy. The foundation of this argument is that the operator cost is no longer of interest due to the degree of automation and inroad of robotics and co-bots at the global market; this is especially true for 'on demand' and low volume manufacturing. Being able to produce and deliver close to the customer outflank mass production when reviewed from a transportation cost perspective, which environmental stakeholders will succeed in imposing on manufacturing. When Amazon now offers drone delivered orders, the competitive field of transportation is radically changing. The introduction of co-bots will facilitate comparative cost, and the acquisition cost of robots are continually becoming cheaper and cheaper.

A paradox is that with increased flexibility and choice of design and optimizations, standardization becomes central. Informant 5 formulates the reason for this very well in the following quote. "*Standardization is the process of making an innovation efficient, and enables efficient communication with third parties – and is ultimately an instrument for sharing*."

Cost efficient solutions frees capital for further developments or providing a way of surviving and adapting to the changes in the market. The actors are also able to offer safer and more reliable solutions for its customers by optimization. Big data allows actors to monitor and analyze the condition of its equipment and in this way increase reliability. Simulation and visualization allow testing and trial of solutions even before they have seen daylight. In this way, material use and other resource usage can be optimized with respect to the operating conditions for the specific task the equipment will be performing. Flexibility, as a result of cost effective processing capabilities, change the frequency of improvements and revision of solutions. Digitalization introduce a range of new capabilities for advanced manufacturing enabling organizations to offer smart contracting and planning by knowing the resource requirements, reliability predictions, quality, price and delivery with a precision not seen today. This opens for new business models. The service industry has already experienced a shift in business models as a result of digitalization and sharing of assets. The same will apply for the manufacturing industry.

5.1 New Business Models

Big Data – "Freemium" and Customized Choice

Big data and the processing of information stemming from real operational experience will move the value from owning the equipment to knowledge about how to best utilize the access to equipment. The pre-conditions related to orientation towards freemium model derives from access to large datasets or assets generating large amount of data, e.g. a ship equipment onboard ships equipped with sensors. Asset owners may offer standardized and limited functions free. Business models utilizing big data can offer solutions for customers to operate from remote positions, where related value propositions are cost reduction, efficiency and detailed control and optimization. This provides the customers with decision-support previously not available. Simulation and visualization will also improve the decision-making process where customers can test and validate solutions before committing to any parameters, costs or risks. A freemium business model fits this digitalized scenario with the analogy to Spotify, which offered a basic version free of charge, and pay for customization, flexibility and extra features.

Safety and reliability – "Power-by-the-hour" and Assurance

Since safety becomes complex and highly decisive for operations providing safety and reliability as a value proposition, it will provide new business models where the expensive asset can be sold with the intention of providing revenue not by the initial sale of the asset, but on the guaranties of reliability and safety. The Rolls-Royce aviation business model 'power by the hour' is one example of this business model, where the revenue is provided by operators paying per hour in operation and Rolls-Royce provide reliability, availability, maintainability and safety assurance. Pre-conditions related to orientation towards ‘power by the hour’ relates to in-depth and detailed engineering knowledge, where product development and service knowledge is essential and critical. This orientation has a good fit with the big data scenario.

Supplying for customer assembly – “1-Click-Check-Out”

The industrial internet of things provide new customer channels, and customer loyalty is targeted towards the provider of short and precise delivery. Additive manufacturing technologies such as 3D printing provide customers with the opportunity to push final design to later stages in the development process. Customers can also perform final assembly of standardized and modularized product and system architecture. Pre-conditions related to orientation towards on demand models derives from standardized and high-volume products.

Legacy assets – “Sharing platforms” and Connectivity

The high capital investments required for complex and expensive assets have given rise for new business models for sharing of assets unused capacity. Examples of these business models are found in the service industry where the companies provide the connectivity between asset owners and individuals in need of a small part of the assets’ capacity. These business models will have huge impact on advanced manufacturing, which has many high cost and high complexity assets. The sharing platform business models, with its connectivity, are contradictory to existing business models within the traditional manufacturing industry. Pre-conditions related to orientation towards sharing platforms derive from new form of collaboration – even with competitors seeking mutual benefit and win-win scenarios. Such models can be combined with the two first scenarios, where the combination constitutes an organizations idiosyncratic competitive advantage.

5.2 Modes of technology acquisition

This study identifying three modes of technology acquisition relevant for digitalization the advanced manufacturing and maritime industry, as shown in figure 7.

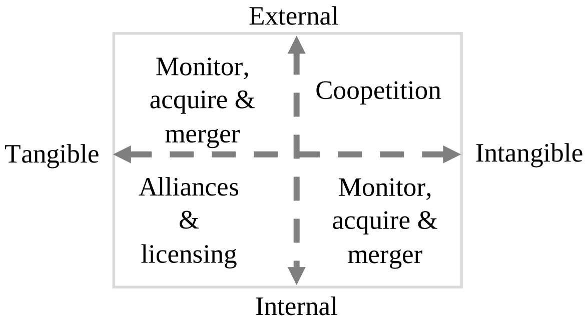

Figure 7: Investment and acquisition modes

Acquiring technology through alliances is a traditional mode of acquisition that will continue to be relevant for digitalization scenarios where the new technology is based on tangible and internal dimensions. An emerging mode of acquisition is organizations investing in capabilities to monitor, acquire, and merge organizations developing the new technology. Examples of such efforts are dedicated functions that interact with and monitor different start-up communities. This requires both intuition and skills. There are several ways creating such listening posts, e.g. through financing and participating in research projects, creating maker-spaces, test and acceleration centers and offering mentoring.

As previously discussed, coopetition is a relative new form of acquisition mode within the advanced manufacturing and maritime industry, where organizations cooperate with competitors on tasks or investments where there exist a greater common goal and mutual benefits. Coopetition as mode of technology acquisition will become an important form of organizing the industry in the years to come. Organizations need to make active strategic choice understanding how to contribute and benefit from this mode of acquisition.

6 Conclusion

This articles case study contribute to the literature on advanced manufacturing by exploring different acquisition scenarios for enabling technology. Further, it contributes to the research domain of technology acquisition by exploring different strategic choice and implications for business models. By exploring strategic choice and introducing coopetition to the discussion within advanced manufacturing, this study expands the portfolio of strategies.

New business models change the way uncertainty is distributed between the actors in an industry, where you share both the potential gain, but also the risk if the investment does not pay off. The investments that are needed to succeed with the digitalization are large and no one company can handle that task alone. When that is said, the investments needed are more related to human and political issues, whereas the monetary investments are overestimated. This serve as enticing opportunities for further research, which should apply quantitative methodology emphasizing longitudinal measures, addressing the shortcoming of this study solely relying on qualitative research design. The uncertainty associated with new technology also require a broad range of investment orientation, which also hold opportunities for further research to enhance our current understanding. Relevant directions for future research inquiry identified in this study were models for uncertainty sharing, questions regarding ownership of data and immaterial property rights.

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Appendix 1

Interview guide - Technology experts

(future enabling technology and capability acquisition)

1. Enabling Technology

1) How do you view or define *Industry 4.0*, or the digital revolution?

2) From your point of view, what are the enabling technologies?

3) Which aspects of manufacturing do you think will see the most impact?

4) How do your technology contribute? (paradigm shift, new business models)

5) And how can this technology be utilized within advanced manufacturing?

6) What are your expectation in regard to timescale?

2. Challenges and struggles

7) What challenges and struggles do you see for manufacturing?

8) And how can these be overcome?

9) How should organizations integrate these new technologies with existing?

3. The incumbents´ role in industrializing new technologies

10) How do you see incumbents´ role in industrializing these new technologies?

11) How should companies acquire these new technologies?

12) How do you view the uncertainty distribution?

4. Required investments and Coopetition

13) What (total) investments, from your point of view, do these new technologies require? (monetary, social, other, please quantify)

14) Are there forms of co-investments where competitors can collaborate to industrialize the new technologies?