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Innovation in the Maritime Industry

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It has been traditionally perceived that the maritime industry, compared to other industries, is less permeable to innovation, where only explicitly defined strategy with centralized and clearly guided managerial leadership would spark some innovative activities. Nowadays, the industry is undergoing a change, where it is believed that the demands for increase in efficiency, safety and protection of the environment can be only achieved by more innovation. The paper tries to find an answer on the question of why there is a sudden shift in the perception of innovation. We have followed the timeline of innovation in the industry of oil tankers. Three distinctive periods have been identified with specific innovation models. The results show that the level of innovation in the industry started to change when environmental friendliness became one of the most important competitive priorities in the industry. This shift has been officially initiated by the policy imposed innovation.

Key words

Maritime industry, innovation, double-hull tanker, environmental friendliness, policy imposed innovation

1. Introduction

It has been traditionally perceived that the maritime industry, compared to other industries, is less permeable to innovation, where only explicitly defined strategy with centralized and clearly guided managerial leadership would spark some innovative activities (Jenssen and Randøy, 2002; Jenssen and Randøy, 2006). Nevertheless, the high development costs and strict industry regulations have been also discouraging companies to innovate (Doloreux and Malançon, 2008).

Nowadays, the industry is undergoing a change, where it is believed that the demands for increase in efficiency, safety and protection of the environment can be only achieved by more innovation (Blakely, 2007). In addition, it has been recognized that to become more innovative, companies need to open up for collaboration with other maritime organizations and organizations from outside the industry (Jenssen, 2003). Particularly, strengthening the collaboration between science and businesses is expected to increase the transfer of advances in research and development (R&D) to the industry, thus enabling the less costly design, building and operation of ships which are safer and more sensitive to the environment (Blakely, 2007; Vivero, 2007; Doloreux and Malançon, 2009).

Innovation in the maritime industry has been traditionally based on experiential learning and incremental innovations where each new ship tends to be a development of a previous successful design (AMSA, 2001). The main profilers of competitiveness of single participants in the industry were associated to some of the traditional competitive priorities like cost management, quality, delivery, and flexibility (Boyer and Lewis, 2002) and innovative activities in the industry were adjusted to satisfy those competitive priorities. Influenced by the industry's contextual factors (increased demand for ships, focus on the capacity, lack of regulations, self-centric mentality) the innovation has been incremental and slow. Recent emergence of another important competitive priority, environmental friendliness is expected to change the way of how innovation is done in the maritime industry. It is believed that in order to boost the competitiveness, the maritime industry needs to augment its competitive priorities (cost, safety, environment friendliness) by improving the ways the innovation is being created. Is the industry ready for that?

The paper explores the development of innovation in the maritime industry by studying the case of innovation in the segment of oil tankers. The paper is organized in the following way. In the following section we briefly describe the complexity of the maritime industry. In section 3 we present the types and models of innovation. Then, in section 4 we present the case of the historical development of oil tankers. The discussion is given in section 5, where we associate different historical periods of innovation for oil tankers with the types and models of innovation. We also discuss the future developments and expected future models of innovation in the maritime industry. The paper ends with concluding remarks.

2. The maritime industry

Maritime industry refers to the activities of various organizations engaged in design, construction, operations, and maintenance of vessels, off-shore structures, and their component parts. It also includes a myriad of organizations that are involved in regulations, insurance, surveying, and financing of ships.

Participants

Figure 1 illustrates the complexity of the industry with its many participants and a vast network of relationships among them. Since focus of the thought experiment presented in this paper is based on the case of innovation around oil tankers we shall briefly describe only the major stakeholders that have been concerned in our analysis.

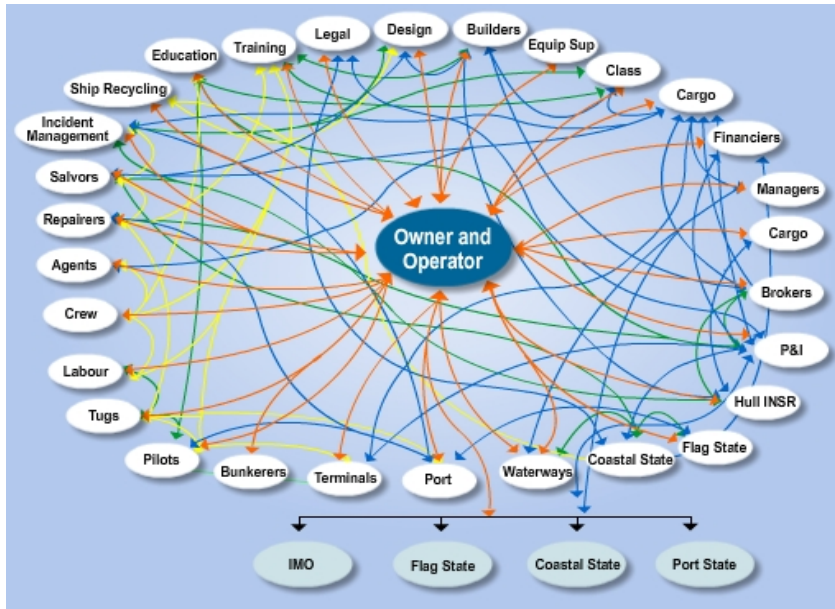


Figure 1: Organizations participating in the maritime industry

Source: MIF - The Maritime Industry Foundation Knowledge Centre

Ship operator is responsible for managing vessel performance, bunkers quality and quantity pricing, and ship routing (MIF, 2011). In most cases, ship operators are usually at the same time the **owners** of the ship. They are also known as shipping companies. The four largest are A.P. Møller-Mærsk, COSCO, Nippon Yusen, and Mitsui OSK Lines.

Design of marine vessels is predominantly in the hands of **naval architects**. Naval architects perform the design spiral, an iterative process starting with the main ship dimensions and hull form, towards the hull structure, propulsion, stability calculations and other issues, further to the cost estimation. A ship design process follows the ship owner requirements and the rules and guidance of a classification society. Usually, a ship owner defines the mission that the ship should perform (e.g. transport of crude oil), the design speed of the vessel, and the weight of the cargo. Strict cost constraints are most often set with regard to ship design, building and

operation. One of a ship owner's main concerns is the fuel consumption and the number of the crew, but he might have other requirements related to hull construction, maintenance etc. Typically, there are a number of iterations which include the interaction between the ship owner and the designer in order to achieve the desired ship characteristics within the cost boundaries specified by the owner.

Shipbuilding is dominated by a vast number of the Chinese shipyards and the South Korean mega shipbuilding companies like Hyundai, Samsung, and Daewoo. Shipbuilding has been always a labor intensive industry which requires high skill craftsmen. It is not uncommon that it can take 2 years to build large freighters or cruise ships. However, shipyards are being intensively modernized with robots and are improving with innovating the manufacturing techniques and process. Due to the high level of complexities, required procedures and scarce knowledgeable labor force they often specialized for niche markets e.g. oil tankers, container ships, cruise ships, etc.

There are numerous national, regional and international **rules and regulations** imposed on ship owners and operators to ensure that their operations are carried out in a safe and secure manner (MIF, 2011). The most important governing body is The International Maritime Organization (IMO). Since the ownership and management chain surrounding any ship can embrace many countries and ships spend their economic life moving between different jurisdictions the IMO was formed to make international standards which would regulate the shipping industry (IMO, 2011).

Classification societies are organizations that establish and apply technical standards in relations to the design, construction and survey of marine related facilities including ships and offshore structures (IACS, 2006a). Class societies validate that construction is according to these

standards and carry out regular surveys in service to ensure compliance with the standards. Major 11 classification societies, responsible for 94 % of the world tonnage, are associated in The International Association of Classification Societies – IACS. Some of the oldest class societies are Lloyd's Register, Bureau Veritas, Registro Italiano Navale, American Bureau of Shipping, Det Norske Veritas, Germanischer Lloyd, and Nippon Kaiji Kyokai.

3. Types and models of innovation

Since its inception in the 1930s, the concept of innovation has evolved tremendously. During that journey academics and practitioners have been able to capture several types and models of innovation. Generally speaking, the types of innovation refer to the level of newness of the new product. Innovation models refer to processes that are deployed to create the innovation.

Types of innovation

The literature distinguishes several types of innovation. Those types are not mutually excluded and very often overlap each other. One of the most common distinctions between the types of innovation is based on the extent to which innovation impacts a firm's capabilities. That view distinguishes between radical and incremental innovations (Afuah, 1998). **Radical innovation** emerges if the technological knowledge required to exploit it is very different from existing knowledge, rendering existing knowledge obsolete. **Incremental innovation** appears when knowledge required to offer a product builds on existing knowledge. Another distinction is based on whether innovation preserves or destroys technical and market capabilities (Abernathy and Clark, 1985). **Regular innovation** is when both technical and market capabilities are preserved, while **architectural innovation** is if both the technical and market capabilities are destroyed.

When technical capabilities are preserved and market capabilities destroyed, it is a **niche innovation**, and when technical capabilities are destroyed and market capabilities preserved, there is a **revolutionary innovation**. With respect to whether an organization develops a whole product innovation or it innovates some of its components Henderson and Clark (1990) distinguish between the architectural and modular innovations. Their distinction is also based on the concept of destruction. They argue that if architectural knowledge is destroyed and component knowledge enhanced, there is an **architectural innovation**. In the opposite case, when component knowledge is destroyed and architectural enhanced, it is a **modular innovation**. Similarly, based on the level of independence between the elements of innovated product, Chesbrough and Teece (1996) distinguish between autonomous and systemic innovations. **Autonomous innovation** can be pursued independently from other innovations. **Systemic innovation** can be realized only in conjunction with related, complementary innovations.

Innovation models

The innovation process was captured in several frameworks, one of which has lately been described and entitled as the generations of innovation (Rothwell, 1992; Rothwell, 1994). Five generations of innovation (1G, 2G, 3G, 4G, and 5G) have been identified. Their brief description is based on Perunovic and Christiansen (2005). The first innovation model was a so called "**technology push**" model. The technology push model represents the **first generation of innovation**. The innovation process was perceived as being sequential and initiated by internal R&D activities and followed by manufacturing and marketing. Rapid increase in competition and customers no longer satisfied with standard products influenced the new approach toward

innovation called "**market pull**", i.e. the **second generation of innovation**. The change in the direction of the innovation process was obvious and ideas for an innovation had started to be sought out at the market, among customers. The **third generation**, or "**coupling model**", was defined in the 1970s as an intermediate model between previous push and pull models. The coupling model recognized necessity for creating the innovation by employing both approaches - technological readiness of companies and true customer's needs. The **fourth generation model** is a so-called "**integrated model**", meaning that parallel development with integrated development teams should exist in a company. In addition, R&D but especially engineering and production are supposed to be integrated and horizontal collaboration should be developed with the leading edge partners (for example: research institutions, R&D specialized companies, etc.). The overarching theme of the fourth generation innovation framework is to decrease the new product development (NPD) time. The continual increase of the competition on the global market imposed a new strategic capability of the companies i.e. to decrease time to market of new product development and at the same time to reduce new product development costs, hence generating the need for the **fifth generation** (5G) of innovation. 5G should enable companies to decrease both NPD time and cost by supporting 4G's integration and networking with sophisticated computerized tools. The 5G model is envisioned to be a true "**networked model**". The 4G and 5G models are performed by organizations which in pursue of innovation have opened their organizational boundaries to other participants in the value chain. This way of innovating has been name given and conceptualized as **open innovation** (Chesbrough, 2003). Open innovation consists of two types of openness. The first is called inbound open innovation and the second outbound open innovation. In the context of inbound openness (bringing the outside in), company makes greater use of external ideas and technologies in its own business. In

the outbound (taking the inside out) kind of openness company allows some of its own ideas, technologies or processes to be used by other businesses (Chesbrough, 2011). In practicing open innovation, an organization has to apply two types of open innovation processes: 1) the process of opening up innovation practices that formerly were (more) closed, and 2) the practices of open innovation: how to do open innovation (Huizingh, 2011). Another prominent model of innovation is **user driven innovation**. It is based on the observation that many products and services are developed or refined by users at the site of use (von Hippel, 1986). Lead users are particularly important for the development of complex products where they may open up the need for new requirements ahead of what is generally available in the market (Hopkins et al., 2011).

4. Innovating the oil tankers

Single hull tankers

Designed in Gothenburg in **1878** for the Brothers Nobel oil company, **Zoroaster** was the first oil tanker carrying oil in two iron tanks joined by pipes. Later in 1880 the first single-hull tanker Moses was ordered where the oil tanks were part of the ship hull structure (Tolf, 1976). In 1883 tankers design advances and the liquid in tanks was divided in smaller compartments to eliminate instability due to free surface effects. The single hull tanker design for the tankers of about 10 000 DWT (dead weight tons) remained almost unchanged until the WW II. After the WWII due to economy expansion the demand for energy increased and crude oil had to be transported in large amounts from distant sources. The tankers fleet multiplied several times and the size grew to about several hundred thousand DWT during the period 1950-1975 (IMO, 2008) and in the late 1970's giant ships appeared exceeding 500,000 DWT. The design was appropriately scaled

so that the main dimensions of the vessel, comparing e.g. a Panamax to an Ultra Large Crude Carrier (ULCC), have roughly doubled. In addition, propulsion (novel technical solutions for giant propellers powered by large engines) and maneuvering issues had to be considered.

The rise of environmental friendliness and the emergence of double hull tankers

The first significant change in design of tankers took place when double hull requirement was introduced at the end of the 20th century. This innovation was a direct consequence of the emergence of the environmental friendliness. The “green” competitive priority was imposed by the maritime industry regulatory bodies after the series of environmental catastrophes.

On March 24th 1989 super tanker **Exxon Valdez** grounded in Prince William Sound and spilled about 37,000 tones of a crude oil. Almost 2,000 kilometers of a scenic Alaskan coast was affected, endangering important fisheries and attractive wildlife. At that time, the oil pollution was the largest in the US history, until overtaken by the Deepwater Horizon incident. The spill created huge interest in media, many protest and a cleanup activity that involved 10,000 people at the cost of US\$ 2 billion (ITOPF, 2011).

The accident prompted an almost immediate reaction from the US regulatory bodies to develop the **Oil Pollution Act in 1990**, also known as OPA 90 (OPA, 1990). Unsatisfied with the existing regulations of the IMO, the U.S. coined this unilateral policy to prevent their economic and environmental interest from future oil spills. After exploring many potential solutions for the improvement of tanker design, policy makers had decided that tankers should have double hulls. A double hull tanker is a ship designed for carriage of oil in bulk where the cargo spaces are protected from the environment by a double side and double bottom spaces dedicated to the carriage of ballast water (AMSA, 2001). The OPA 90 act demanded that all

tankers wishing to sail in the U.S. waters needed to comply with the rule by 2015. Some of the tankers will be banned from sailing in the U.S. waters from 2005 (OPA, 1990).

Regulatory bodies and classification societies had to fill in the gap between the new demands for safety and environmental friendliness of ships on one side, and the economic sustainability of ship owners and operators of the global tanker fleet (consisting exclusively of single hull vessels) on the other side.

Forced by the decision from the OPA 90 act, the **IMO** established the double hull standards in **1992** in the International Convention for the Prevention of Pollution from Ships, also known as **MARPOL** (IMO, 1992). According to their rules, all tankers of 600 DWT or more delivered as of 1996 had to be with double hull. Those with 20,000 dwt or more delivered before 1996 had to comply with standards by the time they are 25 or 30 years old or latest by 2015.

However, the accidents continued to happen. In **1992 Katina** spilled 72,000 tons near the coast of Mozambique, in **1994 Thanassis** polluted the South China Sea with 37,000, **Nakhodka** spilled 16,500 tons near Japan in **1997** (Menefee, 2009). Unfortunately, none of those accidents have caused significant reaction from the regulatory bodies - not until **Erika's** accident in the Bay of Biscay in **1999**. More than 20,000 tons was spilled polluting the French Atlantic coast, causing big damage for fisheries and tourism industries. The magnitude of the spill and the length of the coastline affected resulted in large compensation claims (ITOPF, 2011).

The Erika accident ignited the **IMO** to react with amending the MARPOL's Annex I in **2001** with the purpose of accelerating the phasing out of single hull tankers. The amendment is imposing on all single hull tankers built before 1982 to phase-out by 2007 and for those built after 1982 and for the smaller tankers (up to 30,000 DWT) to phase out by 2015. However, another big accident mobilized the regulators to further accelerate the phase out of single-hull

tankers. In November **2002**, **Prestige** had an accident near Spanish coast spilling 70,000 tons, prompting a cleanup cost of US\$ 3 billion. Awaken by the Erika accident and worried that the single hull tankers that are banned from sailing in the U.S. waters will move their operations into the European Union waters, the **European Commission (EC)** developed their own regulation in **2002** (EC, 2002). The decision imposed the phase out for tankers of different categories from 2005 up to 2010. The decision was effective from 2003. Following the EC's example, the **IMO** amended the MARPOL again, imposing the phase out of some tankers by 2005 with the cat-off date for all tankers by 2010. Even though the regulation was created in 2003, it started to be effective from **2005**.

Technical challenges

The scene for innovation was set. All important stakeholders in the maritime industry have started the race to satisfy the new requirement, which would enable them to continue with operations in one of the most lucrative markets for oil transportation.

Double hull tankers provide additional security in low energy collisions and groundings (Turner, 2009). If we recall the ship accidents described earlier, had the mono hull tanker been fitted with a double hull in the moment of accident, the oil spill would have been reduced. Yet, the double hulls are characterized by some distinctive structural behaviors. As compared to the old single hull tanker, the hull performance of the new double hulled vessel is more vulnerable regarding to fatigue, stress, stability, and corrosion, which impose many technical challenges for design, construction, operations, and maintenance of new vessels.

In case of double hull tankers, the role of design is to mitigate the stress levels which are some 30% higher than those with single hulls (AMSA, 2001). The overall stress level in double hulls is

increased as if the outer hull would be single thus affecting the fatigue behavior of the ship which may result in fatigue cracks and oil leak conditions. Another important issue is that double hull cross section design significantly increases the number of joints between the building blocks, many of them being located in the zones of high stress concentration. In the past, significant number of structural defects and fractures occurred in the tankers that were younger than 10 years old (Rynn, 2007) even though the hull girder strength of the new to be build ship is usually based on least 25 years long design life (IMO, 2003).

Intact transverse stability (ship ability to float in upright stable position) is compromised as compared to a single hull design. Simply said, the double bottom ballast tanks increases the centre of gravity of the whole ship and thereby reduce the intact stability of the ship. Further, the double hull cross section provides enough longitudinal strength and the bulkheads running along the ship in that provide additional strength may not be a part of the design. In this case there is no division of the liquid cargo in smaller areas and the liquid in cargo tanks may have a large free surface effect.

Design, construction, operations and maintenance are tightly knit functional elements of a double hull tanker. Due to the complex design and structure, the operation and maintenance of these ships must be to a high standard since double hulls are more susceptible to certain problems than the old single hull vessels (OCIMF, 2003). The new double hull product would represent an improved solution only and only if all the aspects of construction, maintenance and operation are adequately dealt with (Markides, 2005).

Proper maintenance is solely the ship owner's responsibility. In order to access the hull condition inspections are made by ship owner and other stakeholders who have the interest in safe operation (IACS, 2007). On the regular basis the hull is inspected by the ship crew and port

authorities. Effective inspection is a challenge due to a limited time in the port (Kalghatgi et al., 2009). Corrosion is the weak point of double hull tankers and if undetected may lead to a catastrophic structural failure and environmental pollution. Application of anti-corrosive coatings to the steel surface is a good prevention (IACS, 2006b) but in case of double hull spaces, due to their cellular nature, it may represent a difficulty to inspect and repair the coatings. Furthermore, the steel surface to be coated and inspected is increased several times in a double hull girder. Unfavorable are the salty conditions in water ballast tanks (located in double hull) and acidic conditions in cargo tanks combined with the accelerated aging due to increased temperature (as compared to a single hull design). Failure to maintain the coatings and cathodic protection in the ballast and oil tanks may lead to oil leakage therefore good barriers for coatings should be considered.

During operation in the open ocean or coastal zones and ports several issues have to be taken care of: safe handling of cargo, monitoring of ballast tanks for residual gasses or oil leakage, regular inspection of the structure for defects since a double hull is more susceptible to minor failures. In addition, modern navigation and decision support systems should be available to the ship master in order to prevent hazardous conditions.

Striving to achieve the dominance in the market for double hull tankers, world's most competitive shipyards are using building techniques such as automation of building process and robotics combined with the statistical quality control. High level of accuracy must support the multiple robot welders (Storch, 1996). The first to apply this approach were Odense Lindø shipyard in Denmark and Hitachi shipyards in Japan. In 1990 the first gantry mounted robot was operated in Odense shipyard after earlier successful testing. Thus the necessary technology existed for the building of the world's first double hull in 1992 (Odense Steel Shipyard, 2000).

The mechanical and control systems of the welding robots that can access and move in very restricted spaces still remains a challenge (Ku et al., 2010).

New rules open up the industry for more innovation

The new challenges have accumulated. The participants in the industry couldn't keep up with the pace of the incoming demand for double hull tankers, risen necessity to innovate, and unspecified technical standards.

After a four years gestation period, in 2005 the International Association of Classification Societies (IACS) has adopted the Common Structural Rules for Tankers and Bulk Carriers to be effective in 2006 (IACS, 2006c). Common Structural Rules (CSR) for new vessel design and construction are the result of great cooperation between the classification societies, and exchange of latest knowledge, experience and technical expertise; however they don't represent a radical change to the already existing rules (BV, 2006). Focusing solely on the double hull oil tankers, vessels above 150 m length are covered by the CSR. The new rules are applicable to the double hull requirement and differ from the traditional prescriptive rules (that were valid in the last century) in a way that the ship structure can be optimized in innovative ways satisfying the class rule boundaries. CSR is not formally preventing from radical innovation in design but it would have to be proven that the new design satisfies at least the same structural safety as the one according to CSR.

The CSR have been developed with the emerging IMO Goal Based Standards for ship construction in mind. Goal Based Standards are adopted by IMO in 2010 and will apply to the new built ships starting in 2016. They are organized in a five-tier framework (IMO, 2009) and consist of the "Rules for Rules" (i.e. goals to be met, functional requirements and the verification

compliance) and the detailed requirements developed by e.g. Classification Societies, relevant national requirements and industry standards (after the overall ‘rules for rules’ have been set by IMO).

The goal oriented rather than the old-fashioned prescriptive rules are meant to give more freedom to innovativeness and the ship safety should be verified against these goals at each stage of design, construction and operation (Hoppe, 2005). The goal is that the ship should be safe and environmentally friendly – meaning that the ship should have enough strength, structural integrity and stability to minimize the probability of ship loss or pollution to the marine environment. The technical challenges related to double hulls design, construction (described earlier) are included in the functional requirements and in the future issues related to operation and maintenance should be considered more. In order to comply with GBS, Common Structural Rules by IACS are being harmonized urged by the industry stakeholders (IMO, 2010). To clarify, IMO sets some overall goals and levels of safety to be satisfied with the new construction but the detailed rules and recommendations are in principle the duty of the class societies. Regarding the detailed regulations, the technical tools and procedures should include the risk-based rather than the deterministic methodology.

5. Discussion

The story of the development of oil tankers presented in this paper has shown the interesting pattern of innovation. Three periods have been identified and each of them is characterized with specific contextual influences which have decided on the type and model of innovation in the industry (Table 1).

Period	Characteristics	Types of innovation	Models of innovation
Single hulls	First tanker	Radical Architectural	Market pull
	Division into compartments	Incremental	Technology push
	Growth in size Novel propulsion systems Maneuverability	Incremental Modular Regular Autonomous	Market pull Coupling model User driven innovation
Going green Double hulls	Policy imposed innovation	Radical Revolutionary	Coupling model
	Technical challenges require that key stakeholders collaborate in design, construction, operations, and maintenance	Incremental Modular Revolutionary Systemic	Coupling model dominant Integrated model emerges
Regulations for innovation	Policy makers set the framework for innovation	Expected to be (Incremental – Modular – Regular – Systemic)	Networked model needed Open innovation expected

Table 1 – Innovation of oil tankers

The first period (Single hulls) covers one century, from the inauguration of the first tanker up to the 1990s. It is marked with the two waves of the market pull innovation model; the first when tankers were incepted, and the second when the demand for oil following the post WW II economic recovery intensified the innovative activities to satisfy the rising demand. The imperative was to build bigger and faster oil tankers. The innovation was incremental with modular adaptations of different ship elements. Eventually, the innovation models applied by the key stakeholders in the industry evolved into the coupling models.

Then, several environmental disasters prompted public reaction about how the oil is transported in the waterways. The Americans reacted with the imposed decision to change the design of oils tankers from single hulls into double hulls. Over the years, the regulators have been drawing the policies to accelerate the phase out of the old-fashioned and environmentally unsafe single hull tankers. Some visionary and financially solid companies, like Mærsk, have pulled up their internal R&D resources and started to develop and build the double hull tankers. However, the imposed rules have left the industry with vast amount of challenges which could have been answered only by joining the forces and working on more collaborative new product developments. This has paved the road for more advanced integrated innovation model. After the initial radical peak, the innovation settled to be incremental and modular, but with the flavor of revolutionary and systemic activities.

The requirements were imposed, the challenges were enormous, collaboration for innovation became a necessity, but the standards for new ships were unspecified, which was hindering innovation. Then, the regulatory bodies of this slow and conservative industry reacted surprisingly well and designed the goal based rules, which say what objective has to be achieved, but leave it to the participants to find their own ways of achieving the goals. It is reasonable to believe that such framework will encourage the emergence of networked and open innovation models. However, there will be several years from now until the high level of familiarization and until the rules and guidance by class societies are verified by IMO.

Let us consider the corrosion problem related to ship structure. One of the functional requirements to be satisfied, in order to achieve the overall safety goals, is ship design. Within the design, structural strength must ensure the safety of the structure and the scantlings (dimensions and thickness of hull steel structural members) must be designed with sufficient

safety margin to account, among the other phenomena, for corrosion. The scantlings must be maintained during the ship life. Measures that should be applied in order to meet and maintain the hull structural strength are e.g. corrosion additions (to the thickness), cathode protection, and steel surface coatings. During ship operation, the actual corrosion rate will depend on the actual operation conditions and maintenance, as well as on the quality and maintenance of coatings specified by manufacturer. Preparation and coating of surfaces is dependent on the quality of the construction work in shipyards. Different monitoring on-board systems may be useful for corrosion detection in e.g. ballast tanks but all those technical facilities should be considered already in the design stage where the annual corrosion rate is to be estimated as accurate as possible. Inspection procedures (conducted by the Class Society) should take care of specific areas prone to corrosion (depending on design) in order to ensure conformity with contraction standards. Furthermore, the design must provide the accessibility to all the spaces during operation and maintenance, and areas that need special attention during the ship life cycle should be identified. This kind of design thinking requires collaboration of all the stakeholders since the same level of safety of ship structure must be maintained throughout the whole ship operational life.

6. Conclusion

This paper presented a story of innovation in the maritime industry. The desk research has showed that the oil tankers segment of the maritime industry has been performing traditional innovation strategies where the innovation (incremental) has been triggered only by the ship owner's desire for larger and faster oil tankers. At that time, the traditional manufacturing competitive priorities prevailed in the industry's strategic landscape. Even when environmental

friendliness emerged as one of the most important competitive priorities, the industry reacted only after the strong push from its regulatory bodies. The policy imposed double hull requirement has shaken the conservative tanker vessels industry that was inert for over one century.

The continuously reducing time for the new ship design and building as well as for the ship's maintenance between the two voyages requires the great expertise and innovative techniques to meet these limitations. In order to strengthen the competitiveness and to preserve and even extend the position in the market the industry stakeholders will have to innovate and meet the goals of ship safety and environmental friendliness. Over the decades, the stakeholders' innovation processes have been kept closed and strictly confidential, but the requirements for the hull safety can be achieved in a limited time frame only by increased collaboration between the stakeholders. However, due to complexity of ship design, construction and operation, clear guidance and industry standards are still needed in order for the innovative product to satisfy the safety margins, the ball thus being now in the field of the classification societies. Here, the best methodologies and tools need to be recognized, which will emphasize stronger involvement of universities and other R&D centers. The policy imposed innovation can open an industry for the collaborative and open innovation models.

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