Abstract

Maritime transportation is the most efficient and cost-effective mode of transport. With the appropriate use of advanced technology, the efficiency of the industry can be improved even further. Information systems for the maritime industry have been generally ignored by the IS community. Consequently, we introduce “Maritime Informatics” as a new stream to introduce IS scholars to the many research and practice opportunities offered by the maritime industry. Our goals are to understand the characteristics, operations, and culture of the industry, as well as some major problems that need improvement. By analyzing previous studies addressing the problems of the maritime transportation industry, we aim to provide insight into the maritime transportation research for information system researchers, with the end goal of creating a more efficient, safe, and ecologically sustainable maritime transportation.

Keywords

Maritime informatics, information systems, maritime ecosystem.

Digitization of the Seas

Maritime transportation is the backbone of international trade. With around 90% of the world’s trade carried by sea, maritime transportation is essential for the global economy (IMO, 2013). Including indirect and induced effects, the annual economic impact of the shipping industry is $436.6 Billion (World Shipping Council, 2014b). The industry supports 13.5 million jobs (World Shipping Council, 2014b). With a 4.3% growth rate in 2012, as well as a growing trend throughout history, maritime transportation is likely to remain important in the coming years (IMO, 2013; UNCTAD, 2013). Therefore, certain problems in the industry need to be solved. Conditions should be improved in order to secure a better transportation system in the future.

Maritime transportation is the most efficient and cost-effective mode of transport. Container ships can carry several large warehouses of goods on a single journey, and they are also able to operate with a team of only thirteen people thanks to advanced computer technology (World Shipping Council, 2014a). It is also relatively fast: a journey of around 14,500 km can be completed in a mere days (World Shipping Council, 2014a). Added to that, being capable of carrying large amounts of goods decreases the unit cost of goods transported. For example, the cost of transporting a kilogram of coffee from Asia to Europe is only fifteen cents (World Shipping Council, 2014a). With the appropriate use of advanced technology, the efficiency of the industry can be improved even further.

Currently, the maritime transportation industry experiences communication problems that can inevitably result in chaos, as revealed by the following event. The Port of Felixstowe – UK’s busiest port – was in 2014 in danger of losing many customers due to port congestion. The summer period has always been busy in Felixstowe, but in 2014, the unexpected growth of Asian imports worsened the situation, so much so that many companies had already diverted their ships from Felixstowe to London Gateway Port. Felixstowe was not alone: Rotterdam and Hamburg ports – Europe’s two biggest ports – also had congestion problems in 2014.

Port authorities often complain that ships do not maintain announced schedules. Moreover, carriers do not always communicate with their shippers before making a diversion to a new port. Thus, exporters have difficulty whenever they try to arrange a new route from a new port. (Wackett, 2014)
Serious communication problems in the maritime industry often lead to chaos, as in Felixstowe’s case. Communication and congestion are two of the maritime industry’s major management issues.

Information systems for the maritime industry have been generally ignored by the IS community, with a few exceptions (Cumberland, Jessup, & Valacich, 2002). Consequently, we introduce “Maritime Informatics” as a new stream to introduce IS scholars to the many research and practice opportunities offered by the maritime industry.

In this work, we aim to understand the characteristics, operations, and culture of the industry, as well as some major problems that need improvement. In addition, we analyze previous studies addressing the problems of the maritime transportation with the end goal of creating a more efficient, safe, and ecologically sustainable maritime transportation. Lastly, we introduce maritime informatics as a research stream that studies the application of information systems in order to increase the efficiency, safety, and ecological sustainability of the world’s shipping industry. In this way, we aim to provide a background for future studies in maritime informatics.

**Maritime Ecosystem**

Maritime transportation differs from other modes of transportation due to its unique characteristics (Christiansen & Fagerholt, 2006). Throughout history, the shipping industry has had distinctive traditions, norms, and universal rules, which have formed a rooted and unique maritime culture (Lutzhoff, Grech, & Porathe, 2011). Understanding the industry, its operations, and problems requires a understanding of its ecosystem, which consists of a culture of unique characteristics and conditions (Lutzhoff et al., 2011). In this section, the components of maritime ecosystem (see Figure 1) are explained in detail.

![Figure 1: The components of the maritime culture](image-url)
The distinct characteristics of a maritime ecosystem can be grouped into four main categories: working conditions, global nature, autonomy, and complexity. The working conditions of the maritime industry have many unique characteristics that affect its overall operations. It is inherently global (International Chamber of Shipping, 2009), which requires specific norms and regulations. Despite the fact it continuously interacts with different cultures, the industry still maintains distinctive traditions. One of the most notable historical characteristics is the autonomy of the captain. Also, the maritime industry has a complex nature in terms of the relationships between the agents, the operations, rules, and regulations. All four of these major components need to be collectively understood before considering the application of information systems to improve the ecosystem.

Global Nature

The shipping industry is global by nature, which affects the roles, regulations, and the culture of the industry. Globalization provides an opportunity to serve a more varied market, but also opens doors to a larger number of players, which usually increases competition. As the maritime industry operates in a highly competitive environment, ship owners are compelled to be cost-oriented (Lutzhoft et al., 2011). They seek economic efficiencies in their operations. For example, they hire multinational crews from developing economies to decrease their wage bills, or they reduce the number of crew members on board (Lutzhoft et al., 2011). Knowing the cost-oriented behavior of the ship owners help us to understand subsequent decisions they might make about certain issues such as employee training and technology investments.

The global nature of the industry makes multiculturalism inevitable. Crew members from different nations work and live together during long trips. While it may provide a cost reduction opportunity, it can also create many problems in the work environment (Horck, 2005). One of the major disadvantages of multiculturalism is poor communication between crew members mainly due to their lack of linguistic skills in a common language, usually English (National Maritime Polytechnic, 2006). Even in circumstances in which all crew members speak the same language they might still have communication difficulties originating from attitude-related problems (Lutzhoft et al., 2011).

Moreover, multinational crew members often have relationship problems due to racism, cultural differences, stereotyping, prejudice, and power distance (Horck, 2005; Lutzhoft et al., 2011). Sometimes they may not even find enough common ground to develop basic friendships. Another reason for potential conflict in a multicultural crew is the differences in power distance (Horck, 2005; Lutzhoft et al., 2011). Seafarers from high-power distance countries may accept authority more easily, while those from low-power distance countries may question their superiors directly (Lutzhoft et al., 2011). Cultural differences can also strain relationships between crew members and a ship’s officers.

Autonomy

Shipboard teams are traditionally hierarchical, consisting of a combination of civil-type structures and quasi-military norms (Lutzhoft et al., 2011). The captain has full authority over everything – routes, seafarers, and operations. The captain’s autonomy is revealed in Flexstowe’s case, where ships often decided to change port without informing their customers or port authorities. Based on their judgment, a captain and other officers may make important decisions such as changing the route, the arrival port, or a schedule.

Shipping has traditionally had a power culture and an autocratic attitude style (Goulielmos & Gatzoli, 2012). The power culture is held and transmitted by the ship owner, while the captain has an autocratic attitude (Goulielmos & Gatzoli, 2012). In the past, the ship owners used to stay on their ships, while today their management style is different: “management by communication” (managing the ships from the shore and leading the captain). In addition, they have come to view their ships as commercial properties that can be sold anytime, which shows that there is no sentimental link between the ship and its owner (Goulielmos & Gatzoli, 2012). On the other hand, the captain is always on the ship and the one whose life is at risk in case of an accident. Thus, the communication between the captain and the ship
owner is not always effective, especially in moments of distress (Goulielmos & Gatzoli, 2012). In addition, according to the IMO safety regulations, the captain has the major responsibility for safety issues, with increasing accountability in recent years (Goulielmos & Gatzoli, 2012). Having the highest responsibility on a ship may help explain the autocratic attitude of the captain.

Self-organization is another characteristic of the maritime ecosystem. In the shipping industry, the control of operations is distributed among different agents (Caschili & Medda, 2012). Even though there are international trade agreements, rules, and regulations, such as the IMO’s regulations, there are also agents coordinating ports, ships, and operations. Agents pursue their own advantage in their decisions, and operations by self-organization – “a bottom-up process arising from the simultaneous local non-linear interactions among agents” (Caschili & Medda, 2012).

**Complexity**

The maritime industry has a complex structure with a large number of interacting independent agents. The key agents of the industry are ports, port authorities, shipping companies, terminal operators, commodity producers, and freight brokers. They are independently managed by different parties, but connect with each other on a daily basis. The presence of a large number of interacting agents makes the structure of the maritime industry (Figure 2) highly complex (Caschili & Medda, 2012).

![Figure 2: Complexity of the stakeholders in maritime industry (Adopted from (Maritime Industry Foundation, 2013))](image)

The mutual interactions of agents generates evolution in the system. The industry is co-evolving because agents need to change their actions as they interact with other agents. For example, if a big seaport hub is damaged due to a natural disaster, then the maritime shipping network will co-evolve to maintain operations. Similarly, in the case of a financial international crisis, the maritime shipping network will co-operate with each other in order to share the investment as well as the risk. In this way,
they can stay profitable. Being able to co-evolve makes the structure of the maritime transportation more complex.

The shipping industry also incorporates an element of unpredictability (Caschili & Medda, 2012; Lutzhof et al., 2011). Planned arrival times, departure times, and sailing schedules can change on board (Lutzhof et al., 2011). The most common reasons for unpredictable schedules are weather conditions, and port conditions (Christiansen & Fagerholt, 2006). Weather conditions may affect the sailing time, such as a ship needing to reduce its speed in bad weather. Furthermore, port conditions—mechanical problems, traffic, operating hours—can affect arrival and departure times (Christiansen & Fagerholt, 2006). Although it is not easy to eliminate the variations in shipping operations, uncertainties due to port conditions may be reduced by better communication of higher quality information between stakeholders and by more effective management.

**Working Conditions**

The maritime industry has unique working conditions. First of all, there is often a harsh physical working environment (Lutzhof et al., 2011). Although the conditions may vary from ship to ship, the facilities are generally poor. For example, in some ships, sea water can be used for bathing, while electricity is only available to the higher grade staff (Samuels, Sultana, & Chakraborty, 2013). Crew members must deal with the varying conditions of the seas even as they try to operate safely and efficiently. Besides the often poor facilities, there are other challenges for the sailors, such as natural disasters, accidents, and robbery (Samuels et al., 2013).

Even if the conditions are relatively fair, working long hours at sea create a difficult life (NPR, 2013). A ship is not just the workplace for the crew, but also the crew’s only living space. During longer trips, the ship is the place where crew live, work, entertain, and sleep— it is everything (NPR, 2013). As crew members often share their cabins with other sailors, they don’t usually have privacy or a quiet room to sleep (Samuels et al., 2013). Moreover, they need to sleep in motion in a noisy surrounding, since the ship continues its operations day and night (Lutzhof et al., 2011). In addition, shift work makes sleeping conditions even worse as its schedule correlates with short and poor-quality sleep (Axelsson, Akerstedt, Kecklund, & Lowden, 2004; Lutzhof et al., 2011). Consequently, sleepiness is a major problem for seafarers.

Waking hours also pose specific problems. It is very difficult for a seafarer to get away from the job and have some free time, which leads many workers to refer to their jobs as “a prison with a salary” (Alderton, Bloor, & Kahveci, 2004; NPR, 2013). An American ex-seafarer explains the dilemma as follows: “Seafarers work tremendous hours and they have nowhere to go, either at sea or in port.” (Alderton et al., 2004).

As the testimonies reveal, maritime workers must deal with the reality that their workplace is far away from family, and friends. The remoteness of the working environment and limited access to communication technology often result in an isolated, difficult, and lonely environment (Lutzhof et al., 2011; NPR, 2013). In turn, this situation affects seafarers’ morale, their relationships, families, and shore-based life in a negative way (Alderton et al., 2004). Trying to communicate with one’s family during stressful times, such as when a family member is ill, only serve to exacerbate an already difficult situation. During these times, lack of communication increases the seafarer’s stress level, which can lead to fatigue and low levels of productivity in the workplace (Alderton et al., 2004). Since technological developments increase a seafarer’s chance of communicating with family more frequently and easily, implementing the newest technologies at sea may raise a worker’s morale (and hence, productivity).
Maritime Transportation Literature

Literature Overview

Maritime transportation has received considerable attention from fields diverse as operations research, management, policy, economics, and information systems. We reviewed the literature in a broad range of fields to identify the major problems of the industry, research questions that have already been answered, and ones that remain for future studies. In the previous studies, we observe four main research domains: efficiency, safety, environment, and policy. These arenas represent the ultimate purpose of the research – improving efficiency, safety, or environmental performance. In the current research, we are not directly involved in policy studies, so we exclude this research from our review.

Each study tends to focus on one or more components of the maritime ecosystem. For example, improving efficiency requires a consideration of complex structure of the industry, and improving safety requires a consideration of working conditions on board. We have listed the most highly cited publications studying the efficiency, safety and environment domains of maritime transportation research since 2005 (available on request from the author). We performed a search with “maritime transportation” keyword in Web of Science and selected articles based on their citation counts. We classified them by their research domains, and noted the ecosystem components that they take into consideration.

Detailed literature review, where we listed the field of study, findings, methodologies, and future research suggestions of the articles, shows us that majority of the prior studies have offered solutions for local problems, and have suggested an integrated approach for solving the problems of the maritime ecosystem (available on request from the author).

The highlights of the detailed literature review provided insight for future research. Studies on efficiency emphasize the complexity of the industry, and suggest accounting for the relationships between interacting agents. We believe that this can be achieved by an effective communication between related agents. Safety studies emphasize the importance of human factors, historical data analysis, and traffic control technologies. We believe that information systems can help gathering safety related data, help preventing human related errors, and manage port and sea traffic. Environmental studies focus on the assessment of the environmental performance, and the impact of the environmental policies. Information systems would help gathering environmental data which makes it easier to assess the environmental performance, and monitor the actions of the stakeholders.

The Information Systems Literature

As the highly cited articles do not include any articles from the Information Systems literature, we performed a separate search of IS literature, limited to the senior scholars basket of eight journals1 and the two main conferences of Association of Information Systems (AIS) – International Conference on Information Systems (ICIS), and American Conference on Information Systems (AMCIS). As these journals and conferences are highly recognized in the field, we believe that the list would include any high-quality research which has strong roots in IS literature.

We used the Web of Science database using the key words “maritime transportation” without any date restriction (between 1864 and 2014). We had zero results. We repeated the search with “maritime” as the keyword without any date restriction and found one article, which was not directly related to maritime industry. With “shipping,” we obtained five results. Among these five, only two of them are directly related to the shipping industry (Gordon, Lee, & Lucas, 2005; Rai, Pavlou, Im, & Du, 2012), while others merely mention the industry. In order to make sure that we didn’t miss any articles, we repeated the search in Google Scholar, and had the same results.

We used the AIS database to search for “maritime”, and “shipping” keywords in AMCIS and ICIS proceedings. Among a few results, none of them has the maritime industry as its main area of focus.

1 http://aisnet.org/?page=SeniorScholarBasket&hhSearchTerms=%22basket+and+eight%22
Therefore, we conclude that the maritime industry has been ignored by the IS community. This situation confirms the need to create Maritime Informatics as a new subfield of IS.

In addition to reviewing the selected journals and conference proceedings mentioned previously, we performed a broader search to see if the maritime industry was ever mentioned in IS literature. Cumberland, Jessup, & Valacich (2002)’s work is worthwhile to mention here. The paper, which appears in the Communication of the Association for Information Systems in 2002, aims to introduce a comprehensive list of information systems that support the maritime industry and also to explore the research opportunities in this area. Although their purpose seems similar to ours, their paper is significantly different. First, they focus on the technologies used without analyzing the components of the maritime ecosystem. If the unique characteristics of the industry are not explained thoroughly, the need for research might not be clearly understood and key dimensions overlooked. Another important difference is that they focus on a specific information system only: Automated Identification Systems (AIS). However, we adopt a much wider perspective covering a range of possible information systems used by key stakeholders of the maritime industry. Cumberland, Jessup, & Valacich (2002)’s article had little impact, and we are not aware of any citations.

The Role of IS in Maritime Ecosystem Research

Information systems can create efficiency and raise safety as well as reduce environmental problems in the maritime industry. In order to create effective information systems, it is critical to thoroughly understand the maritime ecosystem – its needs and characteristics. The information system can have a positive impact only if it is aligned with specific objectives (Henderson & Venkatraman, 1993). Therefore, the alignment of the information systems with the goals of the key stakeholders of the maritime industry is critical.

As explained in the previous chapters, the maritime ecosystem has many unique characteristics. Information systems designed for this industry need to be closely aligned with these characteristics. For example, developing an information communication system for seafarers requires that we first consider the needs, culture, and working conditions of the shipping industry. Thus, information systems designed for maritime industry need to be aligned with the goals of the stakeholders as well as with the characteristics of the ecosystem.

In this section, we propose a framework of the maritime informatics (see Figure 3), which arose from our review of the literature, and analysis of the ecosystem. In doing so, we explain the information system needs of the industry and determine ecosystem components that should be taken into consideration in developing information systems for certain industry needs. Next, we provide some examples of information systems that we think would be used in the maritime industry to achieve its goals. We also present the ecosystem characteristics that need to be taken into account in the design and management of those information systems. In this way, we aim to illustrate how to utilize the maritime informatics framework we propose.
In our framework, we first identified the key stakeholders of the industry and their goals. Since the maritime transportation industry is complex, there are many interacting and interrelated stakeholders (Caschili & Medda, 2012). However, it is possible to group the stakeholders into two main categories: society and commercial operators. Commercial operators include ship owners, port authorities, cargo owners, and others (see Figure 2). The main goals of the society are safety and environmental protection, while commercial stakeholders are mainly interested in profit through efficiency. Clearly, some commercial stakeholders also care about the environment and safety, but in order to survive, their main focus should be on efficiency. The International Maritime Organization (IMO) helps society achieve its goals through rules and regulations for safety and the environment (IMO, 2014). On the other hand, commercial operators’ self-interest and market forces are the main drivers of efficiency.

Governments, institutions and companies recognize the importance of information systems in maritime transportation. The European Union has initiated an e-Maritime Initiative to foster the use of advanced information systems in the industry (European Union, 2012). It aims to improve the quality, efficiency of the operators, and the communication between the agents (European Union, 2012). As Dimitrios Theologitis – head of unit “Maritime Transport and Ports Policy” for the European Commission – mentioned in an interview in 2011, it also expects gains in terms of the living standards and education of seafarers (Face of Shipping, 2011). Information technology for the maritime industry also attracts many companies. As a result, many independent information systems have been developed for certain purposes, creating little standardization. As Mr. Theologitis mentions, even though integrating information between all stakeholders is not realistic, the stakeholders, at the very least, need to communicate information. Thus, developing a system that supports data sharing is critical.
Data integration/sharing

Lastly, a distinction between the information systems in terms of their data integration should be taken into consideration. Data integration consists of gathering data from different sources, and providing a unified database. In our case, data integration is necessary within one unit of the industry. In other words, a company can integrate its data thanks to the hierarchical structure – the upper level management having control over the employees. Similarly, data integration is possible as IMO has a hierarchical power over the other stakeholders. In sum, data integration is necessary for open ICT, sensor networks, SMIS, and environmental IT. The other information systems are designed to increase the collaboration between different stakeholders (e.g. companies), which requires data sharing instead of data integration. Data sharing is to share information with a relevant person, in terms of the characteristics of the person, and the location of him/her. There is no need to share all information an agent has. In addition, it is not realistic to force companies to integrate all of their data with other companies. Thus, GIS, vessel-to-vessel ICT, and ship-to-shore ICT should be designed to be data sharing systems.

Conclusion and Future Work

Maritime transportation forms the backbone of international trade. Its success remains crucial to our current global economy and its importance shows no signs of waning. Therefore, both industry and academia must commit themselves to solving prominent problems in the industry. As the most efficient and cost-effective mode of transport, improvements in the efficiency, safety, and ecological sustainability of the maritime industry will have considerable social benefits. In this respect, IMO suggests that digitization of the seas is a way to further improve operations of the industry.

Research in the maritime transportation domain has attracted scholars from different fields: operations research, economics, policy, international trade, cultural, and environmental studies. The ultimate purpose of the research has been mainly to improve efficiency, safety, or environmental performance. By reviewing the literature, we identified problems addressed by previous studies and their approach towards solving these problems. These studies have collectively contributed valuable analysis of (as well as insight into) the industry, as well as some useful solutions to the stakeholders’ critical problems. However, we believe that the maritime industry is ultimately an ecosystem, which requires a broader approach to its problems versus a singular focus on one stakeholder. Even though a local approach might be useful for individual solutions, such an approach fails to address problems which persist across the industry.

An ecosystem approach should be adopted in future studies in order to achieve the efficiency, safety, and environmental goals of the industry. As all stakeholders are inter-related in such a complex ecosystem, and interact with each other on a day-to-day basis, local solutions are less effective. Improving the efficiency, safety, and environmental performance for one stakeholder highly depends on the other stakeholders. Therefore, future studies need to take the problems, needs, and characteristics of the ecosystem into consideration, and seek solutions for the ecosystem-wide problems.

Our work has some limitations. First, we reviewed the recent literature (since 2005) on maritime industry efficiency, safety, and environmental performance. We excluded policy, economics, and technological studies from our literature review, which may provide a different perspective for future studies. Lastly, we don’t analyze the technological restrictions in this study. In the implementation of the information systems, technical constraints will prove critical. For example, the expensive satellite systems will be a critical barrier for developing effective communication systems.

We believe that information systems plays a critical role in maritime ecosystem research. In the current work, we identified the characteristics and main problems of the maritime ecosystem and explained how information systems can serve the goals of the industry. We introduced maritime informatics as a new research stream that studies the application of information systems in order to increase the efficiency, safety, and ecological sustainability of the world’s shipping industry. As the next step, we aim to create a comprehensive research agenda, and present potential research questions, with the sincere hope that this agenda helps facilitate more research in this new important field.
REFERENCES


