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Research Article

Challenges in the integration of Data Management Systems (DMS) in ship operations

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Abstract
While the rapid growth of emerging technologies is changing the practices of industries worldwide, the global maritime industry has been conservative and reluctant to make any significant changes in their management practice. Data Management Systems (DMS) have become increasingly important in many other industries, such as banking and finance, health care, shopping, and different educational institutions, including universities, academic institutions, and journals. However, ship managers have not adopted and integrated DMS to a similar extent in ship operations. The related reasons may include inadequate knowledge, prevailing management practices, a lack of incentives, and high capital expenditure (CAPEX). In this research, 5 key hypotheses were developed based on existing knowledge and scholarship, drawn from a variety of sources in both the public domain and private databases. Primary data was gathered through semi-structured interviews and online questionnaires to test these hypotheses. This article identifies and critically examines some key issues of DMS with respect to ship operations and how it can be used in ship operations to improve management efficiency. DMS currently marketed does not address the industry's requirements, hence, it should be customised to suit the industry's needs by asking vessel managers for their requirements rather than DMS writers assuming them. Training in DMS software is a weak point and, hence, needs more attention. DMS packages should be made more user / operator friendly and intuitive by paying more attention to the UDI to minimise training requirements and barriers to acceptance. Finally, this paper concludes by introducing some recommendations and proposing a model framework for the integration of DMS in ship operations.

1. Introduction

The global shipping industry is currently experiencing a tough time, resulting from an oversupply of ships and tonnage, reduced demand, reduced international trade, and sluggish markets (UNCTAD, 2019). Freight rates remain volatile as the supply of shipping services, fuelled by last decade's shipping boom, remain abundant, while new competitors attempt to penetrate an

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already saturated market (Reuters, 2015; Bakhsh, 2018). Increased regulatory burdens have only increased the challenges (Drewry, 2017; Lowry, 2018). In the meantime, ship operational expenses are on the rise, due to additional expenses caused by new regulations and the increased expenses of human resources. One of the remedies to this is to improve cost-efficiency through operations management, human resource development onboard and ashore (Slack, 2016), and streamlining regulatory compliance and, thus, have an overall smooth ship operations process (Porter, 2017). A frequent complaint, probably justified, has been that, compared to other transport industries, the maritime industry has always been slow to embrace or integrate new technology and automation (Stopford, 2009). One of the reasons for this has been the high capital expenditure that direct process technologies, such as infrastructure and machinery, require (Jiang, 2017).

However, the introduction of new Data Management Technologies, Data Management Systems (DMS) (Addotenkorang & Helo, 2016), and indirect process technologies, such as Internet of Things (IoT), Big Data Analysis (BDA) (Peng et al., 2018), Decision Support Systems (DSS), (Balmat et al., 2011), cloud computing (Januszewska, 2012) enables these infrastructural requirements to be achieved today at more manageable and competitive costs (Ahmed et al., 2017). This could enable the maritime industry to move forward in its operations, strengthening international trade without large capital investments (Thurston & Hu, 2002). Reviews of Maritime Transport published by the United Nations Conference on Trade and Development (UNCTAD) (UNCTAD, 2017; UNCTAD, 2019) have repeatedly highlighted issues with the integration of technology in maritime operations, including big data.

Although digitalization and technology hold the promise of optimization and improvement, the maritime industry has been slow in its technological adoption. Other industries have been leveraging data management for years, whilst the maritime sector has just recently started realizing the importance of data to sustain competitiveness (Tian et al., 2017). The traditional mindset of the industry, combined with limited knowledge about the cost of investment and true yields of big data, has been identified as the main barrier to driving technological change. According to Fields (2015), "the future value of big data can only be realized through organizational and cultural change in combination with the acceptance of appropriate analytical tools, skills and practices".

In this new data era, knowing where to start and what to look for presents challenges in themselves, as data needs to be broken up and analyzed in order to make sense. Businesses that want to benefit from big data analytics must be able to answer questions like; Why do we want to collect data? What do we expect to use the data for? Who will be using the data? Who will do the work? (Sivarajah et al., 2017). Only when key performance indicators (KPIs) are established, and the data is processed, analyzed, and acted upon, can value be created. A common belief amongst maritime actors is that the cost reduction margins of BDA implementations are too insignificant for the investment and the organizational restructuring to be worth it (Wilhelmsson, 2015).

Objectives, methods and data

Based on the above concerns, this study aims to examine how DMS can provide solutions to key operational difficulties in ship operations. Specifically, it addresses the following objectives:

- To critically document and analyze the latest development of DMS and how it is applied in the maritime industry.
- To investigate the necessity to establish DMS software for maritime operations.
- To analyze the key factors which should be included in the DMS and how these factors play their roles in solving maritime operational issues.
- To investigate how different stakeholders in ship operations can benefit from and contribute to DMS.

We do so by using an interdisciplinary framework that integrates information technology, data analysis, concepts, perspectives, and theories from sociology, legal, information, and maritime science. In carrying out our data analysis, we use the existing literature as a tool to analyse DMS and "to develop empirical knowledge" based on it (Corbin & Strauss, 2008). This is followed up with semi-structured interviews with stakeholders in the maritime community to learn from their experience of using DMS and gain insights into the regions of usage, perceived benefits, and limitations of the same.

In this article, we first describe the manner in which DMS is used in maritime operations, and the latest developments in the field (section 2.1 and 2.2), our hypotheses (section 2.3), and the research methodology that we employ and descriptions of our participants and the sample parameters (section 3), followed by a discussion on the results of the familiarity of stakeholders regarding DMS, the manner in which they use it, their issues regarding its deployment, and areas where they see scope for improved usage if its limitations are corrected (sections 4 and 5). In sections 5 and 6, we also present some recommendations which, if acted upon, can improve the use of DMS on ships.

2. Results

A regulatory incentive for the use of DMS currently exists in the International Maritime Organization's (IMO) '*Global ocean observing systems'* (GOOS), '*Energy management plan system'* (ISO 50001), and *'Guidelines on maritime cyber risk management'*, *the European Maritime Safety Agency's* (EMSA) *COPERNICUS* and *SafetySeaNet* projects, and the United Nations Conference on Trade and Development's (UNCTAD) guidance on the use of blockchain technology for Electronic bills of lading. The potential for the use of DMS also exists as a risk mitigation tool (when used with sensors in order to monitor main engine and equipment performance), to monitor KPIs, to aid automation (thus reducing human error and fatigue) and for data collection and processing (required by many states for the regulation and prevention of marine pollution). While DMS is currently used in the maritime sector, its usage has been limited in > 50 % of the respondents to safety, performance, maintenance, and HR-related operations in the form of software. User familiarity with the operating software is high (85 %). Issues identified with the use of DMS are the long time taken for transition to DMS (>12 months in 48 % of the cases), software issues, and lack of updates to the software.

3. The latest development of DMS in ship operations

3.1 The concept of DMS in ship operations

In the maritime scenario, a DMS typically uses a lot of data fed into it, either manually, through sensors, automatically, or through other interlinked documents (Ex. noon reports) and uses it for further analysis and optimization. It can have various uses in the maritime sector; for example, information that is embedded in noon reports could automatically be used by the DMS to construct a monthly deck and engine abstract. Data from these 3 sources could be compared with actual weather experienced to further optimise main engine operating parameters to minimise fuel consumption. Routine advice from weather routing companies can be compared by the DMS with actual speed and fuel consumption data for voyages that have taken place to assess the utility of such routing advice. Near miss reports and accident reports can be used by the DMS to compile injury and illness statistics. Further, all of these can be compared for the entire fleet by the DMS and help operators learn from ships where efficiencies are found to be best.

Stakeholders in maritime operations could be various, including internal employees and external customers. This includes vessel managers, ship owners, and various agencies to whom different aspects of ship operations may have been outsourced. For example, vessel managers often use third party manning agencies in different countries for crew recruitment; however, they might all use the same interconnected crew management system using DMS. The external stakeholders do not have a direct relationship with the organizations. The operational principle states that all operation decisions should reflect the stakeholders' interests (Slack, 2016). In the implementation of DMS in ship operations, the key roles are identified as external regulators (IMO, local authority), internal managers (shipboard and shore), and data stewards (system maintenance personnel) (IGGI, 2005).

As the main external regulator, the International Maritime Organization (IMO) identifies the need for technology integration and data management to improve ship operations. The IMO has contributed to DMS through programs such as '*Global ocean observing systems'* (GOOS) (Tatjana, 2006). The objective of this program was to deploy free-drifting profiling floats to collect information on many aspects to introduce benefits by data management in the oceanography and climatology fields. Further, the IMO's '*Energy management plan system*' (ISO 50001) (IMO, 2015) and regulatory development for DMS such as '*Guidelines on maritime cyber risk management*' (IMO, 2017) prove the necessity of standardizing and integrating DMS technology into ship operations.

The European Maritime Safety Agency (EMSA) has also made a similar effort through the '*COPERNICUS*' project (Copernicus, 2016). Copernicus is "is a "European Union Programme aimed at developing European information services based on satellite Earth Observation (EO) and in-situ (non-space) data. The Copernicus services transform this wealth of satellite and in situ data into valuable information that is streamlined through 6 thematic streams, one of which is Security". Another project, '*Safety at Sea*' (NSR, 2009), has been used for risk assessment in vessel traffic, wind farming, and refuge management. Projects on data management by local authority to enhance DSS and risk management for vessel traffic include the '*SafetySeaNet*' program, a long-range identification and tracking (LRIT) data center (EMSA, 2017a; EMSA, 2017b), the '*EfficientSea*' program (Efficient Sea, 2009), and '*Monolisa2.0*' (Magnus, 2010).

Apart from the external regulators, direct contributions to and from the DMS come from operators, namely, managers, ship staff, and shore staff. The data stewards are personnel involved in maintaining data and software, such as IT professionals or third-party software providing companies. The organization structure of a typical shipping company is focused on the internal IT department and the role of the IT director (Branch, 2014). These managers and data stewards introduce the human element to the implementation of DMS.

The human element in ship operations is a major component of the DMS equation, which directly and indirectly contributes to the performance, implementation, and cost of ship operations. Factoring this, modern ergonomics are developed at the design stage of the vessel construction, with increasing automation to mitigate operational losses (Montewka et al., 2017). Additionally, training needed for the stakeholders for DMS implementation depends on three factors, which are the complexity of the DMS, the number of times it is used, and the variety of tasks performed through DMS (Slack, 2016). Training needs for seafarers in this aspect was identified by IMO guidelines MSC/Circ.1091 ion '*Issues when introducing new technology onboard'* (IMO, 2003). It identified the importance of training and the human-factor to ship operations. The related issues were also examined in research on the '*Challenges and potential of technology integration in modern ship management practice'* (Bhardwaj 2013). This identified the human element and its effect on technology integration in ship management.

3.2 The value of DMS in ship operations

DMS as a process technology directly affects the operational performance of any organization (Slack, 2016). The application in ship operations is to facilitate competitive advantage and move ahead in the shipping market. There are many benefits of introducing DMS to ship operations. For example, DMS related technologies can streamline ship operations through advanced Decision Support Systems (DSS), risk management capabilities, improvement in operational efficiency, cost benefits, and time reduction.

Mitigating risk is crucial as per the existing maritime regulatory framework, such as the International Safety Management (ISM) Code. Risk assessment for every shipboard operation is mandatory to safeguard people, ships, and the environment (IMO, 2014a). A study based on the development of a Graphic User Interface (GUI) for maritime risk assessment (Balmat et al., 2009), identified more advanced DMS software for ship operations.

Blockchain technology is recognized by UNCTAD in its maritime reviews of 2017-2019 as the future of the industry, which has the potential to make many different integrations to ship operations. For example, smart contracts and '*electronic bills of lading*' (EBL) are considered as valuable applications of blockchain technology in the fields of maritime insurance, monitoring maritime regulations and performance, and enabling automated monetary transactions (Ernst & Young LLP, 2017). Although blockchain technology mitigates risks, it introduces challenges, such as regulatory barriers formed by multiple parties in multiple jurisdictions. The reduction of operational costs through the reduction of the paper trail is also provided through blockchain technology. Through EBL it could save up to US$300 per shipping container (ReedSmith, 2018). Blockchain, together with IoT, enables the connection of physical objects to the digital world and improves operational efficiency.

Furthermore, data management can contribute to vessel maintenance operations. It can plan and overcome routine maintenance difficulties through DSS for ship condition monitoring and hull condition assessment (Lazakis et al., 2016) and spare parts management (Christopher et al., 2017).

It is recognized that the use of BDA technology can increase efficiency in monitoring the key performance indicators (KPI) of ship operations (Zaman et al., 2017). Also, wireless sensor networks (WSN) could optimize operations by overcoming operational and environmental barriers (Nikolaidis & Iniewski, 2014). For example, Automatic Identification System (AIS) data has been widely used in the industry in different areas to increase the efficiency of ship operations.

The potential of DMS can also be developed through free Geographic Information System (GIS) information to enhance maritime security, safety, and meteorological information (Kalyvas et al., 2017). It provides transparency to its stakeholders, such as shipping companies, port state control (PSC) authorities, Classification Societies (CSs), seafarers, and insurers.

Table 1 Summary of key hypotheses.

H1	Process of DMS software	This is a software process developed based on the concept of data identification, data collection, governance to filter, synchronization, data analysis, and sharing with all operational aspects to finally achieve leverage. On ships, this would include software used for a DMS and the various inputs and processes involved in collecting data for it (either manual, through sensors, or through interlinked reports).
H2	Design of DMS process	In an organisation, this is based on 3 components; Understanding of the purposes of the DMS by its stakeholders (in this case, ship owners, managers, and ship staff), Evaluation of a DMS based on the nature and the performance (quality, speed, dependability, flexibility, and cost), and completion of Implementation of DMS, based on the stakeholders' knowledge and the complexity of the DMS.
H3	Human factor	This affects the performance and the implementation of a DMS, therefore, training is necessary. In a maritime scenario, this would include shore side staff in office, as well as seafarers who are involved in any aspect of the DMS.
H4	Necessity of DMS	This is due to the complexity of regulatory management and security requirements in ship operations; for example, ISPS related reports required to be made for ports ('Last 10 ports of call and security levels observed"), crew lists, and port paperwork automatically generated for that specific country / port of call by a DMS.
H5	DMS optimized ship operations	This is achieved through enabling DSS, risk management capabilities, performance monitoring and reporting, and operational efficiency through cost reduction and time management, from the ship owners' and managers' point of view. For example, a decision to use a certain range of rpm. for the main engine made on the basis of slip values and fuel consumption during previous voyages, analysed and arrived upon using a DMS.

3.3 Summary of hypotheses

The main purpose of this article is to examine the value, feasibility, and approach of integrating DMS in ship operations based on the general framework established for enterprise operations management. This study is based on the following hypotheses (**Table 1**).

4. Research methodology

The data related to DMS systems presented in this paper is primarily drawn from the existing knowledge and scholarship available in the public domain and is supported by interviews conducted by stake holders and end users. Empirical data referred to in the discussion of this paper was collected by the authors through 2 web-based questionnaires and semi-structured interviews with major stakeholders in the maritime sector, with follow-up data gathering activities conducted through LinkedIn, email, and Skype.

A Sequential explanatory research design was chosen as a methodological qualitative approach, while using quantitative methods for the numerical data collected. Data initially collected and analyzed through quantitative methods leads to the next step in qualitative analysis of the sample (Saunders et al., 2016), and it is this philosophy that we have used. We have tested our hypothesis of whether DMS is used on ships, how it is used (where used) and why it is not used (where it is not). Among other benefits, this approach ensures testing our initial hypotheses, validating our assumptions (where they agree with the empirical data), and also assists in formulating recommendations for a DMS framework. Our strategy included asking participants of their understanding and use of DMS, providing information to them if they were unaware of it, and then asking them for potential uses for it. Our key research question remained, "How prevalent is the use of DMS on ships, and what are the reasons for this?" Quantitative analysis of the questionnaires was used to meaningfully deduce results by using data visualizing methods and to compare findings. Qualitative analysis through a validating questionnaire was used to validate the initial questionnaire from a control sample as an *explanatory mixed-method experiment* strategy. The design of the above strategy and the questionnaires thus subdivided the above aim into 4 objectives, which could be measured using both theory and practical outcomes.

Data collection for this article was first conducted through an internet questionnaire and a validating questionnaire sent to specific recipients through individual emails. The internet questionnaire*, including 12 questions*, was sent to major stakeholders as a pilot investigation. The questionnaire was formed through a popular survey program known as 'Google questionnaire'. The questionnaire was sent with a hyperlink to specific individuals and companies. Completed submissions were received via the internet and, for each submission, an alert was received at the researcher's mail address. Submitted questionnaires were recorded in an Excel form with question coding for further quantitative analysis of data. The questionnaires directed at shipping companies were forwarded with a research access request letter which explained the research interest and the level of access required.

The second questionnaire was a validating questionnaire consisting of 5 open-ended questions. These questions were designed based on the results of the pilot investigation. It was sent to some more specific recipients, who were considered as maritime experts and, thus, more likely to give meaningful answers. These responses and answers enabled a qualitative analysis of the data (Saunders et al., 2016). Questionnaires were distributed to 108 recipients, out of which 47 respondents submitted the pilot questionnaire, and where 25 submissions were of the validating questionnaire.

The stakeholders of ship operations varied from senior managers to executive positions at shore side, and masters, chief engineers to junior officers at sea. The total sea-staff of the sample represented 38.3 % (18 participants). The majority of the sample consisted of masters (9 participants or 19.1 %), and a similar number of personnel (19.1 % or 9 participants) consisted of operation managers (5 participants) and technical superintendents (4 participants). This gave equal representation from both shore and sea staff, between whom most of the ship-to-shore communication for ship operations are performed. Other important data for this article are derived from the key persons in the job roles of IT support, accountants, manning recruiting managers, and senior managers.

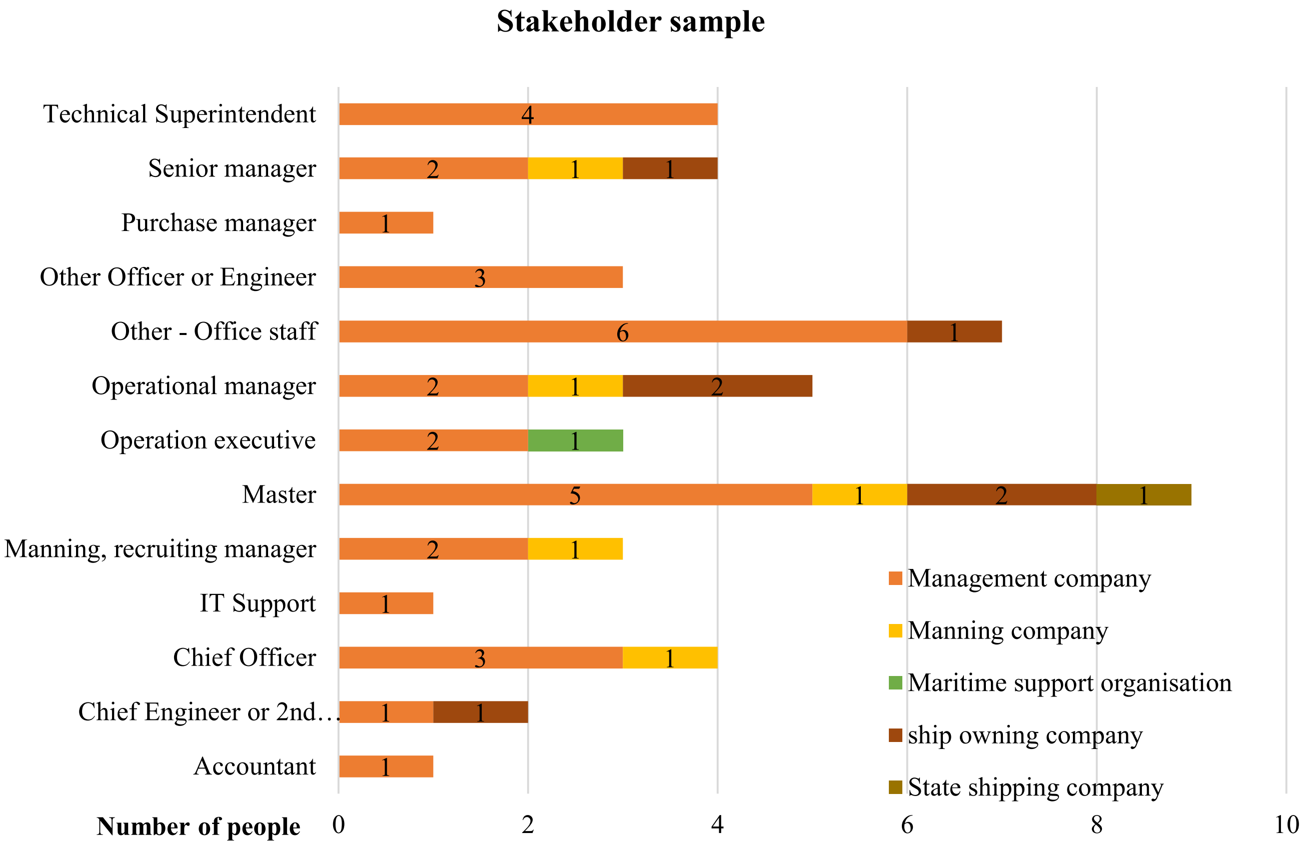

Figure 1 Sample variation of participants as per their job descriptions.

Figure 1 describes the variation in the sample of stakeholders who participated in the questionnaire. Figures categorize the sample by the types of maritime organizations. **Figure 2** describes the variation in the number of organizations as per the number of ships handled. This heterogeneous purposive sample explains the diversity of the stakeholders in ship operations from the targeted population. Further, 72.3 % (34) of the respondents consisted of employees of shipping companies that handle over 41 ships or more; this allows the results to have a strong perspective of the DMS application in larger shipping companies.

In order to acquire more detailed accounts and explore the underlying factors, semi-structured interviews were conducted with a range of key stakeholders in 2018 - 2019. We conducted 25 semi-structured interviews and 12 informal conversational interviews. The semi-structured interviews normally took place in offices or hotels, with an average length of about 30 min, whereas conversational interviews were conducted in the field informally, sometimes over coffee or lunch. Most semi-structured interviews were recorded, while jottings or brief notes were taken in the field of conversational interviews.

Data collected was initially entered in a data matrix developed on an Excel form under different themes to answer the key questions. The results are presented by formulated tables, bar graphs, pie charts, and scatter graphs, as required for the explanation of DMS concepts. Data was analyzed through a template analysis method by developing a '*coding template*' to have hierarchical themes under which the data could be categorized and explained. The template analysis method was chosen as it accords with the research philosophy, approach, and strategy used.

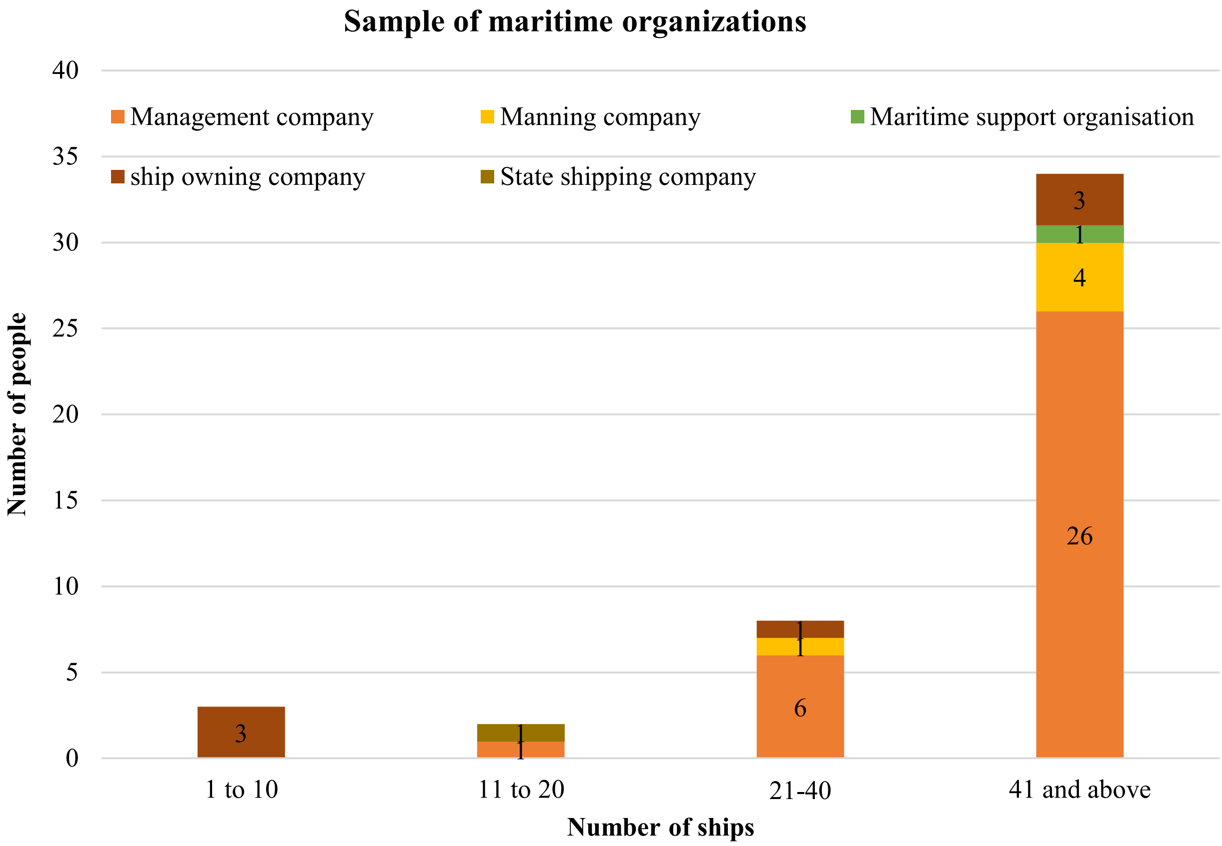

Figure 2 Sample variation as per maritime organization.

5. Results

The data collected in this research describes the knowledge of respondents of the history, formation, and time taken for DMS software in an organization. The quantitative analysis revealed a diverse distribution of results as to the use of hard documents, general Microsoft programs, older versions of the same DMS software, and different DMS software (**Figure 3**). The majority of the respondents had made a transition from general Microsoft programs to company-specific DMS software (17, 36 %).

One key question of this research was to enquire what DMS software is being used for. **Figure 5** illustrates that data from ship operations are managed for various reasons, as per detailed operational aspects. The purposes include safety, performance, maintenance, HR-related operations, security, communication, and others. Stakeholders suggested more than 50 % of DMS software is used for safety, performance, maintenance and HR-related operations. These results further revealed that data generated from maintenance operations (68 %) and data generated through ISM safety (62 %) aspects and reporting take higher importance.

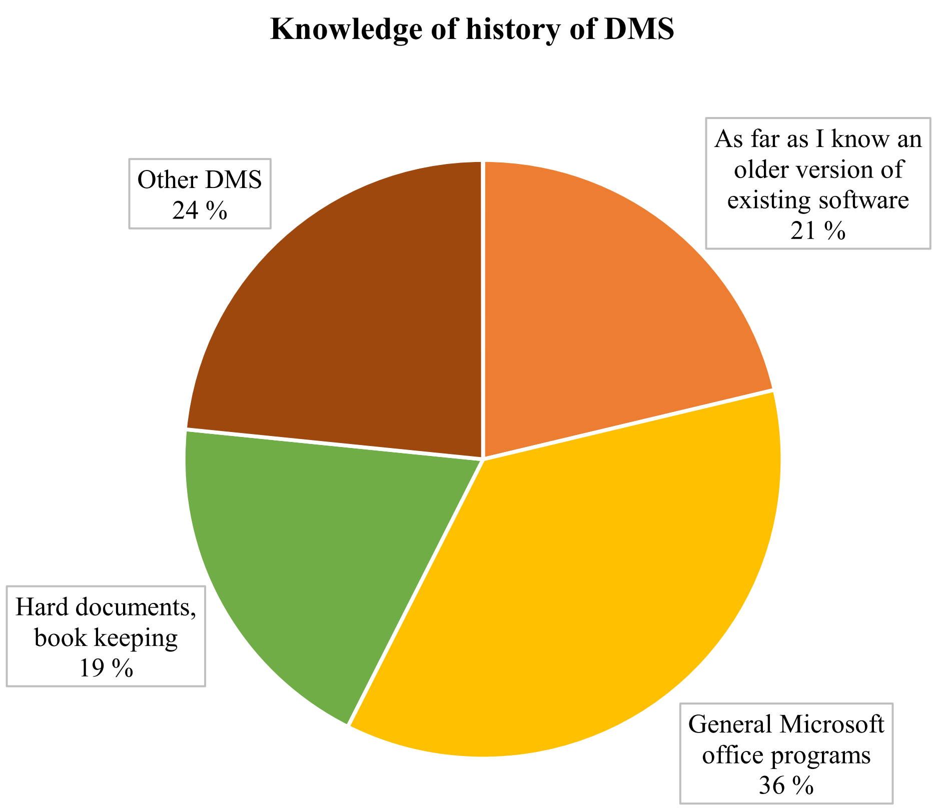

Figure 3 Systems used by the participants' organizations before the current DMS began to be used.

As shown in **Figure 4**, among 29 participants who responded claiming to have knowledge about the transition time frame, the numbers and percentages who responded that it will take more than one year was 14, 48 %, and others (9, 31 %) claimed the period was between 4 - 12 months.

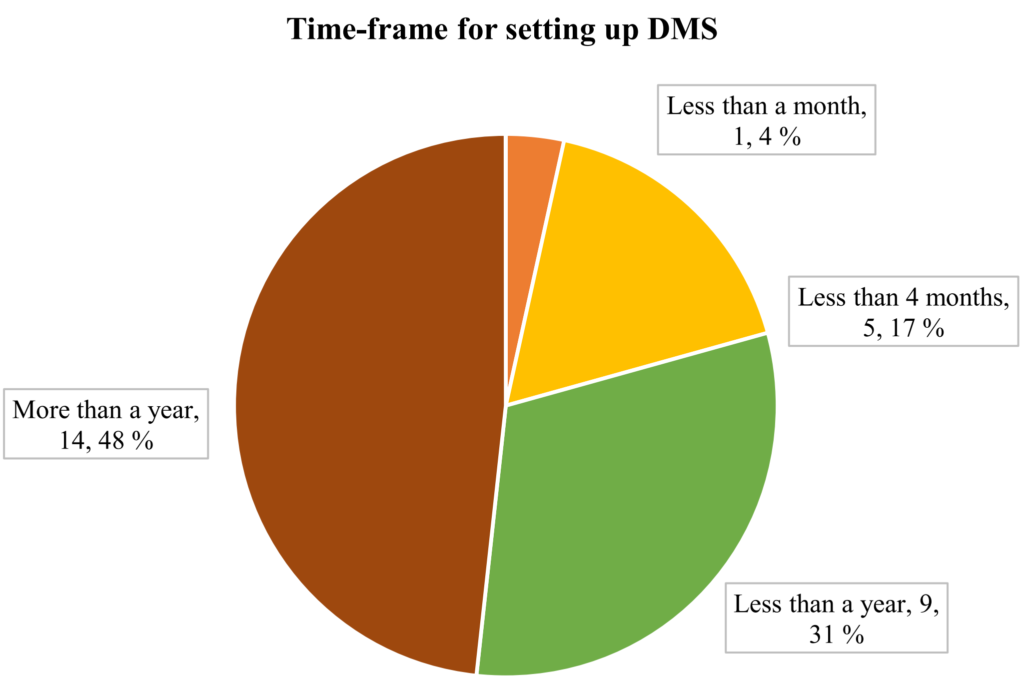

Figure 4 Time-frame for setting up DMS software.

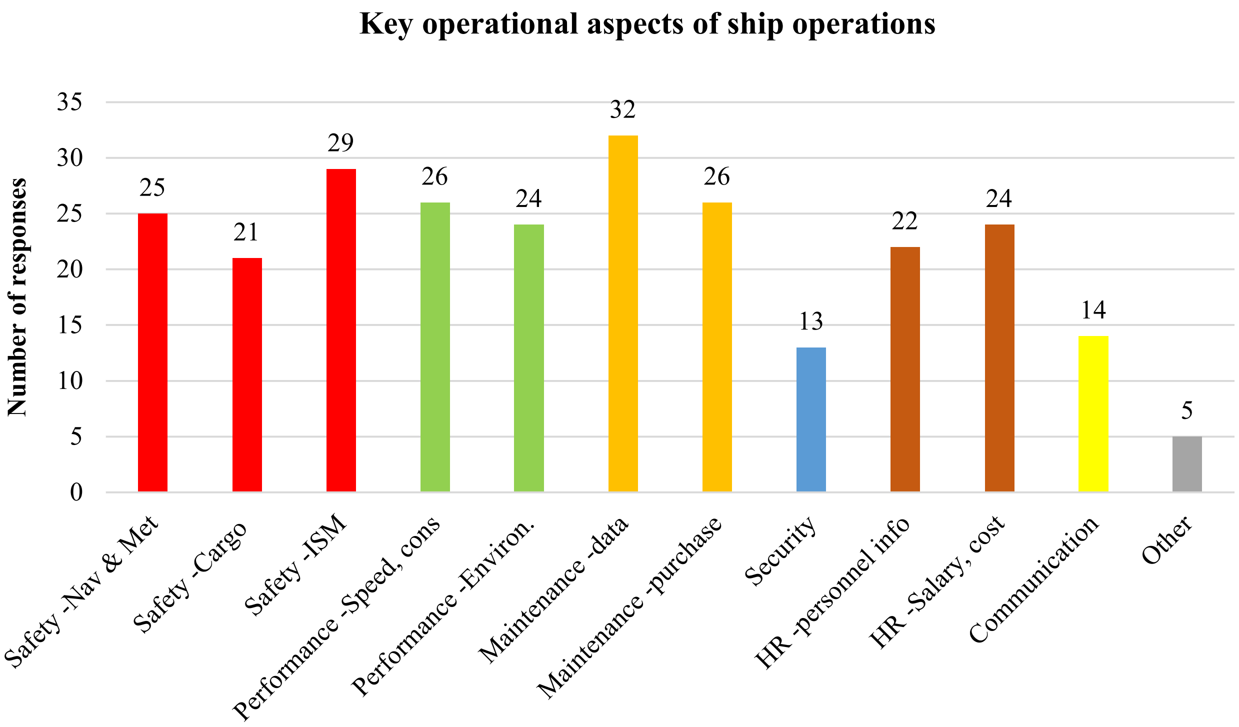

Figure 5 Areas of usage of DMS

Certain operational aspects, such as communication, HR operations, and security, are perceived differently from the ship and shore points of view. The analysis shows these operational aspects are more utilized at the shore end of the operations. Data pertaining to communication is not recognized by the sample as a top-level operational use of DMS (only 30 %).

The familiarity of the stakeholders and the user interaction with the DMS is a key issue when addressing the theme of the human factor of DMS use. Users who are familiar with the DMS can be reasonably expected to use more of its functions, as compared to those who are not so familiar with it. Training helps users become familiar with the DMS quickly, while 'learning on the job' helps them become familiar with it slowly and often incompletely. The results here explain the users' familiarity, frequency of use, training needs and responsibilities, benefits, and difficulties in the use of DMS software in routine ship operations.

Figure 6 indicates that many users considered themselves to have 'expert knowledge' of the DMS they use. 85.1 % of them considered themselves either expert or regular users of DMS software. As far as frequency of usage of DMS goes, 85.1 % of them said that they used the DMS once a day. This could indicate the level to which DMS software has become a part of some aspects of daily ship operations. It could also indicate that, the more frequently people use DMS software, the more likely they become an expert in it.

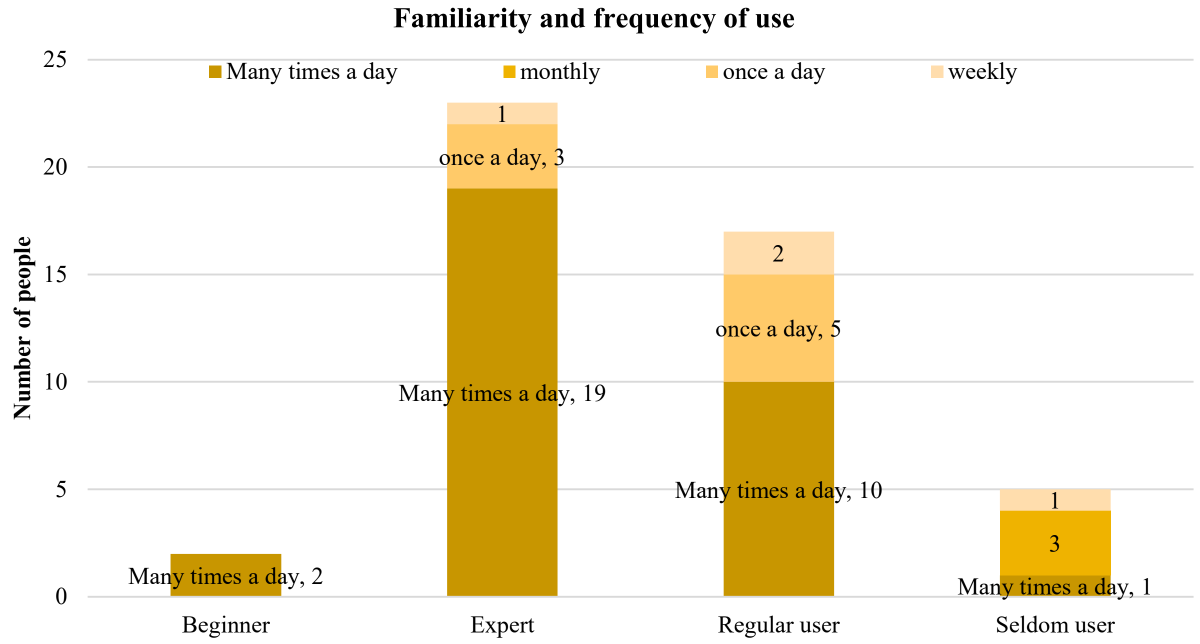

Figure 6 Levels of DMS usage by stakeholder.

Almost 83 % (39 participants) of the sample said that their organizations promote training related to the DMS that they use (**Figure 7**). This positive response was found in a majority of the ship management companies (31) which handle 21 vessels and above. The remaining 8 responses were from manning companies and ship owning companies. While vessel managers almost always train their staff in DMS, maritime support organizations, such as ship agencies and manning agencies, did not appear to recognize the need for user training. Although some large companies (4) did not carry out training, those with large numbers of employees were found to promote training of their DMS operators.

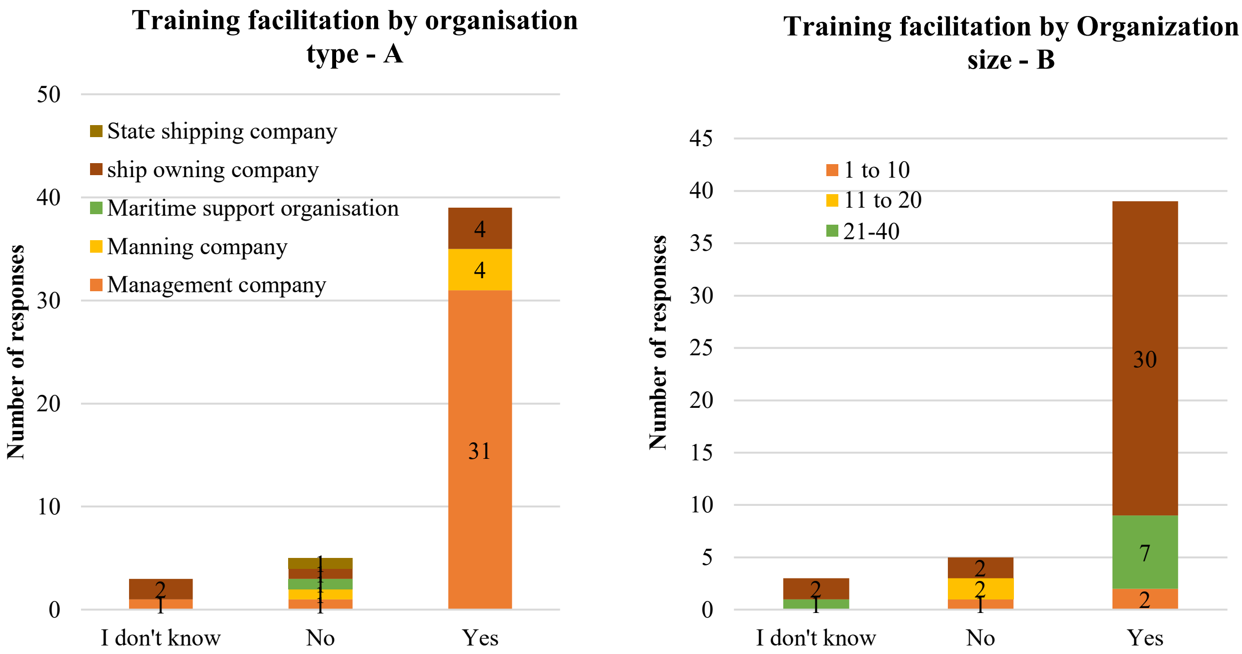

Figure 7 Training facilitation by maritime organization.

Table 2 shows the responses of stakeholders regarding the existing software program. A high percentage of users confirmed that DMS benefited their operations. Among the benefits, efficiency, simplification, easy access, and multiple user access at the same time are highlighted. Stakeholders also pointed out some negative effects of DMS, as shown in **Table 2**. However, recognition of the difficulties was far lower compared to the benefits. The need for carrying out regular updates to software was identified as the most common difficulty for users.

Table 2 Benefits and difficulties of DMS software.

Category No.	Benefit or difficulty	Number of responses: Benefits	Number of responses: Difficulties	Relative proportion of response percentage
1	Save time	36		76.6 %
2	Time-consuming		10	21.3 %
3	Simplify work	38		80.9 %
4	Complicated		11	23.4 %
5	Duplication of work		10	21.3 %
6	Readily available	37		78.7 %
7	Too many aspects in one program		13	27.7 %
8	Much different software		6	12.8 %
9	Multiple user access	29		61.7 %
10	Required regular updates		20	42.6 %
11	Other benefits	2		4.3 %
12	Other difficulties		5	10.6 %
	Total	142	75	
	Response rate	3.02	1.59	

The data collected also shows the financial impact of having DMS software within an organization and feedback regarding suggestions for improvements. **Figure 8** explains the opinions of the sample with respect to the cost of setting up and running DMS software for ship operations. 34 % (16) of the respondents had no knowledge of the costs involved. 57 % (27) of the respondents suggested that the cost of having a DMS program operating for ship operations are considerably ‘minor’ or ‘negligible’, as compared to the total daily running costs of a ship.

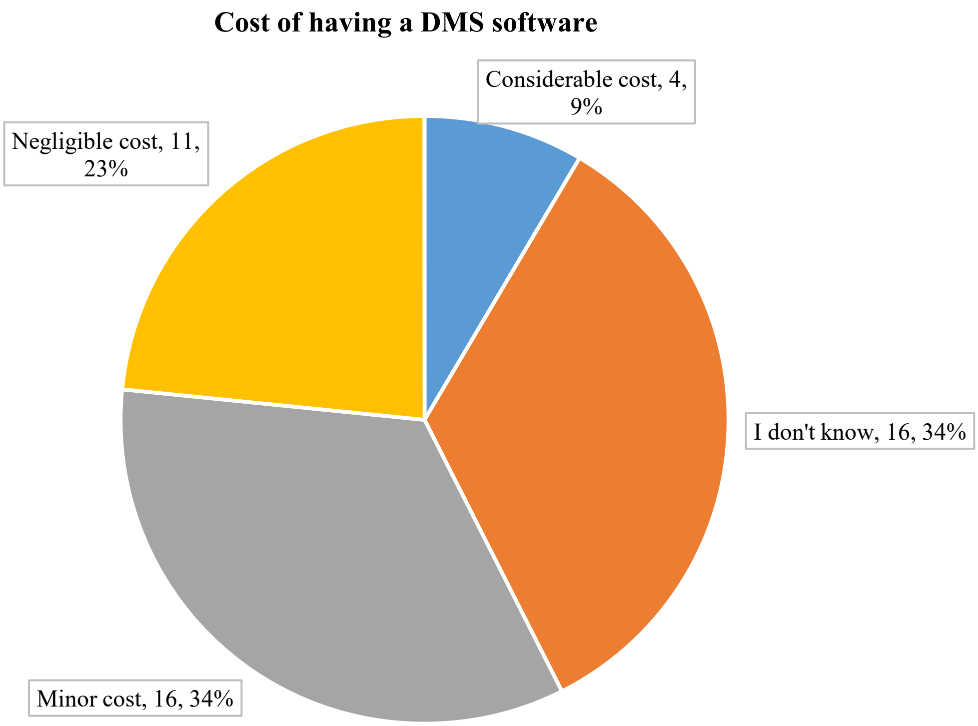

Figure 8 Cost of running DMS software.

Also, a large portion of the participants 81 % (38) were of the opinion that significant cost will be needed for the initial set up of DMS as compared to routine maintenance and operations. Further analysis of the cost components from operating DMS software indicated, as shown in **Table 3**, that almost two-thirds of the respondents confirmed that expenditure for licenses and other infrastructural requirements are the main cost factors, such as upgradation and additional computers and servers for each individual ship. Also, 55.3 % of the respondents explained that service agreements and training needs were also among the major cost factors, followed by 42.6 % reporting the cost of running and maintaining a DMS program.

Table 3 Opinion of stake holders- estimates of the highest apportionment of costs in a DMS installation.

Category No.	Cost category	Number of responses	Proportion of responses
1	License	32	68.1 %
2	Infrastructure- computer	31	66.0 %
3	Cost of IT department	20	42.6 %
4	Service agreement	26	55.3 %
5	Training	26	55.3 %
6	Communication	8	17.0 %
7	Additional power	3	6.4 %
8	NO cost	1	2.1 %

The information received through the open-ended questions was categorized under different main themes. 38.3 % (18) of the participants did not contribute any suggestions and stated that existing DMS is suitable for ship operations. As shown in **Table 4**, the other 38.3 % (18) of the respondents suggested that existing DMS should be integrated with new technology. Also, 23.4 % (11) suggested that standardization of DMS software would be a better approach for ship operations. Another 17 % (8) of the respondents commented that they preferred one system for all operations to different DMS software within an organization. This indicates that there is different software being used for a variety of ship operations. A similar 17 % suggested that additional training should be provided to better use the existing DMS.

Table 4 Suggestions to improve existing DMS software.

No.	Suggestions	Number of respondents	Percentage of respondents
1	Standardise DMS	11	23.4 %
2	One system for all operations	8	17.0 %
3	Use new technology integration	18	38.3 %
4	Additional training	8	17.0 %
5	No suggestions- it is adequate	18	38.3 %
	Total	63	

It was also found that many users were concerned about the monitoring and correcting of planned maintenance systems (PMS) data. Some respondents recommended that data input should enable error detection and prevent repetition from DMS software. As shown in **Table 5**, some other respondents described that their DMS software could be better designed if it enabled additional functions, such as the generation of monthly reports, future prediction, historical data analysis, and so on.

Table 5 Suggestions on additional methods for DMS improvement.

Stakeholder	Suggestions to promote better use of DMS other than training
Operation manager	Monitoring- to correct mistakes in time and prevent repetition
Manning Manager	Understanding of the reliability of data fed into the system
Operation Executive	Training is sufficient
Other office personal	Building a historical database / regular monitoring of PMS / the ability to view and analyze trends / the ability to generate monthly reports for operational summarization
Other office personal	Enabling complete access to all related tabs will allow using DMS at an optimal level

6. Discussion

Most DMS work in different stages, commencing with the collection of data, and culminating in the usage and analysis of said data. While different DMS architecture does this differently, they all generally consist of the following stages: data collection → profile → consolidation → governance → share → leverage.

6.1 Hypothesis 1

The first stage of Hypothesis 1 describes how data is generated from various aspects of a maritime organization, both on board a ship and ashore, to optimize ship operations. Data generated in these different operational regions include onboard voyage performance (for example, through daily noon reports and monthly abstracts), maintenance (for example, through main engine parameters sent via sensors), and cargo information. On the shore side, this is done through regulation updates (for example, flag state circulars sent to ships), reporting (for example, EU MRV reports), financial data, audits, and inspection reports.

The 'profile' of data is used to categorize and inspect whether data quality falls within an acceptable range. This could enable the management of data and to identify data sources and their quality, thus resulting in developing suitable applications. Applications, such as the recording and sharing of environmental KPI and the use of big data to compile reports to owners and charterers, could thus be checked for errors that will prevent future penalties or embarrassment. For example, if the total running hours of the main engine has been input as 26 h (or if its calculation based on input yields such a number), the profile for this data should immediately indicate an 'error' message or warning. The same could be true for a DMS that is used for rest hour data and the management of seafarers.

At the 'consolidation' stage, data is collected by the DMS and stored at a central location (server). This enables linkage within the DMS software and allows key functions, such as the creation of reports from multiple sources. An example of this would be generating KPI reports as per EU Monitoring, Reporting, and Verification (MRV) for air pollution prevention regulations. MRV requires information from navigation, as well as engine performance and some sections related to routine maintenance. Another example is the vessel security pre-arrival notification required by the ISPS interpretations of some ports, which can be generated using cargo information, vessel port-of-call history, and information from last port state control (PSC) as data inputs. Data collection is an important stage of DMS due to the requirements of information links between other operational aspects of the business. Its integrity and cybersecurity, thus, become key associated components, though cybersecurity is equally important in other stages.

Cleaning, or what we have in this paper called the 'Governance' stage of the DMS process, prevents data duplication and adds value by transforming data into a suitable format for different internal operational applications; in other words, data management. Data governance is a key stage from which the company defines how it will use tools for DSS with respect to data accuracy and protection; for example, data about the costs and expenses of a vessel shared with other internal applications such as vessel budget management, and the costs due to operational complications such as accidents and incidents, could be used to generate reports for the entire fleet of ships owned by the same owner. Another example would be the management of rest hours for seafarers and checking if they comply with maritime labor regulations- are there any violations? DMS can prove to be an efficient tool for such expansive, but largely clerical, calculations. Discrepancies should be corrected at the governing stage; for example, if the sum of the work and rest hours for a seafarer are more than 24 h, the DMS can immediately give a warning to the seafarer, thus, he can correct any error immediately at the data entry stage. On the other hand, if there have been violations in the total rest hours (compared to the requirements of MLC), the same DMS can give a warning to the seafarer and the shore side support, so that they can intervene and assist.

The 'share' stage distributes the standardized data to its applications and allows value creation for a leverage effect. This information sharing among the external sources benefits the operations in many ways. In logistics operations, the information is shared and transferred for DSS among the alliances. For these purposes, data governance accuracy and standardization of data format is important. Another example of the distribution of data on vessel performance in terms of vessel inspection and fuel performance will be of benefit to secure a new charter.

The 'leverage' stage is a thorough analysis of data across the enterprise to maintain a good overview of the ship operations and manage the peaks and troughs of operations.

Figure 5 shows that more than 50 % of the respondents indicated 5 - 6 different operational aspects managed by DMS software in their organization. This allows applications and uses such as reporting, performance monitoring, KPI, and cost analysis, which are leverage effects of the DMS, which stand outside of the DMS in use.

DMS functions used by each stakeholder were investigated in Graph 5, which explains the different use of DMS by ship and shore staff, and addresses the use of DMS as compared to earlier methods, the study analysis of the history and formation of DMS in the organization. The evaluation of DMS is done through measurement of suitability for the task, measuring cost benefits, and measuring operational performance.

Corporate performance is described at three different levels, namely, society level, strategic level, and operational level (Slack, 2016). The judgment of operational performance at the broad society level is measured through the impact on its stakeholders, using the 'triple bottom line' approach, people, planet, & profit.

Corporate social responsibility (CSR) at present highlights the necessity of business optimization far more than ever before. Lower fuel consumption directly leads to a lower carbon footprint, thus improving a company's image. With the emergent of environmental regulations, the need to maintain a 'green image' has increased, especially in prominent container liners and the cruise industry.

The measurement of performance at the strategic level indicates five aspects contributing to high profits, namely, enabling future innovation, less capital required to increase capacity, high revenue, low operating cost, and low risk of operation failure (Slack, 2016). Autonomous vessels, where the focus is based on the future development of wireless sensor networks and innovation, cloud base computer systems with low capital expenditure, and DSS to determine low operating costs through optimizing fuel efficiency, fast port turn-around, and weather optimization, are a few of the existing strategies in ship operations. As explained in the literature review, risk assessment and management to reduce unexpected voyage costs is key in today's ship operations, where the freight market stands low.

The third level of performance measurement, based on operations, is the focus of the research; this relies on 5 principle aspects, described as quality, speed, dependability, flexibility, and cost-effectiveness (Slack, 2016). *Speed* is important in ship operations, as this will help achieve the timely utilization of assets and have effective planning to minimize operational costs. Depending on the value of the cargo, ship speed could be determined to save on fuel costs. Frequency or *flexibility* of an operation allows the provision of services such as carrying cargo in small quantities in frequent intervals, and the replenishment of stores and stocks in a suitable time and location, and contributes to the optimization of operations. *Dependability* or reliability applies to ship operations for both meeting schedules and for the delivery of goods to high standards. To provide services with a reasonable freight rate, operations should be heightened to reduce *costs*. In the competitive freight market, the *quality* of ship operations stand out as a measurement of operational performance (Branch, 2014).

6.2 Hypothesis 2

The results obtained through the questionnaire confirmed the benefits of DMS use under four major categories: time-saving, simplification, reliability, and accessibility (**Table 2**). It is evident that the above 5 operational performance factors coincide with the opinions of the stakeholders, described as benefits. As a divergent method of proof, constraints in the use of DMS categories time consuming, complicated, and duplication, as the least popular difficulties, scored only around 20 % of the sample.

This validates the operational performance measurement to evaluate DMS software in terms of achieving speed, flexibility, dependability, and cost reduction, and to increase the quality of shipping service.

Implementation of DMS consists of a range of factors, such as stakeholders' knowledge, process distance, and understanding potential implementation problems. When analyzing suggestions to improve DMS, respondents largely proposed the 'integration of software with new technologies' (38.3 %) (**Table 4**). This indicates that the stakeholders are generally knowledgeable of the existing DMS and request more sophisticated systems to enhance operational capabilities. Additionally, the general feedback on the suitability of existing DMS systems indicates the inadequacy of process technology implementation and, hence, confirms Hypothesis 2.

6.3 Hypothesis 3

Because the human factor affects the performance and the implementation of DMS, training is necessary for maritime organizations. **Figure 6** suggests that most of the operators are skilled users who use the program at a higher frequency, and the training requirement was identified by most of the maritime organizations with large human resources (**Figure 7**). The training cost of DMS is identified as a contributory cost factor for its operation (**Table 3**). These results, together with Hypothesis 2, confirmed the importance of the knowledge of stakeholders affecting the understanding and implementation of DMS. Utilizing the IT expertise of the organization, the majority of the sample indicated the training responsibility needs to remain with the internal IT department.

6.4 Hypothesis 4

Hypothesis 4 concerns the necessity of DMS, which is confirmed by the results in various uses of DMS. As shown in **Figure 5**, the applications include ISM reporting, safety record keeping, and maintenance record keeping as required by class requirements.

However, personal data and information collection with the individual consent regulation (GDPR) have an adverse effect on DMS software integration due to the additional burden of regulatory compliance. A large number of data monitoring processes and collection done by manning companies requires the allocation of an additional 'data protection officer', as per this new regulation (EUGDPR, 2016). The objectives of DMS, to manage complex data and simplify ship operations, will now have to deal with software compliance regulations. Furthermore, IMO guidelines on cyber risk management contribute to the software regulatory burden (IMO, 2017). This nullifies the purpose of simplifying ship operations but establishes Hypothesis 4 due to regulatory complexity and security.

The necessity of DMS could be due to the competitive shipping market, as industry leaders, such as Maersk, resort to digitalization and the use of DMS (Porter, 2016; Porter, 2017); the rest of the competition will adopt DMS for ship operations just to survive in the market.

6.5 Hypothesis 5

Hypothesis 5 states that DMS optimizes ship operations by enabling DSS, risk management capabilities, performance monitoring and reporting, and operational efficiency through cost reduction and time management. Ship operation enhancement methods, DSS, and risk management are not established through the results of this study; however, previous research done on these aspects used in the maritime industry is very comprehensive. Performance monitoring and reporting, on the contrary, were suggested as the main uses of DMS by more than 50 % of the sample (**Figure 5**). The data generated from communication operations takes low priority among the uses (**Figure 5**); this indicates that most DMS used for ship operations are independent of the reporting and communication software. The benefits of using DMS pointed out time-saving and management as a few of the most direct impacts on operations to strengthen this hypothesis (**Table 2**).

The results identified the costs related to DMS as minor compared to daily operating costs. The cost factors were identified as licensing, service agreements, and other infrastructural costs which come at the initial set-up stage (**Table 3**). The measurement of cost benefits is difficult to evaluate, due to the lack of knowledge of the sample in this matter.

Optimization of ship operations through DMS does not comprehensively establish Hypothesis 5. Risk management, DSS, and cost benefits were not sufficiently addressed by the suggestion of the stakeholders. However, it is evident that maritime organizations at present use DMS to enable time-saving and performance monitoring of ship operations.

Electronic Chart Display and Information System (ECDIS) use in ship operations proves that the standardization of DMS will have positive effects on operations. 23.4 % of the sample suggests standardization of the system, whereas 17 % pointed out the use of one system for all operations (**Table 4**). Standardization could be of many forms, such as in terms of the program, data quality, or transferring standards. Leading cyber security providers DNV GL identifies the richness of maritime data and standardized digital platforms (DNV GL, 2017) for ship operations. Further, third party DMS providers for weather routines, such as StormGeo (StormGeo, 2017), allow standardization in charter party clauses for route optimization through DSS and risk management.

7. Conclusions and recommendations

Interviews suggest that the use of DMS onboard ships remains far lower than its potential would dictate. This paper examined some key issues of DMS and how it could be used in ship operations to improve management efficiency and to use data effectively to optimize costs. The trend across the world has been to embrace technology where it improves operations. The integration of DMS in ship operations is viable, and further aided by the availability of virtual databases and the advancement of technology to implement DMS in a relatively short time with low capital expenditure. This study indicates that the operating expenditure of DMS is relatively minor or negligible, and the time span for setting up a system is around a year. This, and the requirement to keep up with the technology among competitors, should encourage maritime organizations to integrate DMS software in ship operations if they address some of the deficiencies that we have identified. These include the need for training and familiarisation needed for personnel assigned to operate the system, and a vendor strategy of identifying and delivering what the customer (vessel manager or owner) wants, rather than providing them with what the vendor has developed on his own.

For better implementation of DMS in ship operations, it is necessary to have a specific technology road map and establish methods to identify potential problems. Without feedback and regular system checks, continuous and full implementation of DMS is impossible. One recommendation is to anticipate the drawbacks resulting from complications during the processes. DMS systems currently available on the market do not address the industry’s requirements; hence, they should be customised to suit the industry’s needs by asking vessel managers for their requirements, rather than DMS writers assuming them. Training in DMS software is a weak point and, hence, needs more attention. DMS packages should be made more user / operator friendly and intuitive by paying more attention to the user interface (human machinery interface or HMI) to minimise training requirements and barriers to acceptance. An increase in stakeholders’ knowledge of DMS and providing sufficient training will help identify any drawbacks and can help the developers in addressing potential problems. It is also suggested that DMS should have built-in error detection methods to improve accuracy and utility. Other recommendations include the function of generating monthly reports, trend and pattern analysis, maintaining a historical database, and increasing the leverage effects of DMS, thus maximising its utility for end users.

8. Limitations and scope for further research

While we have made every attempt to minimize any errors, we are cognizant of limitations of our research. A larger or different sample could lead to different results. Our research focused on end users; on the other hand, research focused on developers of DMS could lead to a different perspective and is worth researching. It would also be worth researching what seafarers feel about DMS, and which areas they believe could improve shipboard operations.

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