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The contribution of risk management in ship management: The case of ship collision

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ABSTRACT

Ship operators are developing their business in a competitive and highly regulated industry. For ship operators is important to utilize management systems in reducing potential threats to shipboard crew and cargoes carried. This paper enhances the risk management principles in respect to financial damages related to a ship collision. A methodology is proposed involving a performance management system to measure the expected costs and benefits of a ship's collision caused to its ship operator. As essential parts of the research methodology, Fuzzy Sets and Analytic Hierarchy Process (AHP) are referred to design scorecards, which identify key points for accident prevention on board ships. The ship operators may use the results in evaluating their management systems through taking into account the economical burden that will be generated to ship operators in case of a collision incident. In this paper, the expected benefits of risk management, the principle root causes and consequences of bulk carriers collisions are discussed.

1. The challenges of modern ship management

The "2012 Review of Maritime Transport" published by the United Nations Conference on Trade and Development reveals that the total volume of goods loaded worldwide in 2011 was 8.7 billion in tonne (UNCTAD, 2012). At the same time, the world fleet was more than 1.5 billion deadweight in tonne in January 2012. The above figures show how important the sea trade is for the wealth of the nations. On the other hand, it is the obligation for ship operators to provide ships of high standards. A ship operator may own ships or manage a fleet for ship-owners (Klikauer and Morris, 2003). The definition of a ship operator in this paper is therefore any person, or company, who has the responsibility for the operation of its own ships or manages ships of other owners. Typical examples of a ship operator would be a ship-owner, ship manager or bareboat charterer. A ship operator is not different from any other profit-seeking service firms in the shipping industry (Triantafylli and Ballas, 2010), in a sense that profit will necessitate the long-term business survival of the company especially during depressed market cycles.

A ship operator makes a profit by hiring the space of each ship that he operates to transfer cargo for a voyage or a specific period (Li and Cullinane, 2003). From a commercial perspective, the ship operator has contractual obligations in a charter party as the carrier. The shipper requires a carrier to care for the suitability of his vessel in order to fulfil the transportation of cargo with safety. The carrier is obliged to provide a ship constructed, equipped, supplied and staffed according to the international regulations on the design and operation of vessels in order to execute the voyage safely and to overcome those risks it is anticipated to meet during the charter known as ordinary perils of the sea (Plomaritou et al., 2011). Therefore, the selection of appropriate vessels to carry out shipping activities is crucial for charterers and the technical reliability will be one of the most important factors for selection purposes (Yang et al., 2011). Furthermore, the acquisition of a ship requires a high capital. High capital requirements can discourage potential entrants of firms that can profitably enter the industry (Triantafylli and Ballas, 2010).

After several efforts eventually, a common regulatory regime became reality when an agency of the United Nations, International Maritime Organization (IMO) was established in 1948 to promote safe, secure and efficient shipping on clean oceans (Dahlstrom et al., 2011). Since then the legislative framework developed by the IMO consists of about 50 conventions (Perepelkin et al., 2010). To some degree the regulations imposed by the IMO established a common and acceptable foundation, and as a result safety at sea was improved significantly within just a few decades. Notwithstanding their justification, such regulations have imposed significant changes upon the business of ship operators because they must operate their ships under a complex maritime regulatory regime, which consists of regulations posted by flag states, coastal states, and the IMO (Mitroussi, 2004b; Alderton and Winchester, 2002). Ships visit ports of different states on a regular

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basis and consequently they are subject to different regulatory regimes. When a foreign ship calls in a port, the ship, crew and its equipment should comply with the requirements of international regulations (Cariou et al., 2009). If a ship is found to deviate from these standards then the authorities will pose penalties such as detention from sailing (Knapp and Franses, 2007). In addition, some states have extended their jurisdiction through their Exclusive Economic Zones (EEZ). Hence, a ship sailing in the area of EEZ, even if it does not intend to call a port of that state, may have to comply with some restrictions (Keyuan, 2002).

A further challenge for a ship operator is that the shipping industry suffers from a negative public opinion. This was caused because various stakeholders were often ready to lower IMO standards if this meant increase in the profit margin. In this context the shipping industry created negative externalities, which contributed to the creation of a low public image (Fafaliou et al., 2006). Consequently, in the case of an accident public opinion will press governments and authorities for immediate punishment against the ship operator (Sampson, 2004; Chantelauve, 2003). An involvement of a ship operator's ship in an accident may result in bad reputation for his company, heavy finance consequences, loss of lives, and even prison convictions for his employees (Chen, 2000). From this point of view, it is beneficial for ship operators to comply with the maritime regulations while they are pursuing their basic goal, which is to create profits for their shareholders. Fafaliou et al. (2006) suggested that these ship operators apply a standard level of operation and conform to requirements of regulations and conventions, no matter what the costs of compliance are.

Human errors, technical and mechanical failures, and environmental factors are commonly underlined factors leading to shipping accidents with different percentages (Celik et al., 2010). In order to avoid such errors a ship operator must find appropriate human resources to fulfil positions on board his ships and ashore. Availability and quality of human resources are the cornerstones for a rational management system of a company. A main certification standard for the shipping industry is the Standards of Training Certification and Watch-keeping for Seafarers (STCW) which was introduced in 1978, and amended in 1995. Its main objectives are the establishment of an international system for training, supervision, assessment, and certification, the assurance that mariners have knowledge and competence to do their job, the assignment of responsibilities to all parties involved, and the establishment of control mechanisms for the verification of the above-mentioned purposes (Triantafylli and Ballas, 2010). However, due to changes in crew labour resources, it is common for ships to be manned by crew members from the Far East when their ship operator is based in Europe. A ship registered under an open registry may have limited restrictions regarding manning such as crew nationality and manpower. As a result, some companies operate their ships with cheap labour from developing countries overlooking their lack of skills (Klikauer and Morris, 2003). However, despite the wage differential separating the two tiers, highly-paid national seafarers are not yet fully supplanted by lower-paid third-party national ones (Tsamourgelis, 2009). This phenomenon clashes with the typical theoretical model of cost minimization or profit maximization. It could be an indication that a high number of ship operators give emphasis to the high standards of their seamen.

Personnel training has been identified as a source of competitive advantage for a ship operator (Triantafylli and Ballas, 2010). However, there are not many IMO regulations setting the appropriate standards that an individual involved in a shore management position should have. Such a regulatory gap allows a ship operator a great degree of flexibility in choosing personnel ashore increasing his liability for these choices. Demand for human resources ashore is sometimes generated by regulations to cover specific positions as Designated Person Ashore (DPA) required by the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code) (IMO, 2010). In a similar way the International Code for the Security of Ships and of Port Facilities (ISPS Code) introduced the position of the Company Security Officer (CSO) (IMO, 2003). The initial version of the ISM Code did not include specific requirement that would qualify an individual as a DPA. To overcome this problem an IMO circular was issued in 2007 stating the qualifications, training and experience necessary for undertaking the role of the designated person (IMO, 2007). Emphasis is given that a preference is given to persons who have a degree in management, engineering or physical science, or an experienced certified ship officer. On the other hand, section 11 of Part A of the ISPS Code requires each shipping company to designate a person to act as the CSO for one or more ships, depending on the number or types of ships the company operates. The qualification and training standards for a CSO are clearly stated in the ISPS Code.

In a case of an accident a ship operator should be in the position to prove conformance with the above commercial and regulatory obligations. Otherwise, the company will be financially exposed to claims. One of the main threats for a ship is collision with another vessel. According to the 1972 International Rules for Collision Avoidance (COLREGS), collision is a situation where the blame falls on both parties. The collision is a hazard that could put at risk at least two vessels per incident. As per COLREGS requirements when two power-driven vessels are crossing so as to involve risk of collision, both ships should take action in order to avoid the collision (Chauvin and Lardjane, 2008). The consequences of a ship collision were examined in the past in terms of pollution (IMO, 2008a), structural damage (Tagg et al., 2002), stability issues (Vanem and Skjong, 2004) and emergency evacuations (Vanem and Skjong, 2005). Pedersen and Zhang (2000) suggested that for side shell damage due to ship–ship collisions, larger vessels are expected to have somewhat smaller damage relative to the dimensions of the ship than smaller vessels.

Early studies remarked that collision avoidance proficiency undoubtedly has elements of knowledge and skill such as regulatory and procedural knowledge, understanding ship handling characteristics and use of navigation equipment, which can be successfully taught, learned, and assessed in conventional ways (Taylor, 1998). At present, due to technological advances and to new maritime regulations, there is an increasing demand for new nautical marine instruments to be installed in the bridge, and the breadth of navigational information complicates on-duty officers' decisions (Tsou and Hsueh, 2010). Stitt (2003) argued that some navigation equipment such as Automatic Identification System (AIS) will be a useful tool to provide additional information, but should not alter the way in which the COLREGS are to be applied. Nevertheless, Chauvin and Lardjane (2008) in their study noticed that deck officers do not always perform a maneuver according to COLREGS. From the above literature, the results for a ship involved in a collision could include loss of life, damages to own ship, to other ships and to the environment. In a collision incident/accident, the most likely cause would be human error on both ships involved. Therefore, the ship operator will be liable for own damages and damages to third parties.

In this paper, it is proposed that ship operators should be able to measure crucial managerial issues by using a measurement system. Drawing from the above literature review, it appears that the key elements that should appear in such a measurement system are customer satisfaction, regulatory compliance, human resources and emergency preparedness. In Section 2 the literature is extended to identify benefits and weaknesses from existing measurement systems used in the shipping industry. Section 3 proposes a research methodology of a management system tool that will include the four key elements to minimise the financial exposure of a ship operator due to occurrence of an accident. Measurable indicators are presented as the foundations of the proposed tool in Section 4. Eventually the proposed model is tested by the means of a case study in Section 5 and concluding remarks are presented in Section 6.

2. Existing management systems

The majority of the IMO regulations had to do with technical issues such as the construction of ships and the training standards of seamen. However, a main weakness that was revealed was the management of ships by ship operators. In this context some notable efforts have been made towards this direction by the IMO with the introduction of the ISM Code. Furthermore, ISO 9001:2008 standards appear to have a broader applicability in the shipping industry as a comprehensive managerial tool. The examination of both standards could be indicative of what indicators should be the constituent components of a management system. The information provided by both systems should be used to measure financial disasters caused by accidents.

2.1. ISM Code

The IMO encouraged the establishment of a Safety Management System (SMS) in accordance with the ISM Code that was a critical milestone for maintaining a legislative control in shipping (Celik et al., 2010). The ISM Code is related to the improvement of the public control and follow-up and the improvement of contract relations among the flag states (Triantafylli and Ballas, 2010). The ISM Code required a ship operator to lay down an SMS of work involving management of risk along with self-checking and self-critical measures for the purposes of verifying and continually improving its performance (Bhattacharya, 2012). For instance in paragraph 10 of the ISM Code, the procedures, requirements and obligations that a shipping company must have in place are described so as to ensure the company's conformity with the international regulations (Lazakis et al., 2010). The ISM Code applies at all levels ashore and on board ships. It includes twelve paragraphs that cover a wide range of issues as they appear in Table 1.

An SMS depends on effective management of information provided from the ship and other sources such as inspections by port state control officers and classification societies. This information is used for carrying out quality ship management and quality ship maintenance by setting the foundations for a preventive maintenance regime (Lazakis et al., 2010). However, lack of knowledge to evaluate such information may mislead a ship operator about the safety standards of his ships. Early studies have shown that to some national cultures it may be difficult to fully understand and adopt the concept of management systems which were introduced, mainly from the USA, together with new technologies (Hofstede, 1983; Brock, 2005; Pagell et al., 2005; Dimitriades, 2005). Furthermore, a misunderstanding of the ISM Code elements could exist in an organization itself. The findings from Tzannatos and Kokotos (2012) show a considerable disparity between managers' and seafarers' understanding of the use of the ISM Code resulting in a wide gap between its intended purpose and practice. According to Talley et al. (2005) the ISM Code is an attempt to regulate human actions because they are likely to lead to ship accidents claims. Such a belief devaluates the purpose of the ISM Code. It has also been argued that many small-scale owners, representing a significant proportion of the market, may experience various difficulties in complying with the ISM Code requirements and consequently they may choose to give their ships' management to a third party ship management company (Mitroussi, 2004a). From the above criticisms a further limitation that reveals is that the ISM Code has failed to convince that it is something, more than paperwork and that it can be used as a tool to increase profitability for a company.

Table 1
The paragraphs of the ISM Code.

Clause	ISM Code paragraphs
1	Objectives
2	Safety and environmental-protection policy
3	Company responsibilities and authority
4	Designated person (S)
5	Master's responsibility and authority
6	Resources and personnel
7	Shipboard operations
8	Emergency preparedness
9	Reports and analysis of non-conformities, accidents and hazardous occurrences
10	Maintenance of the ship and equipment
11	Documentation
12	Company verification, review and evaluation

2.2. ISO 9001

The limited scope of the ISM Code has led organizations to propose other management tools. A quality system such as the ISO 9001:2008 standards set by the International Organization for Standardization (ISO) appears as a positive solution. ISO is a requirement imposed by some governmental agencies on companies competing for public procurement contracts and some major customer groups on their suppliers (Kleindorfer and Saad, 2005). The application of these standards by a ship operator will aim at improving quality of services, which inter alia is satisfaction of charterers, terminals, and cargo owners in terms of speedy and safe delivery of cargo (Triantafylli and Ballas, 2010). Usually these companies are certified by ISO 9001 on a voluntary basis in order to assure their customers about the quality of the services they offer. A company that complies with the ISM Code and ISO 9001 focuses not only on the internal efficiency, but also on the quality of services that produces, as well as on the effects that its operation has on the environment (Fafaliou et al., 2006). The clauses of ISO 9001:2008 standards are shown in Table 2.

Celik (2009a) proposed a systematic approach for exploring the compliance level of the ISM Code with the ISO 9001:2008 in order to structure an integrated quality and safety management system (IQSMS) for shipping operations. The adaptation of ISO quality standards in shipping business provides invaluable benefits with regard to the technical management of merchant fleets, and is also very useful for both improving the service quality and enhancing customer satisfaction in the market. However, in the same research (Celik, 2009a) problems have appeared on ensuring the compliances of the ISO quality standards with the relevant maritime regulations while structuring an integrated management system in practice. Furthermore, it should be stressed that the ISO standards are voluntary. The scope is limited to quality and customer satisfaction without any evidence that economic aspects are not overlooked.

2.3. Risk management in the shipping industry

Shipping industry has been considered as a high risk sector due to the hazards that ships and crew members are exposed to on a daily basis. The consequent impacts of shipping accidents vary in scope, including loss of life, extensive marine pollution, damage to ship or its cargo, and others (Celik et al., 2010). Therefore, it is very important for a ship operator to develop a risk management

Table 2
The clauses of ISO 9001:2008 standards.

Clause	ISO 9001:2008
1	Scope
2	Normative references
3	Terms and definitions
4	Quality management system
4.1	General requirements
4.2	Documentation requirements
5	Management responsibility
5.1	Management commitment
5.2	Customer focus
5.3	Quality policy
5.4	Planning
5.5	Responsibility, authority and communication
5.6	Management review
6	Resource management
6.1	Provision of resources
6.2	Human resources
6.3	Infrastructure
6.4	Work environment
7	Product realization
7.1	Planning of product realization
7.2	Customer-related processes
7.3	Design and development
7.4	Purchasing
7.5	Production and service provision
7.6	Control of measuring and monitoring devices
8	Measurement, analysis and improvement
8.1	General
8.2	Measurement and monitoring
8.3	Control of nonconforming product
8.4	Analysis of data
8.5	Improvement

system in order to verify that his company can deal with such a risk if it occurs. The concept of risk management is well known in the shipping industry, since it is used in various shipboard contingency plans, as it is proposed by the IMO. The IMO recognizing that a main hazard in the shipping industry is oil pollution, which could be the outcome from many situations, issued a guideline for the Shipboard Oil Pollution Emergency Plan (SOPEP). Guidelines for the Development of a Shipboard Oil Pollution Emergency Plan are published by the IMO under MEPC.54(32) 1992 as amended by MEPC.86(44) 2000 and MEPC.117(52) 2004. SOPEP is a manual, in which according to Regulation 37 of Annex I of MARPOL, every ship of 400 tons gross tonnage or more and every oil tanker of 150 tons gross tonnage or more must carry on board in case a pollution incident occurs or is likely to occur (IMO, 2004). According to the plan a list of situations that could put a ship at risk includes fire/explosion, collision, grounding, and excessive list, etc.

Through the SOPEP plan, emphasis is given to the actions of the captain in an emergency situation in order to deal with an unexpected discharge of oil. It also provides guidance as to the actions to be taken for the safety of the crew. Further requirements include issues such as reporting to authorities and cooperation. However, despite the experience of the master and his crew, many reasons such as stress may force the seaman to be confused and act in a wrong way. The SOPEP manual fulfills objective 1.2.2 of the ISM Code where ship management companies have to document the following actions:

1. *Provide for safe practices in ship operation and a safe working environment.*
2. *Assess all identified risks to its ships, personnel and the environment and establish appropriate safeguards.*
3. *Continuously improve safety management skills of personnel ashore and aboard ships, including preparing for emergencies related both to safety and environmental protection.*

The principles behind a risk management area are adequately presented in the ABS guidance notes on the investigation of marine incidents (ABS, 2005), which provide a detailed analysis of how a marine incident can be prevented and what corrective actions should be followed in terms of efficient management. The guidance includes also principles of effective emergency preparedness planning. Therefore, it is used as an additional source of information. Among these sources, four common stages of risk management that emerge are risk analysis, planning, training and review. The risk management is a concept that has been dealt in other industries. Watkins and Bazerman (2003) proposed notable risk management principles that are the only contribution dealing with three main phases of a crisis management plan. These phases consist of identification, assessment and management (Kramer, 2005; Pollard and Hotho, 2006). By comparing the above existing crisis management plans some common steps are highlighted. Initially a risk analysis is carried out to assess any potential hazards. Then planning is necessary to be carried out in order to minimise the identified hazards by following acceptable practices. A well-established training schedule, which should include drills, can verify the alertness of the employees. Finally, a review process can be implemented to identify any possible weakness of the risk management procedure.

3. Research methodology

The main aim of this study is to ensure the provision of the information required for redesigning risk management principles in order to combine them as part of the commercial management of a ship. Specifically, this paper proposes a hybrid methodology to redesign current risk management requirements in order to establish an advanced management system towards reducing potential hazards for seafarers on board bulk carriers caused by collision. Ship operators may apply the methodology in order to evaluate the economic burden that will be generated to ship operators in case of a collision incident.

The proposed research methodology is developed as a management system tool that will combine the key elements of risk management with existing managerial systems assisting a ship operator to reduce his financial exposure to an accident. For a ship operator the main aim is the economic success of his company. Therefore, emphasis should be given to answer the question of how the risk management could be integrated in his existing management system contributing to economic success. The proposed methodology has the following objectives:

1. Identify key perspectives and indicators for ship management.
2. Rank perspectives and indicators for their significance in ship management.

3.1. Identify perspectives and indicators for ship management

Balanced Scorecard (BSC) is used as the foundation for this methodology because compared to other performance measurement methods it has a broad applicability in many business sectors (Punniyamoorthy and Murali, 2008; Shafia et al., 2011). The early experiences of companies using BSC have demonstrated that it meets several managerial needs since it includes both financial and non-financial indicators together in a measurement tool. The BSC is the most recognized and utilized contemporary performance measurement system (Tung et al., 2011). Havold and Nesset (2009) applied BSC in the shipping industry since many business executives demand simple, low cost measures for benchmarking purposes or for use as measures in a balanced scorecard. Perepelkin et al. (2010) established a system for measuring the performance of flags by developing a methodology to measure flag state performance which can be applied at the regional or global level and to other areas of legislative interest. Wu and Liu (2010) developed a system of BSCs to enable managers to gain a greater understanding of the practical effect of ISO certification. Havold and Nesset (2009) proposed a BSC as a benchmarking tool to measure aspects of the safety culture of an organization which relates closely to ISO 9001:2008, the ISM Code and organisational learning. Karahalios et al. (2011) proposed a system of balanced scorecards to measure the regulatory performance of various stakeholders involved into the shipping industry.

By using the BSC, companies must create a system that simultaneously aligns and integrates four interrelated perspectives: (a) financial, (b) learning and growth, (c) customer and (d) internal business (Kaplan and Norton, 1996a,b). Both financial and non-financial indicators are incorporated, and the business is analysed from four perspectives in turn. The indicators help management to gain an in-depth and comprehensive understanding of the company's overall performance. Each perspective should include a set of measurable indicators that could show the link of risk management with the daily management aims of a ship operator. Kaplan and Norton (1996a,b, 2004, 2005) noted that many companies are using similar measures in order to evaluate their perspectives.

3.2. Rank perspectives and indicators for their significance in ship management

The weight of each indicator/perspective can be evaluated in the context of a multiple criteria decision problem. Vinodh et al. (2012) suggested that by utilizing the Analytic Hierarchy Process (AHP), the weight of each indicator/perspective in an individual BSC can be obtained quantitatively. AHP established by Saaty (1994) is a method, which can solve multiple criteria decision problems by setting their priorities. Following the AHP a set of criteria and alternatives for a given problem is organized in a hierarchical structure. A decision maker can assess his evaluation separately at each level subjectively. Park and Lee (2008) argued that although AHP is based on a user's experience and judgment, its results are objective and realistic.

Decisions made using the AHP occur in two sequential phases: hierarchy design, which involves decomposing a decision problem into a hierarchy of interrelated decision elements (i.e., goal, and evaluation criteria) and hierarchy evaluation, which involves eliciting weights of the criteria and synthesizing these weights and preferences to determine alternative priorities (Zheng et al., 2012). Then the best decision can be chosen when qualitative and quantitative aspects of a decision are included (Saaty, 1994, 2003). To calculate the relative weights of criteria, it first requires the pair-wise weight assessments between the criteria at the same level of a decision hierarchy. In an arbitrary random reciprocal matrix, A there exist some i, j and k for which $\alpha_{ij}\alpha_{jk} \neq \alpha_{ik}$. Then the weight of a specific element in the pairwise comparison matrix, w_k can be obtained as follows (Vargas, 1982):

$$w_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n}a_{kj}} \quad (1)$$

where $k = 1,2\ldots n$.

When multiple pairwise comparisons are evaluated, some degree of inconsistency could be expected to exist. The AHP method provides a measure of the consistency for pairwise comparisons by introducing the consistency index (CI) and consistency ratio (CR) (Ung et al., 2006). If consistency ratio (CR) suggested by Saaty is above 0.2, the person making the judgment should seek additional information, re-examine the data used in constructing the scale, and then make a new judgment (Wedley, 1993).

3.3. Fuzzy set theory

In the traditional AHP method, the scale of pair comparisons among criteria is restricted to crisp numbers. The AHP method does not fully take into account the uncertainty associated with the mapping of one's judgment to a number (Ayag and Özdemir, 2006). Therefore, AHP is criticized for its unbalanced scale of judgment and failure to precisely handle the inherent uncertainty and vagueness in carrying out pair-wise comparisons (Zheng et al., 2012). Similarly in this case due to lack of previous data it is necessary to rely on judgements of experts. Experts should evaluate the validity of the produced BSCs. Yet experts may have to rate the criteria using linguistic variables such as "equal important" or "moderate important". A linguistic variable is a variable whose values are not numbers but words or sentences in a natural or artificial language (Zaddeh, 1975). Fuzzy numbers are introduced to appropriately express linguistic variables. Fuzzy set theory has been used to tackle complicated problems due to incomplete and imprecise information that characterizes the real-world systems. It is, therefore, suitable for uncertain or approximate reasoning that involves human intuitive thinking (Ebrahimnejad et al., 2010).

The most commonly used fuzzy numbers are triangular and trapezoidal fuzzy numbers (Wang et al., 2009). In this paper the triangular fuzzy numbers are used due to their simplicity. A fuzzy number is a special fuzzy set $M = \{(\chi, \mu_M(\chi)), \chi \in R\}$, where χ takes its values on the real line R: $-\infty < \chi < +\infty$ and $\mu_M(\chi)$ is a continuous mapping from R to the close interval [0,1]. A triangular fuzzy number $\tilde{M}$ can be defined by a triplet (a, b, and c) as shown in Fig. 1. A triangular fuzzy number is defined as (Cheng et al., 1999):

$$\mu_{\tilde{M}}(x) = \begin{cases} 0 & x < a \\ \frac{x-a}{b-a} & a \leqslant x \leqslant b \\ \frac{c-x}{c-b} & b \leqslant x \leqslant c \\ 0 & x > c \end{cases}$$

The operations of triangular fuzzy numbers are expressed below (Dagdeviren and Yuksel, 2008):

1. Fuzzy number addition.

$$(a_1, b_1, c_1) + (a_2, b_2, c_2) = (a_1 + a_2, b_1 + b_2, c_1 + c_2) \quad (2)$$

2. Fuzzy number multiplication.

$$(a_1, b_1, c_1) \times (a_2, b_2, c_2) = (a_1 a_2, b_1 b_2, c_1 c_2) \quad (3)$$

3. Reciprocal fuzzy number.

$$(a_1, b_1, c_1)^{-1} = \left(\frac{1}{c_1}, \frac{1}{b_1}, \frac{1}{a_1}\right) \quad (4)$$

For fuzzy numbers a defuzzification process follows to obtain crisp numbers (*M_crisp*). The method to calculate the crisp number for a triangular fuzzy number (a, b, and c) is to compute the centre of the fuzzy number's triangular area by Eq. (4) (Wang and Parkan, 2006):

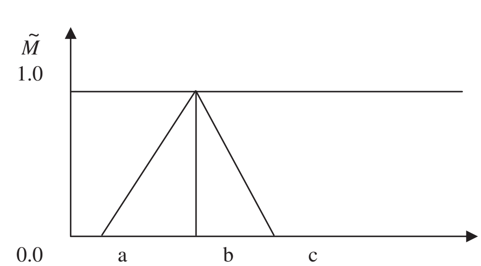

Fig. 1. A triangular fuzzy number $\tilde{M}$.

$$M\_crisp = \frac{(b+a+c)}{3} \qquad (5)$$

4. Proposed model

A ship management system should measure the success of a ship operator including the main elements of existing management systems described in Section 2 and the financial success of a company. Karahalios et al. (2011) suggested that the following key elements can be the foundation of a performance management system for a ship operator:

1. Problem statement.
2. Identify the perspectives and indicators for evaluating the costs and the benefits of risk management in ship management.
3. Develop a hierarchy for evaluating perspectives' weights.
4. Evaluate the weight of each perspective and rank them for their burden in the ship management.

4.1. Problem statement

The main goal for a ship operator is mainly economic distinction in a very demanding industry. To achieve this aim all his customers should be satisfied with the supply of high-standard ships and crew. Customers should include a variety of stakeholders such as flag state, port authorities, insurers, charterers/cargo owners and crew members (Karahalios et al., 2011). As it was revealed by the literature review involvement in an accident could cause severe economic damage for a ship operator. Therefore, the concept of risk management should be used as a tool for avoiding such economic disasters.

4.2. Identify the perspectives and indicators for evaluating the costs and the benefits of risk management in ship management

4.2.1. Selection of perspectives and indicators

A detailed comparison of existing managerial systems such as the ISM Code and ISO 9001:2008 standards' shows many similarities. Although these two tools are different in scope, some elements such as human resources, planning and measurement are common (Celik, 2009b). Therefore, those elements should be used as indicators for designing a scorecard. In order to complete a management system it is appropriate to measure financial perceptions. The BSC provides four basic perspectives capable of monitoring the performance for a ship operator. Therefore the use of a scorecard measuring those four perspectives will form the foundation of a scorecard. The financial perspective is about the costs due to incidents/accidents and profits through reducing incidental/accidental risks. The customer perspective includes what the customers expect from a ship operator such as quality and productivity. The internal business perspective is the procedure that should be followed to avoid an accident such as training, planning and review. Finally, the learning and growth perspective is used to measure the resources that are required to provide a safe ship and includes technology, human resources and knowledge. A generic proposed BSC for a stakeholder, which includes the chosen perspectives, is shown in Table 3.

4.2.2. Evaluation of scorecard

It is of utmost significance to demonstrate that the perspectives and indicators from the scorecards are valid. The validation is achieved by the means of a survey where industrial experts rate each indicator and perspective for its significance. Those experts should have an appropriate academic and industrial background working in shipping companies either directly or by evaluating their performance as employees of port state control or classification societies. Eight experts were chosen in this study, each having a reasonable mixture of academic qualifications, professional qualifications and industrial experiences. The qualifications of experts are shown in Table 4. Following the approach of Karahalios et al. (2011) the experts can subjectively rate the importance of each BSC item in a scale of five linguistic terms, where each term will correspond to a fuzzy number as it is shown in Table 5.

The first task for the experts is to determine the fuzzy memberships of the linguistic terms for use. Each expert is required to evaluate each linguistic term in a scale from 1 to 9 according to the Saaty's scale in the AHP theory (Harker and Vargas 1987). Fuzzy numbers of Table 5 represent linguistic terms from equal to absolute importance. The membership functions of fuzzy numbers are determined by experts. According to expert opinions (E_i) each linguistic term can be represented by a triangular number $n = (a_z, b_z,$ and $c_z)$ where $z = 1, 2,...,9$ and a_z and c_z are the lower and upper values of the fuzzy number, respectively. The b_z is the middle value of the fuzzy number with a membership value being equal to 1. The average of r experts' opinions $E_{\tilde{M}_z}$ will be used to determine the fuzzy number for each linguistic term (Ung et al., 2006):

$$E_{\tilde{M}_z} = \frac{\sum_{i=1}^{r} E_i}{r} \qquad (6)$$

Table 3
Perspectives and their indicators.

Perspective	Indicators	ISO 9001:2008	ISM Code
Financial perspective	Profit	NA	NA
	Revenue	NA	NA
	Cost	NA	NA
	Use of assets	NA	NA
Customer perspective	Productivity	8.2.4	NA
	Competitiveness	7.1.2	NA
	Quality	4	NA
	Reputation	8.2.1	NA
Internal business perspective	Human capital	6.1, 6.2.1	6
	Information capital	6.3	1.1.7
	Organizational capital	5.5, 5.4.1, 5.5.1, 5.5.2, 6.2.2	3.3, 4, 5
	Innovation	5.1, 5.5.1, 5.5.3	1.2.2.3
Learn & growth perspective	Risk analysis	5.1, 5.5.1, 5.5.3	1.2.2.2
	Planning	5.4, 8.5.3, 7.3.1	7
	Training	6.2.1, 6.2.2	6.5
	Review	5.6	1.4.6

Table 4
Qualifications of experts.

	Academic certification	Professional certification	Managerial experience	Experience (not managerial)
Expert 1	BSc	Ship surveyor/auditor	20+ years	10–14 years
Expert 2	MSc	Ship surveyor/auditor	15–19 years	15–19 years
Expert 3	HND	Captain	5–9 years	20+ years
Expert 4	MSc	Ship surveyor/auditor	15–19 years	5–9 years
Expert 5	BSc	Ship surveyor/auditor	10–14 years	10–14 years
Expert 6	HND	Ship surveyor/auditor	10–14 years	20+ years
Expert 7	MSc	Captain	5–9 years	10–14 years
Expert 8	PhD	Captain	0–4 years	20+ years

Table 5
The 9-point scale of AHP with fuzzy numbers.

Intensity of membership importance	Fuzzy number	Definition	Membership function
1	$\tilde{M}_1$	Equal importance	(a_1,b_1,c_1)
2	$\tilde{M}_2$	Equal to weak importance	(a_2,b_2,c_2)
3	$\tilde{M}_3$	Weak importance	(a_3,b_3,c_3)
4	$\tilde{M}_4$	Weak to strong importance	(a_4,b_4,c_4)
5	$\tilde{M}_5$	Strong importance	(a_5,b_5,c_5)
6	$\tilde{M}_6$	Strong to demonstrated importance	(a_6,b_6,c_6)
7	$\tilde{M}_7$	Demonstrated importance	(a_7,b_7,c_7)
8	$\tilde{M}_8$	Demonstrated to extreme importance	(a_8,b_8,c_8)
9	$\tilde{M}_9$	Extreme importance	(a_9,b_9,c_9)

4.3. Develop a hierarchy for evaluating perspectives' weights

It is essential to present how the proposed system of perspectives and measures/indicators should be used regarding ship management. As shown in Fig. 2, the tiers indicate the main direction that should be followed gradually. The initial perspective at Tier 1, in the graph, is learn and growth, which contains all the existing management knowledge, information systems and represents the human resources and information technology. By starting from the base going upwards, the existing knowledge, which is the innovation, should lead to an effective information management system capable of monitoring all the company activities. Tier 2 is the internal business perspective, which represents the procedure of implementing a regulation. Tier 3 is the customer perspective, which indicates the results of a regulation in business practices. Customer satisfaction will increase if there is more production and better quality. An increase in quality and productivity will increase competitiveness of the company and consequently will improve its reputation. Tier 4 is the financial perspective, which indicates the economic achievements or losses from the implementation of a regulation. In Tier 4 the increase or loss for the existing assets value of the company should be followed from cost reduction to profit. It should be stressed that the profit of the company is the determining factor of the future survival of the company. Tier 4 is not the end of the process but the end of a cyclic process. The process is repeated from Tier 1 where part of the profit will be reinvested to develop the knowledge and experience acquired through the process. By adopting the past experience in the existing procedures, the company will gain innovation for further growth.

After the evaluation of the BSCs for their validity by experts, the next step is to rank the scorecard's perspectives and measures/indicators according to their weights of importance. By making pair-wise comparisons for the perspectives, it is possible to identify which perspectives are more important for a ship operator than the others.

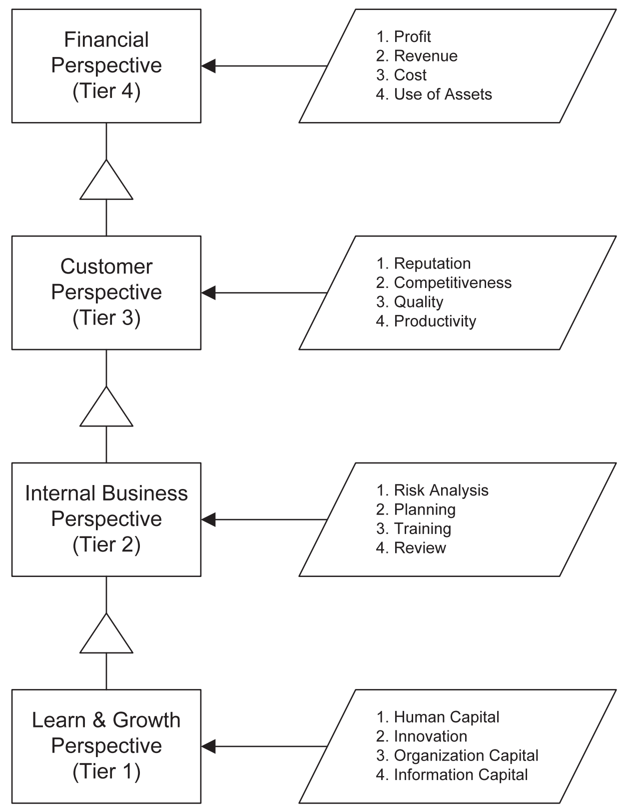

Fig. 2. The link of the proposed perspectives and their indicators.

4.4. Evaluate the weight of each perspective and rank them for their burden in the ship management

A survey is conducted through research questionnaires in which eight chosen experts had to verify the selection of the proposed BSCs and provide their feedbacks with regard to the regulatory authority of the representative stakeholders. Each expert was required to evaluate each linguistic term in a scale from 1 to 9. This evaluation from every expert is represented by one fuzzy triangular number and the average value from all the experts' judgements determines the fuzzy number for each linguistic term. The results for the linguistic terms are shown in Fig. 3. For example, given that the eight experts are involved in the analysis of calculating the membership of strong importance, it can be obtained as follows by using Eq. (6).

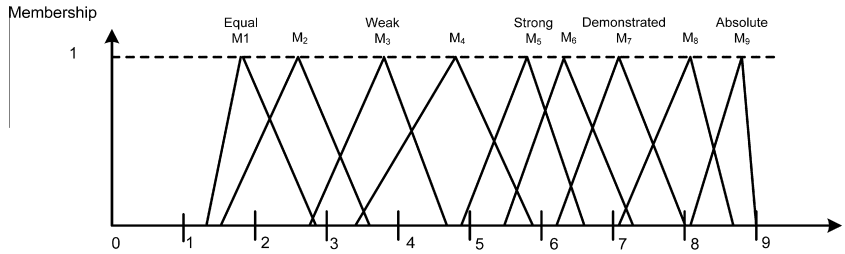

Fig. 3. The memberships of the calculated fuzzy numbers.

$$E_{M^{\sim}_s} = \frac{\sum_{i=1}^{8} E_i}{8} = \frac{(5,6,7)+(4,5,6)+(5,6,7)+(5,6,6)+(4,5,6)+(5,6,7)+(7,8,8)+(4,5,6)}{8} = (4.78, 5.87, 6.62)$$

In a similar way, the membership functions of the other linguistic terms can be computed.

A pairwise comparison matrix is completed for the chosen perspectives in Table 6. The fuzzy numbers are then added and averaged with Eqs. (2) and (3) respectively. For the fuzzy numbers a defuzzification process follows to obtain crisp numbers (*M_crisp*) by using Eq. (5). All the defuzzification results from the fuzzy matrix of the perspectives are shown in Table 6. For the perspectives' crisp matrix from Table 6, the CR value for the $n = 4$ matrix is calculated to be 0.2 where the CR is smaller than 0.2.

Table 6
Defuzzification results of perspectives pairwise comparisons.

Perspective	Finance	Customer	Internal	Learn & growth
Finance	1.000	6.238	3.850	3.636
Customer	0.161	1.000	3.701	2.139
Internal	0.262	0.272	1.000	3.269
Learn & growth	0.279	0.472	0.310	1.000

Table 7
The weighting of divisions.

Perspective	Priority
Finance	0.541
Customer	0.213
Internal	0.157
Learn & growth	0.089

Table 8
The average rate of indicators.

Perspective	Indicators	Rate average
Financial perspective	Profit	**4.75**
	Revenue	**4.37**
	Cost	**4**
	Use of assets	**3.12**
Customer perspective	Productivity	**4.5**
	Competitiveness	**4.75**
	Quality	**4.62**
	Reputation	**3.87**
Internal business perspective	Human capital	**3.37**
	Information capital	**3.5**
	Organizational capital	**4**
	Innovation	**3.25**
Learn & growth perspective	Risk analysis	**2.75**
	Planning	**2.5**
	Training	**2.5**
	Review	**2.75**

By using Eq. (1) the perspectives are ranked in terms of their weights. In Table 7, the ranking order of the perspectives is displayed in terms of their weights in the management process. It appears that the most important perspective is the financial followed by the customer satisfaction, the internal business and eventually the learn and growth. The next step was to validate the chosen indicators. To avoid numerous pair-wise comparisons experts had to rate the significance of each indicator in a scale 1–5 and the averages are shown in Table 8. The Cronbach α coefficient was used to measure the internal consistency of the average rate of indicators shown in Table 8. The value of Cronbach α was calculated to be 0.74 which is an accepted area.

5. A case study

There is no consensus on the statistical distribution on the causes of shipping accidents due to the different viewpoints of accident analysis and investigation approaches (Celik et al., 2010). Therefore, to demonstrate the applicability of the tool a case study is carried out. In this case, the type of ship that is chosen to be investigated for its implication in a collision accident to a ship operator is the bulk carrier.

The data for this case study was collected from GISIS, which is a database provided by the IMO (GISIS, 2013). This database contains casualties and incidents data reported by the IMO member states as per IMO instructions (IMO, 2008b). From the total 43 collisions that were examined, 45 bulk carriers where involved of which two did not cause any notable harm, meaning that the bulk carrier remained fit to proceed and human and environmental safety was not threatened as a result of the collision. In another ten incidents the damages caused by collisions were found minor. From the remaining incidents, twelve collisions caused severe structural damages to at least one of the ships involved. Two ships flooded without sinking and two fire incidents were reported. The most catastrophic results were the total loss of eight fishing boats where seven of them incidents caused loss of life and two pollution cases. To categorize the severity of each incident the scale of Table 9 is used (Lois et al., 2004). The incidents were grouped according to the severity index and the results are shown in Table 10. As it is shown in Table 10 in a collision incident, the most probable consequence is either critically or catastrophically in terms of its severity for the business of the ship operator. The incidents used in this paper are shown in Table 11 with respect to the geographical distribution. It appears that the majority of collisions occurred near coasts; this is in line with the findings from other researchers (Hsu et al., 2008; Kokotos and Linardatos, 2011; Hsu, 2012). The time period for incidents and accidents is shown in Table 12. From the accidents reported it is clear that the number of incidents varies significantly each year.

5.1. Expected contributions of the proposed model

As per COLREGS requirements in a ship's collision, the ship operator will always be responsible for claims. From the data

Table 9
Severity index.

Scale	Definition	Examples
1	Negligible	Injury not requiring first aid, no cosmetic vessel damage, no environmental impact, no missed voyages
2	Minor	Injury requiring first aid, cosmetic vessel damage, no environmental impact, no missed voyages
3	Significant	Injury requiring more than first aid, vessel damage, some environmental damage, a few missed voyages or financial loss
4	Critical	Severe injury, major vessel damage, major environmental damage, missed voyages
5	Catastrophic	Loss of life, loss of vessel, extreme environmental impact

Table 10
Incidents per category and severity.

Incidents	Category	Probability	Severity
12	Major damages	0.26	4
10	Minor damages	0.22	3
8	Total loss	0.17	5
7	Loss of life	0.15	5
2	Pollution	0.04	5
2	Flooding	0.04	4
2	Fire	0.04	4
2	No	0.04	1

Table 11
Geographical distribution of incidents.

Incidents	Geographical area
3	Traffic/fairway
5	Narrow water
2	River
8	Port
9	Deep sea
12	Coast
6	Anchorage

Table 12
Time period for incident and accidents.

Year	Number of incidents
2011	1
2010	3
2009	3
2008	5
2007	10
2006	4
2005	7
2003	3
2000	3
1997	1
1996	2

above, it is clear that in case of collision a ship operator will be exposed to financial damages, which was found to be the most important perspective. The cost of repairs, pollution cleaning and compensation to other parties are expected to be high. In a recession period, the financial impact could be high enough to force the ship operator to cease his business. The contribution or risk movement could therefore be seen as a tool of helping avoid business disasters.

Furthermore, it is likely that at the time of the incident many of his customers will lose their confidence in the managerial organization of the ship operator. From a regulatory point of view, customers should include the flag state, coastal authorities and the classification societies. Also if the ship is chartered, the ship operator will be liable to the cargo owners and charterers for damages and delays. Insurers and crew members are also considered as customers. The purpose of ISO 9001:2008 standards is to maintain the confidence of customers through quality. Customer satisfaction is the second highest perspective and in case of collision, the ship operator has failed to meet those standards. It is expected that through careful planning the affected customers associated with a disaster should have been identified.

The aim of the ISM Code is to improve safety and protect environment. The main paragraphs of the Code clarify the obligations of the ship operator regarding crew selection, training, maintenance and planning of shipboard operations. One of the main reasons that could lead to a collision incident is human error. It is solely the responsibility of a ship operator to minimize human error through careful planning and training. Such responsibility should ensure that information flow from ship is evaluated by personnel ashore through established communication channels. Inadequate correspondence from ashore could be a threat for shipboard operations. A careful risk management planning should have been capable of facilitating the identification of relevant issues and solutions should have been placed.

The ISM Code and ISO 9001:2008 standards include the risk management principles such as review of existing procedures and plans. Ship operators should examine data from real cases in order to update existing plans like SOPEP. As it is shown from the severity of the accidents, it is for the commercial benefits for a ship operator to well maintain his ships and select crew with competence. Information from past accidents should be used to improve existing shipboard plans. For instance, in Table 11, it seems that most of the collisions have been reported near coasts and the more fatal ones are those involving fishing boats. Those two facts should be used to update existing navigation and emergency instructions. Onboard drills should also include scenarios with collision with a fishing boat.

6. Conclusion

The results from the case study showed that for a ship operator the most significant perspective is the financial one. Meantime, the involvement of a ship in an accident could cause a severe commercial impact as well. An accident could cause catastrophic financial losses for a ship operator. The suggested measurement system is a tool linking risk management with internal business, customer satisfaction, financial, learn and growth perspectives taken into account.

This paper suggests that the commercial priorities of a ship operator should be re-examined. Issues such as internal business and risk management should be re-evaluated for their weight in ship management in order to avoid financial losses due to an accident. A precautionary risk planning by qualified personnel is always a better solution to minimize the possibility of catastrophic results of a collision.

The proposed methodology is a unification of methods, which are brought together in an advanced model. The application of fuzzy AHP with the assistance from experts produced a decision-making methodology applicable to a ship operator. Ship operators can use this methodology in order to find gaps into their existing management systems based on the obtained results. It could also assist in understanding of compliance requirements with ISO and ISM Code systems.

The examination of a case study with data from IMO showed that 17 cases involved in a collision with a bulk carrier were catastrophic, 16 critical and the remaining 12 minor. The most catastrophic results in terms of safety were caused when the other ship involved was a fishing boat. The results are highlighting therefore the need for better planning when a bulk carrier is sailing in fishing areas.

The proposed tool was tested on ship operators who manage dry bulk carriers. This type of ship was selected in this research because it had suffered a high number of casualties. It is suggested that the tool can be applied to carry out studies on other types of ships such as tankers and container vessels. It is also worth of investigating the issue as to whether other ship operators who manage more sophisticated designed ships face more difficulties with procedures such as risk analysis.

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