THE ROLE OF A SHIP'S MASTER IN THEORY AND PRACTICE: LESSONS FROM MARINE ACCIDENTS

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Abstract

We analyzed seven marine accidents. The paper concurrently contributes to finding ways to remedy the ineffectiveness of ISM Code. The Code was supposed to *eliminate* 'human error'. Statistical evidence shows that human marine accidents do occur. We show that an improvement in safety will be attained by understanding and improving 'safety culture' of ship masters. The ISM Code rested on 'commitment on top' of the company. We present shipping company's culture and the attitude of an autocratic captain. We analyze the requirements of ISM Code from a ship's captain, showing that the Code is a 'total safety management' standard, not a quality standard as proclaimed. We show that a master's lack of understanding not only of linear, but also of nonlinear, management, leadership and motivation are serious shortcomings in marine accidents. Most captains in the case-studies analysed here are shown to act under commercial pressure. Master's culture is important due to the 'management from a distance' that exists in shipping industry. Moreover, as shown, the provisions of the Code give a master the *overriding authority* in emergencies. He is the dominant personality who may 'commit' a mistake that results not only in the loss of the ship and the cargo, but also of his life. The case-studies showed that masters were unable to visualize the outcome of an impending danger in time, or to learn from similar accident (Estonia), or to assess the severity of the weather beforehand. The analysis uses the concept of 'logistics equation' as a 'marine accident model'. Our recommendation to improve safety and protect marine environment is for a change of culture towards 'one of open access communications' on board and within company.

About the authors

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Introduction

Appropriate institutions, to satisfy the needs of maritime community in the pursuit of its business objectives, were established early in history (1745, 1760). The first need was to know the condition of the vessel that charterers wanted to charter and underwriters had to insure (1745). This task was undertaken by classification societies (1760 - Lloyds Register of Shipping: the 1st class). Since then, ships have been put in classes (A1 = highest) indicating also ship's technical durability for years to come (100 years for example = 100 A1). The above historical development pushed, naturally, shipping community's interest towards the *technical side* of the ship, where classification societies since then, and to the present day, act as inspectors. Also, and as a result, act as providers of more than a dozen certificates to ensure in writing that in *building* and in *repairing* a classified ship is 'seaworthy'[1] and remains so until scrapped.

Historically, the *technical condition* of the ship was only *necessary* condition for a *safe* journey. The *sufficiency* condition rested, however, on human element. This has been ignored for roughly a quarter of a century since the establishment of modern merchant marine (1875). A safe journey is a 'man-machine interface' (Goulielmos-Tzannatos, 1997), requiring reliability from both hardware and software (i.e., the human element).

Statistics of marine accidents show that marine accidents do occur, despite the efforts made by the dedicated supervising institutions – IMO, classification societies, flag administrations, PSC/port state control and ship-owners. Great hopes, however, were born with ISM Code, established in 1998, signalled a long-awaited shift in the attention of the IMO towards human element – the valued 'missing sufficiency' required to *eliminate* marine accidents and pollution of the sea, once and for ever.

Sagen's (2008) report depicts current reality. The Norwegian government appointed a commission of inquiry to investigate an accident involving anchor handling on board the vessel '*Bourbon Dolphin'*, which capsized and killed eight people in 2007. The commission remarked: (1) the company did not follow ISM Code requirements that all risks should be identified; (2) the Code demands procedures for key operations that the vessel will perform, but in this case nothing specific was prepared; (3) the company did not insist upon appropriate qualifications for all crew-members for operation; and (4) both class and flag failed to detect the failure of company's SMS/Safety management system in their usual audits. Safety defects were detected, which would increase risks even in routine operations. Personnel must be competent to perform risk assessments. Each vessel is unique and risk is different if two ships work together as in this case.

Talking about statistics of marine accidents, Figure 1 indicates the development of world ships lost (2001-2008), when 100 ships of 80,000 gross tonnages (gt) each used to be lost per annum on the average.

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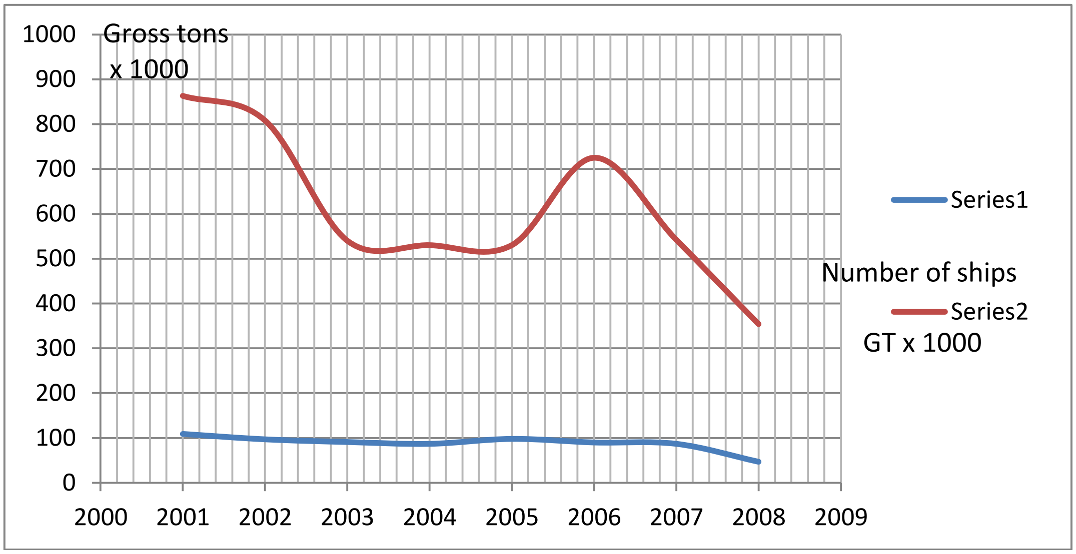
[1] 'Seaworthiness' for IMO means proper construction of, and equipment for, the vessel; proper numerical recruitment; a vessel's suitability to cope with sea perils and with cargo to be transported.

Figure 1: Total World Losses (2001-2008) of Merchant Ships of 500 gt and Over.



Source: Data from ISL (Institute of shipping logistics), Bremen, (2008).

As shown in Figure 1, ships lost (2001-2008) averaged around 100 vessels per year, despite the ISM Code (1998). The exception is 2008 (when only 47 ships were lost). In terms of gross tonnage, year 2006 showed the stronger peak (725,400 gt).

It is worth noting is that a shipping company is characterized by the fact that its top management and its (floating) factory are in different places[2]. This is 'management from distance'-MFD. As a result, *effective communications* must be at the heart of this kind of management. Moreover, *control* is the imperative management function[3] (Goulielmos, 2002) in the case of shipping. MFD, despite higher communication costs, provides lower effectiveness. The importance of the role of the master, therefore, from this point of view is high, as he is the only manager and liaison with the shore management on board. He is the only person present to exercise the control function on behalf of the owners (alter ego).

In the past, ship-owners used to stay on their ship. For modern ship-owners, ships are money-making tools and can be sold for a profit at any moment. There is no sentimental link with the vessel[4]. Unlike the captain, the ship-owner stays and works at the shore head-office and uses means of communications to manage the ship and lead the captain. 'Management by

[2] UK Maritime and Coastguard Agency (2008) confirmed our observation.

[3] Linear management is only in use nowadays in companies. Its objectives are to pursue *effectiveness* and *efficiency* in a mechanistic way (due to Newton and Taylor). The basic principle of nonlinear management is to admit that there are cases allowing for a disproportionate result to a change in the independent variable. A marine accident is a nonlinear phenomenon, as a very small change in the independent variable (e.g. weather) can result in a very large response in the dependent variable (vessel broken in two or sea environment polluted; comp. the case of M/V *Erika*).

[4] Three ships is estimated to be the average number owned by each shipping company worldwide, implying 30,000 shipping companies with about 90,000 ships of over 100 gt. In January 2008, there were 45,000 ships over 300 gt.

communication' could be another term here. Is, however, the communication effective? In particular, does it function in moments of distress? It is obvious that management at sea is much more difficult than that on shore.

This paper argues that increased attention should be paid to the safety culture of a ship's master, given the introduction of ISM Code in 1998 – as modified in 2002 – and its ineffectiveness to eliminate human error, injuries, deaths and sea pollution. The difficult combination of a shipping company's management from a distance, with specific provision of the Code that gives the master overriding authority in the area of risk, increased the difficulties. Moreover, the master's ignorance of the principles of linear and nonlinear management, leadership, and motivation may actually be a component in the faulty safety system to which master's character/psychology contributes. Our analysis introduces the concepts of the 'logistics equation' and 'open access communications' as two tools that, we believe, will eliminate marine accidents.

Literature Review

Havold (2000) argued that the occurrence of accidents led to the search into *safety culture* and *cultural* aspects. Safety culture is defined as a series of beliefs, norms, attitudes, roles, and social and technical practices, *established to minimize* the exposure of employees, managers, customers and third parties to hazard. For him, a clear understanding of the system and its safety features is needed, as is an *incentive system* encouraging safety in operations and a positive attitude towards safety features.

Ek and Akselsson[5] (2005) reported the results of safety culture assessments on board six Swedish passenger ships in international traffic, using observations, questionnaires, and interviews focusing on 508 employees. They found good safety culture. They also identified the importance of the relationship between organizational climate (i.e., challenge/motivation, support for ideas, freedom, and playfulness/humour) and safety culture. However, differences were found in individual's perceptions of safety culture between ships, vessel types,[6] and hierarchical working positions. The average level of shipping safety culture was lower compared with air traffic. Safety culture dimensions were: (a) attitude, (b) related behavior (high scores), (c) learning, (d) fairness, and (e) flexibility (low scores). *Officers had more positive perceptions of safety culture than ratings.*[7] There were also clear differences between ratings and officers for *flexibility*. The authors suggested an improved reporting system (and learning processes) for incidents and for deviance from the ISM Code. They also argued that, in contrast with air traffic in Northern Europe, shipping industry is stuck within 'blame culture', as this was also found by Veiga (2002).

Knapp and Franses (2007) examined 183,819 inspections in 10 'port state controls' worldwide (1999-2004: a post-ISM Code period). Forty-seven percent of the world fleet was inspected, with general cargoes accounting for 36%. Fifty-four percent were found to have no deficiencies and only 5% were detained (except Indian Ocean MoU/memorandum of understanding, which had 9.96% detention rate), while only 6% had more than 15 deficiencies. These authors found a very high rate of non-compliance with ISM Code.

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[5] Similar to previous studies in air traffic control.
[6] High speed craft/HSC versus Ropax/passenger-cargo/trucks ferries.
[7] With the exception of the engine department in one high speed craft.

Theotokas and Progoulaki (2007) investigated the impact of the presence of foreign crews on board 303 ships of 11 Greek owned/managed companies in 2003. They questioned 100 seafarers – mainly officers – and 11 officials in companies engaging in 'tramp' shipping. They argued that crews are more effective when all crew members participate in the decision process, and work under a flexible leadership and management style. Fifty-eight percent of companies preferred a centralized[8] leadership style, while 34% of seafarers preferred a participative one[9]. This indicates a conflict of cultures between companies and officers. Given that 95% of crew members asked were officers, it is interesting to see that the overwhelming majority disliked a 'despotic' leadership style. But only 27% of the respondents wanted a 'democratic' style of leadership. Fifty-nine percent preferred either a centralized or a participative style. What is indirectly implied is that in 2003 the predominant leadership style was either despotic[10] or centralized, and that a minority of officers would have wished it otherwise. It is disturbing that companies were found to place great emphasis on *punishing* disobedience. As argued there is a serious break between the culture of officers and the culture of companies. Moreover, safety training must take place on board, although only 25% of respondents endorsed this.

IMO (1995) stated: "the application of the ISM Code should support and encourage the development of a safety culture in shipping. Success factors for the development of a safety culture are, inter alia, *commitment, values and beliefs*". IMO (2008) further argued[11] that: "an organization with a safety culture is one that gives appropriate priority to safety and realizes that safety has to be managed like other areas of business. For a company to achieve a safety culture it must: (1) recognize that accidents are preventable by correct procedures and established best practices. (2) Think constantly about safety and (3) seeking continuous improvement."

Grabowski et al. (2007) took a novel and interesting approach and asked how the shipping industry could prevent accidents. Their sample was 943 participants in 37 tanker vessels from three fleets. In effect, they studied 'accident precursors'[12] in shipping in 2006 over 500 shipboard and shore side respondents and more than 20 vessels (US and international). They argued that the culture of the company is *separate from the culture of the vessel*. Each vessel is unique. The fundamental objectives are to *improve the shipboard safety culture and minimize human error.* On board there is a need for communication, problem identification, prioritization of safety, vessel responsibility and vessel feedback. There are also 21 metrics for shipboard safety. There were several significant correlations between individual perceptions of safety culture and flag, class, owners, age and managing office.

Lappalainen and Salmi (2008) argue that ISM Code has significantly contributed to the progress of maritime safety in recent years. Shipping companies and crews are now more

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[8] Decisions are imposed, but in a climate of trust and collaboration.

[9] Opinions of subordinates are taken into account, but without an ultimate trust. It is indicative that 100% of companies preferred either centralized or participative style.

[10] Decisions are imposed; here we have a low level of communication, trust and team work spirit.

[11] Certain delegations in IMO and in FSI in 1994 called for more attention on *safety culture*. Australia stated that it agrees with the view that flag administrations have to encourage and support the development of a safety culture in shipping. This is preferable to pursuing the enforcement of rigid and strict interpretations of what is required by the Code. The UK argued that the mandatory adoption of the Code had to support and encourage the development of safety culture in shipping. Legislation by itself will not succeed. Commitment, belief and values of key personnel in the shipping industry are also required. Intertanko also argued that the most basic target of the Code is the creation of a safety culture.

[12] These are: conditions, events or measures that precede an undesirable event and have some value in predicting the arrival of the event (accident, incident, near miss or undesirable safety state).

environmentally friendly and safety-oriented than 10 years ago. They concluded that a safety culture has emerged and is developing in the Finnish maritime industry. They subscribed to the opinion of one maritime inspector that, "in the long run, a safety culture will establish itself, but it will take time."

The UK Maritime and Coastguard Agency (2008) initiated a project in 2007-2008[13]. According to this project, 91% of the respondents felt that the Code helped to improve safety at sea in a general way; 83% felt that safety improved in their company too. The cost, however, of marine insurance claims rose significantly. To account for improvements identified by the survey, one may take into account not only the ISM Code, but also: (a) the revised STCW/95 as well as MARPOL conventions (e.g. oil majors' intensified vetting inspections), (b) the condition surveys by P&I clubs, and (c) the deepening knowledge and understanding of the Code by PSC inspectors. In early 2008, a Paris MOU reported that 20% of inspections (1,031 in number) showed deviations from ISM Code. Some companies employed an additional crew member to support the effective implementation of the Code on board. This means that existing crew members are unable to cope fully and properly with Code's requirements. Respondents stressed the lack of standardization in the interpretation of what is actually required within a Safety Management System. It seems that the Code fell into its own trap, which was to be very general so as to embrace all 30,000 or so shipping companies. As a result, it seems that another culture is developing out of necessity: *that of the external auditors of PSC*[14]. The study recognized that the *transient nature* of much of the seafaring workforce is a great barrier to the creation of a safety culture. Moreover, the distance of a vessel's owner from his (her) ships was seen to be a further potential barrier to developing a *strong* safety culture. Strong and effective leadership and supervisory skills are needed. Commitment from senior management and from all those involved in the implementation process, is in such cases, required.

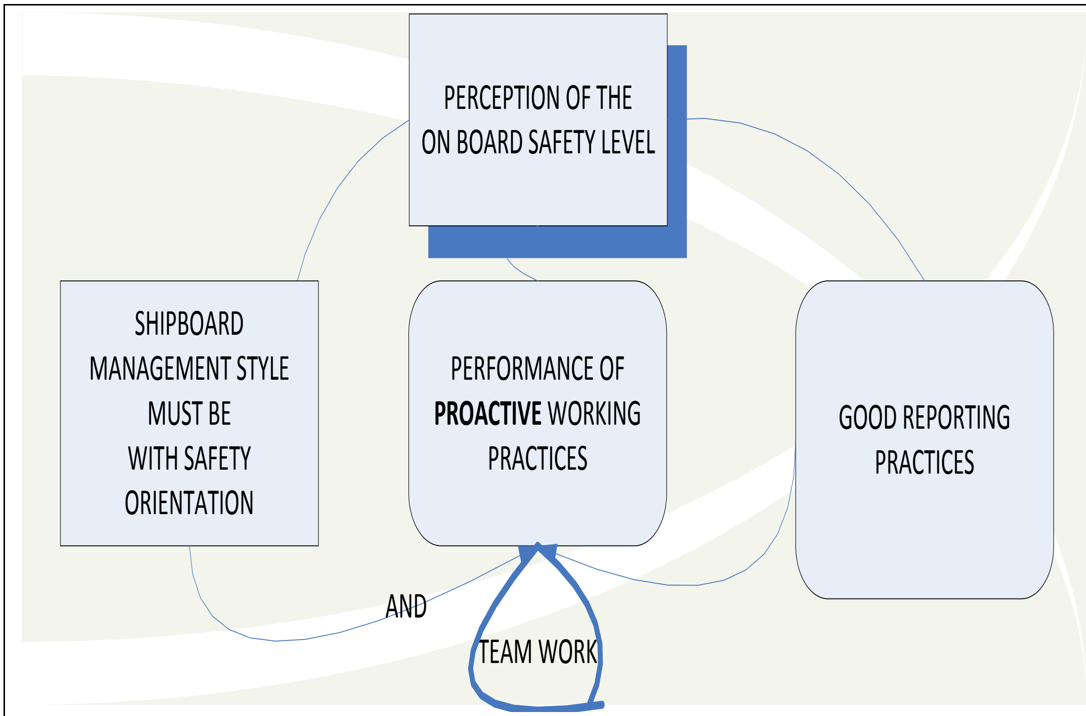
Ellis et al. (2010) argued that seafaring is the occupation with the highest mortality rate in certain developed countries (UK and Denmark). They conducted a study over 16 maritime administrations (2000-2005) (but only four gave detailed data). Flags were classed into 4-5 groups: A, B, and C being second or open registries and D being the traditional maritime registers. There 2,352 persons were injured or killed. Fatalities numbered 200 in flags A, 167 in flags C, and 70 in D. Flags D, however, had most injuries overall. In 2000- 2006 injuries and fatalities were not eliminated as expected due to the Code; 4,846 seafarers were injured and 105 died out of 22,548 seafarers on average per year. Officers (14,670 in 2004) suffered fewer injuries than ratings (10,270 in 2004), i.e. 13 against 95. This is due to the fact that officers were older, more experienced, more aware of risks and involved in less dangerous activities. This means that there is no transfer of safety culture from officers to ratings, which is contrary to the requirements of the Code.

Oltedal and Wadsworth (2010) based their research on the concept of safety culture, which achieved prominence in 1986 following the Chernobyl disaster. Their investigation covered 1,262 questionnaires from 76 Norwegian vessels in 2006, from white and grey lists[15] only. They assumed that risk perception is an indicator of shipboard safety level (and closely related to risk behaviour) as it had been previously suggested by Rundmo (1996). Shipping

[13] Titled "The impact and effectiveness of the ISM Code in the UK fleet and its influence on the development of a safety culture in the commercial shipping industry".
[14] This is interesting and might be the subject of further research.
[15] Black-listed vessels did not reply.

safety is a person-oriented issue; procedures and standards are in place to control the behaviour of seafarers. But they argued, following Frank and Osler (1998), that in the end there had been limited success because accidents involving human error were increasing. They argued that a more holistic understanding of accidents and their causes is needed, as suggested by Mac Rae (2009). Human error arises from working conditions on board, producing productivity pressure, facing poor training, and inadequate manning, as stated by Hetherington et al (2006). Previous academic research has paid limited attention to the working life and management on board. Oltedal and Wadsworth (2010) arguments may be shown below (Figure 2).

Figure 2: Perception of the on Board Safety Level.



Source: Inspired by Oltedal and Wadsworth, 2010.

We see that safety is better perceived as *team work*. However, worth noting is that this idea is not at all present in Greek shipping. The captain is, indirectly, the person on board who will enforce what is shown in Figure 2: safety orientation, proactive working practices and good reporting. The power culture/autocratic style presented below is not only the culture of the ship-owner, but also the culture of most Greek captains.

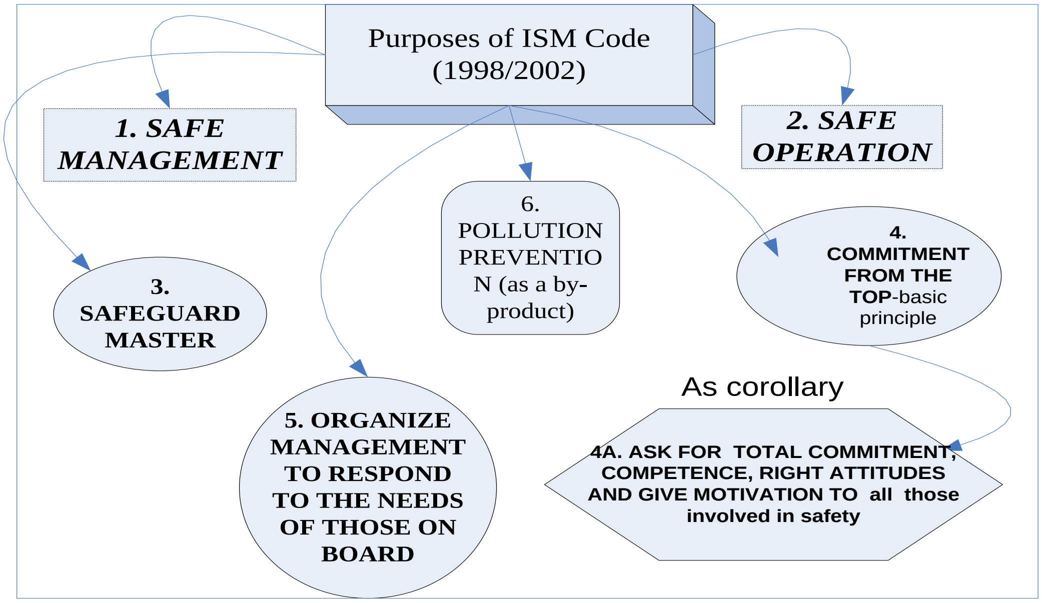
Hetherington et al. (2006) indicated that low manning levels, fatigue, stress, work pressure, poor communication, adverse environmental factors and long periods of time away from home are a crucial combination. They argued that it is widely accepted that organizations with a *strong safety culture* are more effective at preventing work-place accidents and injuries.

In summary, papers investigated the important shipping nations – Sweden, Greece, UK, Denmark, Norway, Finland and US. All stressed the importance of safety culture, and are found to be inferior vis-à-vis air traffic. Greek captains seem to embrace a non-democratic style of management. Obviously, there are two separate safety cultures, and a rupture between Greek companies and their officers. There is also disobedience. All studies suggest improvements and indicate defects of the ISM Code in failing to reduce deaths and injuries. Many studies ignored working life on board and therefore focused less on the master, which is the focus of this paper.

What Kind of "Standard" Is the ISM Code?

The purpose of ISM Code (1998/2002) – the Code – was to provide a standard for the *safe* management and operation of ships, a by-product of which is to prevent pollution. From this, we can understand that Code is intended to be a 'safety standard', combining two main functions (Figure 3).

Figure 3: The Purposes of the ISM Code 1998/2002



Source: ISM Code 1998/2002 (IMO).

As shown in Figure 3, the Code is intended to guide all shipping companies to attain a standard, which if adopted, it is expected to ensure *safe* management and operation of ships. Moreover, the Code is intended to safeguard the master in the proper discharge of his (her) responsibilities. In the past, the whole blame for an accident was placed on the captain, who stood in a principal/agent legal relationship (alter ego) (Anderson, 2005). In addition, the Code is intended to ensure the appropriate means to those on board to carry out their safety duties. In the past, reasons of cost effectiveness prevented expenditure on safety.

The Code is based on commitment on top. The Code requires top management to be committed to safety[16]. Safety is to be based on commitment from all involved, and on their competence, behavior and motivation for the desired result. This is a statement of a 'total

[16] This was natural in the past (especially in the case of the *Herald of Free Enterprise* in 1987). Officers used to point out deficiencies to top management that could have led to a marine disaster sooner or later, but they were knocking on a door of a deaf person.

management commitment to safety', *but is it also a total safety management*? For *total safety management* the following is required: (1) a plan for safety, (2) lines of responsibility, (3) recognition and assessment of dangers, (4) channels of communication, and (5) safety effectiveness (monitoring and control) (Cooper and Phillips, 1995).

The Code requires that the company "defines and documents the responsibility, authority and interrelation of all personnel, which manage, perform and verify work relating to and affecting safety and pollution prevention" (Section 3, Para 3.2). This is a requirement for clear lines of responsibility, we can say. This provision is also found in a broader version in Section 1 (Para.1.4.3), where it is stated that the company should "define levels of authority and lines of communication between, and amongst, shore and shipboard personnel". This covers channels of communication. In Section 6 (Paras. 6.6 and 6.7), it states that the company should establish procedures by which ship's personnel receive relevant information about 'safety management system' (SMS) in a working language or languages that can be understood by them[17]. Moreover (Para.6.7), the Code also states that, "the company should ensure that ship's personnel are able to communicate effectively in the execution of their duties related to the safety management system".

In addition, in Section 1 (Para.1.2.2.2) it is stated that the company should establish safeguards against all identified risks, which is "recognition *of dangers*". In Section 7, the Code requires that, "the Company establishes procedures for the preparation of plans and instructions, including check lists for key shipboard operations concerning safety of the ship and prevention of pollution". The Code's objectives and targets are based on proper reporting, documentation, company's verification, review and evaluation of SMS. On top of this, external periodic certification and verification are carried out by ship's class. So, summarizing all the above, we showed that the Code *is a total safety management system* based on linear management and organization theories prevailing in 1998, the time of its publication. It is definitely not a *total quality management standard*.

However, commitment from the top is considered to be a much weaker requirement (Goulielmos et al, 2008) than responsibility from the top, which is considered more appropriate for safety. Moreover, motivation is required by the Code. Later, the Code (Section 5) made motivation[18] the responsibility of the captain. But, the captain must first be taught motivation theory in order to accomplish this task[19].

In addition, the Code expects management to adopt the proper organization so that the Company can respond to the needs of those on board, meaning: the supply of spare parts, machinery and stores and approvals of the repairs requested. Also, training and education, and the possession of proper certificates are implied. Unfortunately, the Code does not mention anywhere the word 'culture' in general, or 'safety culture', in particular. These are defined as follows.

Culture is a pattern of basic assumptions – invented, discovered or developed –by a given group, as it learns to cope with problems of external adaptation and internal integration. This

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[17] This holds for shipping only due to the multiculturalism of crew. In practice safety manuals have to be written in language understood by PSC inspector(s)…

[18] Motivation theory simply suggests combining something that the company wants (safety) with something that the crew members want (e.g. a loan, promotion, recognition, trust)…

[19] A recent survey (2010) at www.pwc.gr showed that, in 12 shipping companies in Cyprus, Greece, Denmark and Sweden, with 39,500 seafarers and 1,320 ships,: "for seafarers having especially high performance, recognition of their efforts and pecuniary rewards are important for their permanent motivation".

(process) has worked well enough to be considered valid, and therefore to be taught to new members as the correct way to perceive, think and feel in relation to those problems. This is a modified definition attributed to Schein in 1985 and can be found in Havold (2000). This means that the captain has to teach to the new members of the crew his culture.

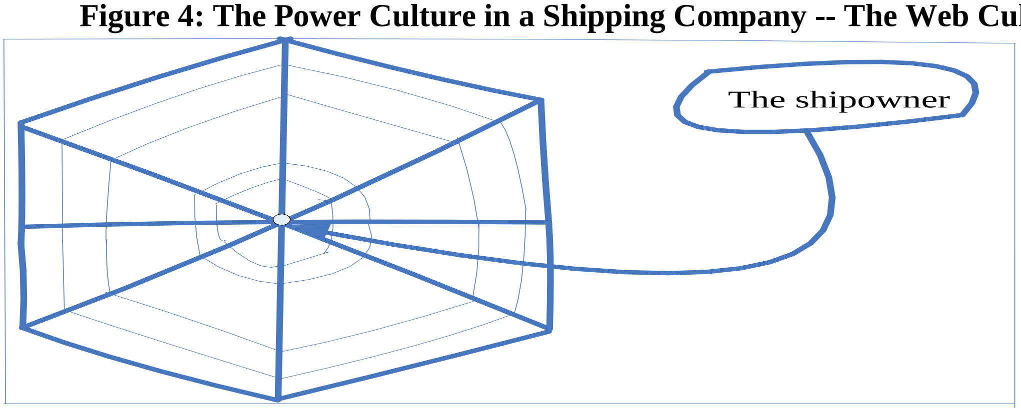
Safety culture is a series of beliefs, norms, attitudes, roles and social and technical practices, which are established to minimize the exposure of employees, managers, customers and third parties to hazard. This is a definition attributed to Dyrhaug and Holden in 1996 and can be found in Havold (2000).

Worth noting is that certain authors erroneously argued that the Code is a 'total quality management standard' (Mitroussi, 2004; Kristiansen, 2005; Lappalainen, 2008). In reality, quality in shipping is achieved if a vessel complies with her charter party, and if cargo is delivered in the condition loaded and in the time and place agreed. This is what satisfies the charterer and meets his (her) expectations[20]. The Code is not concerned with whether cargo is finally delivered intact or not, as long as the cargo does not end up in the sea (pollution), nobody is injured or dies, and no third party's property is damaged. It is obvious that Code does not care if cargo delivered is in improper condition or quantity. Moreover, the Code does not address the question of whether compliance with the Code diminishes profits or increases losses (*quality is not free* in shipping as in other industries). In addition, the Code cannot replace ISO Standards 9001 or 14000. The Code *is not* an environmental standard as well, though is related to pollution, which can be caused by crew through cargo loss, vessel loss or leaks or bunker flows into the sea. Goulielmos et al (2008) showed that the Code is a 'safety standard' focusing not only on top management of the company, but also on top management of the vessel.

The Culture Prevailing in Shipping Companies

The culture of shipping companies presented fits the Greek-style of shipping management, but we think this model to be general. This is a power structure held by shipping companies managed by an individual (personal or family companies). This culture is named after Jupiter[21], indicating that all power in the company comes from one source: the ship-owner (Figure 4).

Figure 4: The Power Culture in a Shipping Company -- The Web Culture.



Source: Unknown.

[20] It is another matter that charterers since 1998 require compliance with ISM Code.
[21] Greek mythological God -- leader of other 11 Gods, ruler of the shore, and of everything on it.

The characteristic of this business culture is the existence of a *unique* central source of power, which is the ship-owner, as mentioned – holder and provider of the required resources and finance. The diffusion of his (her) power takes the form of rays extending from him to the periphery (i.e. to departmental managers). It functions on what has been done previously (past performance and reputation), but it does not create learning experiences from past mistakes[22]. It maintains few regulations, few procedures and a low degree of bureaucracy[23]. It requires good selection of key-persons[24] (operators and managers in the departments). In this culture, processes and logic do not function. Decisions are taken broadly as a result of equilibrium between various influences. It is a strong and proud culture. The company has to establish *discipline* among employees, including the master. In contrast to this culture, management from distance produces many regulations[25] and procedures. All circulars are drafted in the head-office departments for the sake of the vessel and for those on board (mainly the captain, chief engineer, and chief steward).

The advantage of the Power culture is that decisions can be taken *quickly* and action can follow *promptly*. This is desired by Greek shipping companies, which work in a very volatile business environment. This is also required when the company faces threats or risks. Persons working in such companies have adequate personal welfare (through profit participation) and have strong motivation, provided they do not take great risks and undervalue safety. Moreover, these persons must have an orientation towards power, and possess a political mind. The availability of finance and/or power enforcement ties managers to the central web. These companies believe in people and judge by the results, while they are tolerant of the means used to achieve ends.

Master's Culture and Personality – ISM Code Requirements

Master's Culture and Personality

Greek captains also have a power culture and an autocratic style[26] of command (Theotokas and Progoulaki, 2007). Masters *do not involve* themselves in team work, as mentioned. All requests from office are addressed to the master and only technical issues are directed to chief engineer through master. Moreover, the captain fills out the evaluation forms of everybody else on board and forwards them to head office. The captain is responsible for everything on board acting on behalf and for the interest of the company; for overtime, seniority bonuses, bonuses and promotion. His personal safety culture does not necessarily coincide with

[22] In fact, mistakes in this culture cause the intervention of management/departmental managers with a circular, demanding that there should be no repetition of the same mistake; or outlining the right procedure, depending on the seriousness of the mistake.
[23] Management from distance invalidates this characteristic.
[24] The careful selection of managers and operators was typical of all great Greek shipping companies, especially in core functions: chartering, operations, manning, port captains, legal, insurance and technical.
[25] One captain received no instructions from the office, but he was told to consult ship's files laid in some 100 dossiers. For this, he needed 5-6 days, time he did not have or did not spare.
[26] Captain is a leader who tends to centralize authority, dictates work methods, makes unilateral decisions and limits crew participation below the level of the first mate (Robbins and Coulter, 2005, in another context). Our judgment is based on 14 years experience working as department manager in a shipping head office in Greece of one of the authors.

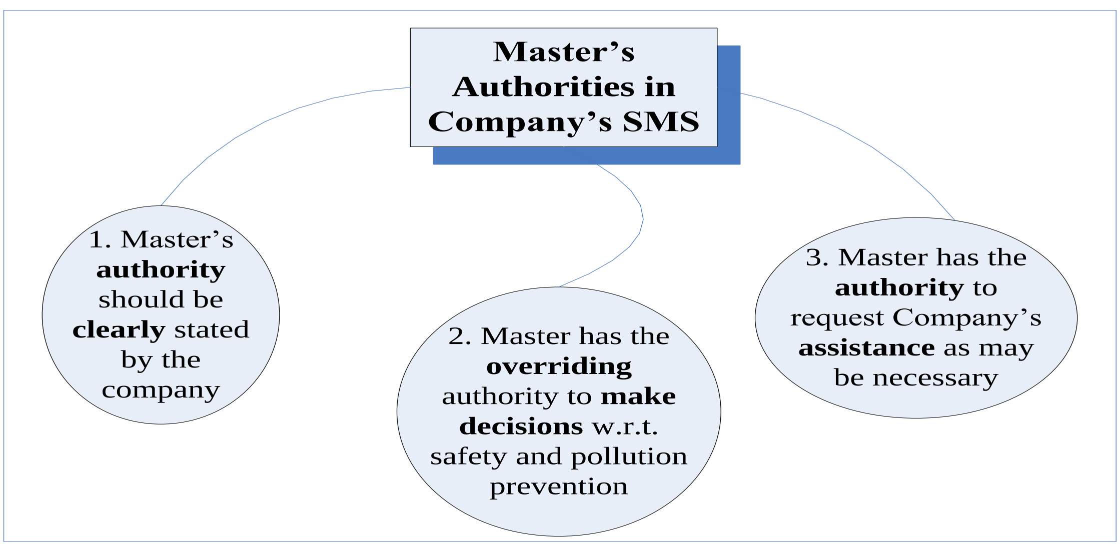
that of the company, especially in time of distress. In a recent survey (www.pwc.gr, 2010), shipping companies now want their officers to have capabilities in many areas like: administration, leadership, communication and co-operation with multicultural crews.

The master is part disciplinarian-accountant-lawyer, and part seaman/navigator. Above all, perhaps, the captain needs to command the respect of all officers and crew and to have more than a fair measure of self-confidence and ability for cool and rational judgment, sometimes at very short notice and in times of crisis. The captain also has to be a servant in law, an agent for the shipowner and to some extent for the owner of the goods; to obey the instructions of the charterer as the charter party may require, command the crew, hold a position of special trust and of a fiduciary relationship with the owners, and bear *absolute responsibility for the safety of the ship* and remain in command even in the presence of a pilot[27].

ISM Code Demands from the Captain

The Code has two provisions regarding master: one giving him authority and another giving him responsibilities, hopefully, in a good balance (Figures 5 and 6). The Code imposed, however, more duties and responsibilities upon the master (Anderson, 2005) than used to be. And after 2004, companies also gave the master additional responsibility for ISPS Code (security on board vessels and in ports).

Figure 5: Master's Authorities and the ISM Code, 1998/2002



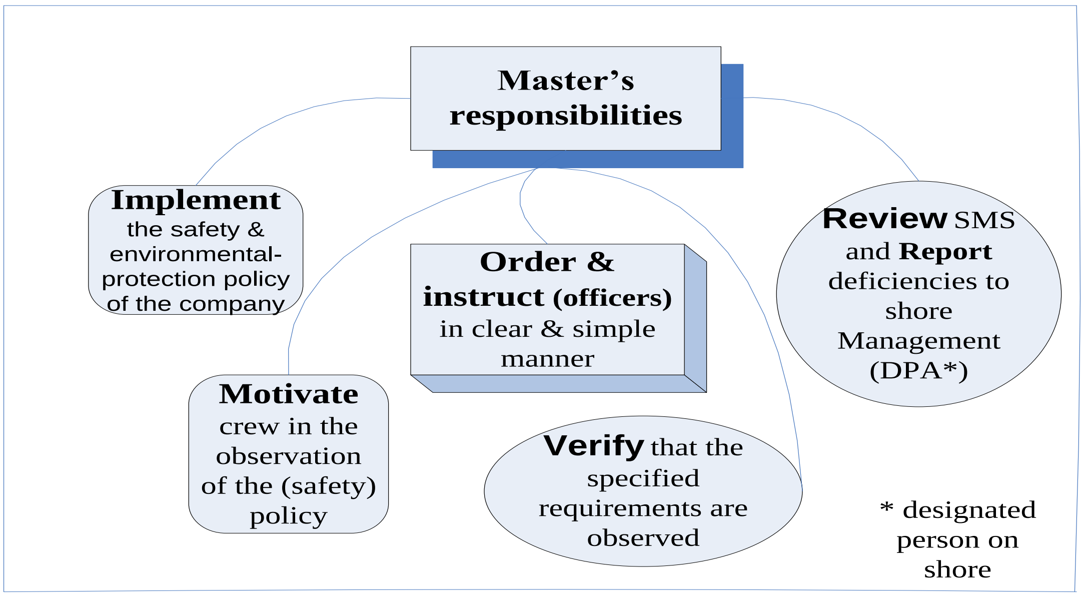
Source: ISM Code 1998/2002.

As shown in Figure 5, the Code makes the captain's culture dominant over that of the company, giving him the overriding authority to decide exclusively on safety matters and pollution prevention. So, the master's culture legally is more important in accident containment.

[27] Hill (1995) cited by Anderson (2005).

In companies' safety manuals the provisions of the Code quoted strangely are exclusively taken only from Sections 5 and 6 [28]. So, the master's authority is not clearly defined, if mentioned at all. Also, other requirements are added to this[29]. An important provision for preventing marine accidents, and for the central point of this paper, is that the master has the unique authority to act as he believes fit in emergency situations, even to go *against* instructions from office or commercial pressures. So, the master's culture counts more, though companies ignore this culture or take it for granted and do not try to shape it towards safety as they should.

Figure 6: The Responsibilities of the Master According to the ISM Code, 1998/2002



Source: ISM Code 1998/2002.

As shown in Figure 6, master must motivate[30] officers towards observing safety (leadership / motivation issue); to implement[31] the policy and review SMS and report to the office (designated person ashore or DPA); verify that the Code safety requirements are observed (i.e. create the safety policy, control it, and report about it – a planning and a control issue). It is obvious that the captain's full responsibility is the *whole safety issue*. Moreover, the captain must be clear and simple when giving instructions to subordinates (communication issue).

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[28] Especially, paragraphs 5.1-2, 5.1.5, 5.4, 5.5 and 6.1.2, 6.2, 6.3, 6.7.

[29] Companies now added the whole issue of security (ISPS Code, 2004) as a new responsibility of the master, perhaps in an effort to kill two birds with one stone (safety and security). ISPS is the by-product of 11th September, 2001.

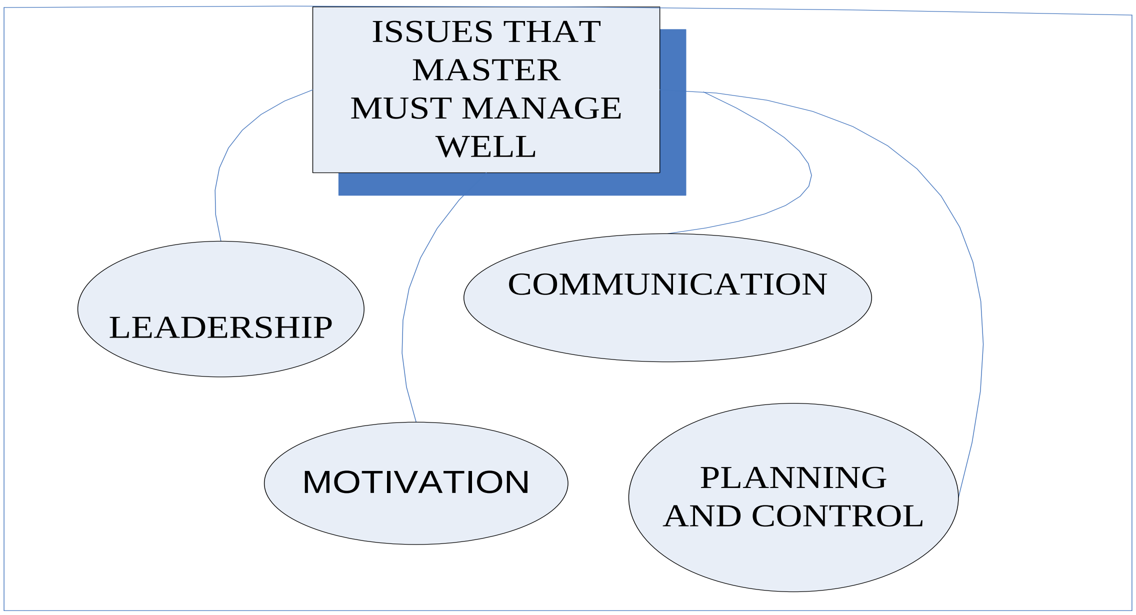
[30] IMO's Human Element Working Group at MSC 82 observed that in order to properly motivate seafarers, companies should take into account shipboard feedback (*Report ISM* 11/May/2008, p. 10).

[31] In *Report ISM*, 2008, it is mentioned that one of the biggest factors in developing a 'functioning safety management culture' is the manner in which the tasks are performed, the instructions given and the ways in which all important reporting and response mechanisms embrace and mesh with the human element. See also the participation of ITF in this issue http://www.itfglobal.org.

Linear versus Non-Linear Culture

An understanding of nonlinear culture, we believe, could help the master more when facing accidents, but we doubt whether masters are aware of linear management, let alone nonlinear management. The issues that preoccupy the master are many and important (Figure 7).

Figure 7: Safety Functions that the Master Must Perform.



Source: inspired by ISM Code.

Based on nonlinear management (Battram, 1998), culture is a complex adaptive *system*, which is both self-organizing and learning. The culture of any group of people is that set of beliefs, customs, practices and ways of thinking, which they have come to share with each other through *being and working together*. Sadly, this description is not fully applicable in a vessel, where crew-members come and go frequently (UK/MCA, 2008). Moreover, the captain's safety culture is transmitted to officers and ratings, and remains if all have survived from a marine accident as a result of the captain's culture. In this important issue, 'teaching failures' instead, as we did in the seven case-studies below, we believe is an important step forward.

A master who acts as a linear manager views issues differently than the nonlinear one. Theories of linear organizational culture suggest that entrenched attitudes are very resistant to change. In such systems, change, if it happens at all, has to be pushed through using various change agents. So, the very busy captain is likely to abandon the whole safety effort, resorting to the cliché that 'people do not change'.

Modern linear management (Battram, 1998) is based on the assumption of the rational person. The rational person is characterized by perfect knowledge and ability to obtain and retain perfect information. Also, it is assumed that, at work, people are always rational and logical, and that decisions are always about selecting the best alternative. It is assumed that the person is scientific, meaning that decisions are always logical, perfectly quantified, based on an understanding of cause and effect, and carried out without emotions or other distractions.

Human culture is conveyed through transmitters, called, in the nonlinear literature, 'memes'. These live in our memory, in our brains, and are not under our direct control. They have an inclination to want to be passed on from brain to brain. They are used (Dawkins, 1989; Battram, 1998) to explain the transmission of human culture from person to person. The elements of culture transmitted are: ideas, tunes, political slogans, policies, learning, education, training, fashions, stories, ideologies, jokes and clichés. Our decisions are sometimes based on a number of clichés, stereotypes, and statements coming from our parents, our superiors, our religion, or our wise men. *These may be wrong in a particular situation.* As a professional, the master must use a discretionary attitude in judging the various circumstances where such influences should be ignored.

The Logistics Equation as a Model to Explain Marine Accidents

It is useful before discussing actual marine accidents to show how nonlinear philosophy could help in avoiding marine accidents. Assume that the ship's present condition and weather are related through a simple linear relationship (a difference equation) – the 'logistics equation'. Assume further that Xt is the present situation of the vessel (the dependent variable) and let C be the control coefficient (i.e., weather). We assume C to denote the severity of weather taking values from 0 to 4. These values are related to beauforts; this coefficient is independent. Let Xt+1 be the future situation of the vessel after the influence of the control coefficient. We multiply Xt by (1-Xt) for the system to remain within bounds. We derive the following equation[32]: Xt+1 = C Xt (1-Xt) [1], where t stands for time (Figure 8).

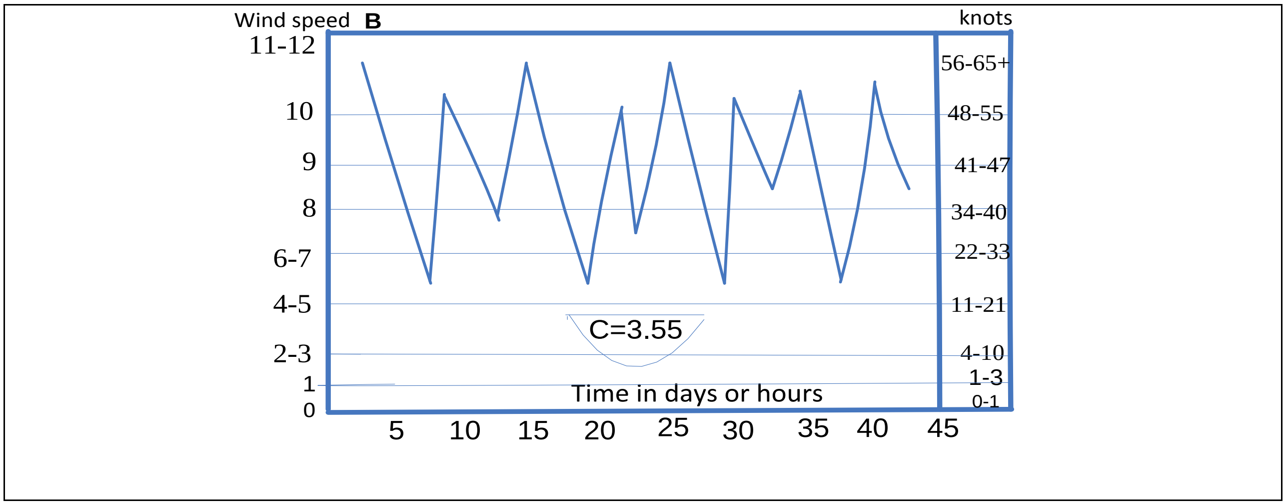
The values of C will determine the fate of the vessel. If the weather is mild and the winds 0 to 3B[33], then C will alternate between 0 and 1, and the situation eventually approaches calm weather. If the winds are 3-5B, but stable within this range, then C can take values from 1 to 1.50. These two situations are not dangerous and are characterized by a 'low degree of chaos'.

If, however, the wind blows strongly, 6-7B, C then takes values from 1.50 to 3 and the wind alternates between 6B and 7B; this in a steady manner. The wind, in this case, is within bounds and C takes a maximum value of 3. Now, if the winds blow stronger, say 8B-9B (= a gale), C then takes values from 3 to 4. This model indicates that the destiny of the vessel appears to be random and her complex behavior cannot at all be controlled by the captain. For C > 4, the whole situation is chaotic.

[32] This is the logistics equation. This has been used as a proof that even simple linear systems –under certain control coefficients like C - may lead to Chaos for C>4. This has been used to describe the growth of populations, but in 1995 was also used to model accidents in USA. See 'Chaos theory and disaster response management' downloaded 15/03/2001, by L. Douglas Kiel, University of Texas at Dallas.

[33] Beaufort's scale.

Figure 8: A Graph of the Logistics Equation: Xt+1=3.55Xt (1-Xt)



So, a marine accident is the combined result of control coefficient C = wind speed, on future condition of vessel (Xt+1). The captain in the first case study below underestimated C. With C=0-3, i.e. 0-7B, the vessel *could* carry out her voyage from Turkey to Piraeus, (as this was also suggested by office), given that her pumps could cope with incoming sea water and list contained. But at C=3.55, the vessel was lost due to listing of over 15 degrees and winds 8B-9B. The captain could have saved the vessel, and his life, if he had known that small events (cracks, plate fatigue, and weaker pump power) can cause great results (loss of vessel, of lives and of cargo) (as exactly in the case of M/V *Erika*) according to nonlinear law and the value of the control coefficient. Given that weather forecasts now are possible for one week forward, this model can be used as a forecasting tool.

> Case Study 1: Vessel *Tenia II*, [34] 855 gt, dry cargo, departed from Burgas, Bulgaria on 9th Dec. 1980. Loaded with steel rods, destined for Alexandria. Sea condition was very bad (9B). Next day, sea water entered engine room, mixed with diesel and stopped power generator. Main engine as a result reduced speed. Vessel shifted dock to be inspected. Given her condition and bad weather, shifting resulted in running aground). Sea water entered ship's bilge system and caused a list of 8-9 degrees. Ship came afloat after 3 days with the aid of a tug. The German class inspected the vessel on 05/01/1981 and found her…seaworthy. On 18/01/1981 another ship collided with *her*, and caused damage on left side, below water line. All ship's cracks/damages were water-proofed with cement. On 06/02/1981 ship departed. The weather was still bad (6-7B), and next day winds increased to over 7B. The rudder did not function properly due to an oil pump problem and ship switched to a very tough manual steering. The vessel showed a

[34] These case study descriptions come from the proceedings of the 'Greek Higher Investigation Council of Marine Accidents'. European style dating used – day, month, year.

list, reaching 17 degrees, due to fatigue from sea waves (08/02/1981). The ship foundered. Eight lost.

This accident is attributed to the captain's inability to assess the condition of the ship in relation to prevailing weather. The class also is responsible. The permission to depart, from Turkish port authorities, was also wrong. Three human errors caused one marine accident. The captain, out of his culture of pride, failed to assess risk indicated by the high control coefficient (weather).

Case Study 2: M/V *Iris*, dry cargo, classed 100A1; departed on 11th Feb. 1979 with 11,400 tons of sugar in bulk for Lisbon. Three days later winds increased to 8B-9B with 8-10 metre waves. Captain reduced speed to protect ship from fatigue and asked permission from Lisbon port to dock; permission was denied. Next, strong winds and waves destroyed a bow watertight cover used to prevent water from entering holds. Crew restored damage, but not fully. Next, ship started to list 4-5 degrees on right. Captain decided not to signal SOS, thinking of the rescue expenses, without a serious cause… The list was gradually increasing reaching 20 degrees. Captain then signalled SOS. One crew member found plenty of water in the double bottom. Attempts to correct list failed, and the list increased to 65 degrees. The ship foundered on 15/02/1979 having a list of 80-85 degrees. Seven died.

The captain was officially charged with negligence for failing to navigate ship to a refuge port. He could, of course, have navigated the ship and run her aground on a coast of Lisbon – a proposal made by the chief engineer at a too late stage. Captain should have disobeyed port's instructions and entered port. This denial, however, is not the only case, where port authorities, *in the same area*, denied it to vessels in distress. In another marine accident, the denial of the port raised a huge and vituperative discussion in EU about specifying ports of refuge beforehand.

Case Study 3: M/V *Melete*, a dry cargo vessel of 35,489 gt. She carried iron-ore and coal. Ship underwent repairs from 21/09/90 for 42 days, at Ulsan, South Korea; repairs were unfinished, because the repair yard went on strike. A charter then appeared– a common commercial pressure. The bilge system was not functioning properly. This was due to the cargo the ship used to carry, and, of course, to wear and tear. An inspection in Japan (08/04/1991) found signs of wear evident inside bow hatches on brackets and on joints; there was evidence that parts of hatches were broken, particularly in number 2 and 8. Class inspected ship on 05/05/91; ship departed on 07/06/91 for Australia, with her life-saving appliances deficient. Flag allowed ship until 30/09/91 to bring number of life-saving appliances up to the required number[35]. On her last voyage she started loading iron ore on 10/08/91 at 1524 hours at Dampier/Australia. Captain, after a visit to town, was completely preoccupied with loading and supervised loading, even during night. He was heavily preoccupied with loading. Iron ore did not load

[35] She never was able to do so as she foundered in the meantime.

> evenly[36] in the hatches, piling up in the middle, due to fixed silo loading. Moreover, many unusual sounds and vibrations heard. On 11/08/91 at 1037 hours the very fast loading finished within about 10 hours receiving a cargo of 70 000 metric tonnes. The weather was good *for the first three days*. Crew members, however, were preoccupied with measuring water level in the bilge system manually and in the bow hatches. The ship had problems with the bilge system in the past. On 15/08/91 and for 7 continuous days winds blew at 7-8B and locally at 9B (41-47 knots) (control coefficient). These fatigued the ship still further.
>
> In bow hatches water entered and pumps were unable to cope. On the afternoon of 23/08/91, Captain, after consulting office, ordered changing course for Mauritius. On morning 24/08/91 captain ordered crew to prepare lifeboats, to wear life vests and embark. The ship had a serious bow list so that sea water passed over the bow deck from one side to the other. At the last moment captain ordered SOS. The ship started to founder rapidly; an explosion took place between 2nd and 4th hatch. The ship broke in two. A second explosion took place a few minutes after, between 8th hatch and accommodation. The survived second mate told flag that a crack has been found in hatch 1, one day before foundering. This crack obliged captain to change course for nearest port, 400 miles away (2 days sailing at ship's reduced speed of 8-9 knots).

The captain's culture did not let him to arrive at clear decisions. He had only one year of experience in Class A of Captains, and only 10 years in the company; he was grateful for being appointed master in charge. In another ship, he had signalled SOS inappropriately; this damaged his reputation and made him reluctant to act in time in this last journey. The order to abandon ship was given too late, at 0730 hours in the morning, when ship foundered; side plates were taken away by waves. Statistics indicate that 81% of this kind of ship is lost soon after the 3rd four-year special survey[37].

The captain made many other mistakes. First, he was tolerant of the attitude of the company to skimp on expenses for spare parts; excessively tolerant in permitting ship to leave repair yard without completing the most essential repairs concerning the integrity of the inside spaces of hatches. He used cement to waterproof the cracks that appeared. He failed to restore ship's pumping system (bilge system, keel duct). He failed to cope effectively with the crack that appeared in hatch one. He failed to signal SOS and ask for help from near-by ships in time. He was reluctant to signal SOS in time to rescue the crew and himself because of his previous wrong decision[38]. He failed to train crew of how to abandon the ship[39]. He, the class, and the flag failed to restore the number of missing lifeboats. The class further failed because the date of completion of the third and crucial 4-year special survey was rescheduled. All of the above mistakes caused 25 deaths. Moreover, the captain underestimated the weather (control

[36] This loading was dangerous, and if bad weather was encountered, the possibility for cargo to change position was great and the capsizing of the vessel inevitable.
[37] The British used to sell their ships at 11 years of age, to avoid the fourth year survey, and these were then sold to Greeks (Goulielmos, 1974, unpublished PhD thesis).
[38] Master in the above case study obviously needed help from a psychologist to free him from past persistent ideas.
[39] Two crew members rescued did not use the lifeboats, but fell in the sea.

coefficient) and did not anticipate its deterioration, and he did not change course while good weather prevailed to reach a nearby refuge port.[40]

As Reason (1997) argued the safety culture of vessel is the product of captain, of other officers and ratings[41], and of company. It is a *joint culture* composed of values, attitudes, competencies, and patterns of behaviour; they determine the commitment to, and the style, and proficiency of, a ship's safety programs. Vessels with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventive measures.

> Case Study 4: M/V *Pelhunter*, carried 367 containers. The ship was well manned and maintained. PSC found no deficiencies on 07/03/95, except one non-functioning EPIRB, which later functioned. Vessel loaded 237 TEUS with ceramic plates on 09/03/95 in Castellon (Spain) and departed for Salonika. Stability was intact. Weather was bad from the start with winds of 7-8B. Next two days there were winds of 6-7B and on third 7-8B. The ship so reduced speed to 6-7 knots. On 13/03/95 winds increased to 8B. The ship showed 2-3 degrees right list. The list was felt by both second engineer and captain. They tried to pump out water from the bilge system, but there was no water there. Listing increased to 5-6 degrees. Hatches were inspected by 2 crew members, but no water was found there either. This really was a mystery. List increased to 15 degrees, but on left side this time. The waves were high and passed over the bow and containers stacked. Captain felt that the ship was heavier by bow and *decided to turn* the ship 180 degrees to relieve her right bow side. The turn reduced ship's stability. Water covered main deck and Captain signalled SOS and asked second mate to signal MAYDAY. Captain then ordered crew to abandon ship and to board on boats and life rafts. The ship listed 20 degrees. The SOS was broadcast at 1033 hrs on 13/03/95 from the reactivated EPIRB. 12 died. The weather was bad on 13/03/95 with 12-14 metre waves in the morning and winds of 45-55 knots. Later waves were 14-17 metres high and winds 55-65 knots, or 11B-12B.

The captain was blamed for the accident. He failed to navigate the ship to a safe anchorage, before signalling MAYDAY, given that weather information indicated *a further deterioration*. He failed to realize that water[42] was coming in from the anchor chain holes.[43] The turn of the ship he decided hastened foundering. He failed to reduce speed to half, and as a result ship suffered fully the fatigue from winds and waves. MAYDAY message (at 1030 hours) was late, and delayed the subsequent search and rescue. Increasing and alternating listings, from 5

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[40] Assuming that the ship could have maintained a speed of 14 knots with winds at her back, she could reach Mauritius in less than 2 days. This assumption is valid if the crack did not become wider and pumps could cope with incoming water.

[41] Ship's boatswain was foreigner and inexperienced and used to give false reports of the depth of bilge water to the first mate. For managers *control* is imperative in shipping. In addition, the relevant measuring system of bilge water was out of order…

[42] Though a definite explanation of the possible way for water to enter bow space was not found, all deck holes can be blamed. There were, however, only three possible causes. Air vents and man holes may also have contributed and perhaps the firmness of boxes should also been checked (for dislocation).

[43] Older seamen used to block these openings with cement in the case of a gale. The master did not comprehend the reasons for this past wisdom.

degrees right to 13 degrees left, were not understood by captain. The captain failed to make a personal inspection to find the cause of incoming water, after crew members reported that hatches and bilge system had no water[44].

Master and Safety on Board: Lessons from Additional Case Studies of Marine Accidents

> Case-study 5: Dry cargo vessel *Athen Sky*, 7719 gt, departed loaded on 17th March 1979 for Basra. When she was in the Gubal channel in the Red Sea, (North of Suez), a vessel was shown navigating towards vessel's right side. Captain judged to be on a collision course and commanded a change in ship's course to right; as a result…the ship ran aground on the nearby coral reefs. The vessel listed three degrees left. The captain signalled SOS and MAYDAY and went through all required distress actions; but this was …not a distress situation. Twelve crew members demanded to sign off. The captain, unable to resist to their pressure, allowed them to depart while he needed them. He explained that he did so to avoid creating panic among the rest of the crew. The vessel refloated with the aid of a tug and ship's engine, on 24th March 1979, and departed for Suez.

The captain obviously failed to act as a *leader*. Also, he made an erroneous decision to change course; he did not reduce ship's speed in going right, as he should. The crew apparently did not believe in the captain's ability to navigate. This last characteristic, however, is required for a safety culture to pass on to crew. When the captain's actions prove to be right, it *creates* a culture, as the definition of a safety culture requires.

> Case Study 6: Car passenger ferry boat *Estonia*, foundered with 852 dead on 28th Sept. 1994. She departed on 27th Sept. 1994 on 1915 hours from Tallinn for Stockholm; she encountered winds of 15-20 meters per second and waves of 3-4 meters. At about one hour after midnight, a crew member heard a strong metallic sound coming from bow; he informed captain. At 0105 hours many passengers and crew members heard unfamiliar sounds for at least 10 minutes. At 0115 hours the ramp used for entry into the car deck, was destroyed by waves and water entered violently. By 0125 hours the ship had a list of 30-40 degrees; master signalled SOS. At 0150 hours ship disappeared from all radar screens. Ship's wreck found on 30th Sept. 1994 without ramp or visor.

The cause of the accident was the faulty technical construction of the visor and the grave underestimation of the strength of the materials used. The joints between the visor and the vessel were broken. The loss of the visor, due to weather condition (4 metre waves), and the defective materials, caused the loss of the ramp as well. Moreover, the visor's construction was not in accordance with SOLAS convention. The captain was blamed for inertia, as he started to react only when list reached 30 degrees and the car deck was full of water. By so doing, he missed the opportunity to slow down the foundering of the ship and speed up rescue operations. The captain was not also aware of another similar accident that occurred on ship *Diana II* in 1993, where her

[44] Certainly, hatches and bilge system are the most likely suspects.

visor had been destroyed too. Crew saved *Diana II,* however, by reacting properly. The *Estonia*'s master did not learn from the reactions of another captain/crew under similar circumstances.

> Case Study 7: M/V *Lena*, a dry cargo vessel of 8,739 tons left Glasgow in ballast for Rouen/France on 08/06/79. The weather initially was good; thick fog was expected. Visibility dropped to zero next day. Captain, was called to vessel's bridge when thick fog first appeared; he took all the anti-collision measures[45]…apart from reducing speed. Captain was preoccupied with reaching Rouen as soon as possible to satisfy office instructions: "urgent arrival at Rouen, immediate loading and departure". The fog cleared suddenly and Captain put ship on automatic pilot. The second mate was then on the bridge as watch officer. Captain erroneously retired to his office to prepare pays, lists, provisions request lists, bills of lading, etc. From time to time he visited bridge as he did not trust the second mate; he said: "if you see a ship, let me know at once". The second mate indeed saw a boat 8-9 miles away and with his binoculars confirmed that it was a fishing boat (French vessel *Antiochia*). The vessel, however, was heading towards the boat, which had failed to raise the proper flags indicating fishing and/or having low speed for the same reason. The second mate did not inform captain as instructed, underestimating danger. He informed only the first mate who took over the watch from him, but this happened too late. The vessel was fast approaching the boat, which was only 2½-3 miles away. Suddenly very thick fog re-appeared. The first mate informed captain. The radar did not show anything. The captain took over manual steering, but maintained full speed. The ship did not alter course and ship's siren did not sound. The fishing boat's siren, however, sounded, but only when it was too late. The collision killed four sailors.

The above accident – under a commercial pressure – also raises the communication issue (Goulielmos and Goulielmos, 2005). The talk between captain and second mate was of a paternalistic, top-down model of communication, which fails to convey the messiness and difficulty of human communication. In this inadequate model, the speaker behaves like a parent, even though the model is totally dependent on the other person listening. The second mate ignored the captain's instructions, and only informed the first mate at last moment. The second mate ignored the captain's instructions to redress the low esteem that captain had for him. Small mistakes, however, produce large results.

As we suggested in the case of marine accident F/B *Samina Express* (Goulielmos et al, 2009), open access communications on board, like those used by Xerox Corporation, can prevent such problems. The Xerox Corporation uses receiver-based communication (RBC) to improve continuously the work of its repair teams. Each worker has a walkie-talkie, which is carrying messages all the time.

If the captain had heard from the second mate that a boat was shown in 8-9 miles away, then he would have rushed to bridge in time and four lives could have been saved. Many accidents occur when the master is not on the bridge, against regulations, in time of difficult and dangerous navigation (e.g. *Exxon Valdez*, *Samina Express and Titanic*). Open communications could help cope with this problem.

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[45] Siren sounded from time to time and radar was consulted all the time.

Conclusions

The paper presented the culture of seven important shipping nations (Sweden, Greece, UK, Denmark, Norway, Finland and US). All nations stressed the importance of *safety culture*, though it was found to be inferior to that prevailing in air transport. Seventy-three percent of Greek captains seem to like a non-democratic style of management. Obviously, there are two separate cultures in general and safety cultures in particular between a Greek company and its officers. All studies suggested improvements and indicated defects of ISM Code. People are removed from the ISM Code. Also, the studies reviewed did not focus on *culture on board*, or on the influence of master due to problems of knowing what happens on board and in spite of his crucial role outlined here.

We showed that ISM Code deals only indirectly with quality, even though many authors describe the Code as a 'total quality standard'. The requirements of Code were described, indicating what is expected of the company, of the master, and of the crew. Also, the Code's weak points are commitment from top and watching PSC inspectors to generate their own safety culture.

We have indicated that the culture that prevails in shipping companies (Greek management style) is the *power culture*, where power is held and transmitted by the ship owner. In addition, the captain's culture is autocratic. Though the Code makes specific demands on the master, companies have also assigned security issue on to him. The Code requires the master to motivate, lead and employ linear management, though he knows nothing about and he has never been taught them. Marine accidents, as shown in this paper, occur in a nonlinear environment, where a small factor (e.g. a crack) can produce a disproportionate result (ship's loss).

Marine accidents are caused by the use of linear communications in a paternalistic style, which is ineffective. We proposed open access communications. Moreover, marine accidents occur because masters underestimate the power of weather and the fatigue caused on to the ship. The weather, as shown, is a control coefficient in the 'logistics equation' model and may be forecast for a week at least. The ship's condition, even new and well-maintained, may not be sufficient when winds blow at 9B or higher.

In seven case-studies of marine accidents, the master's culture and attitude were presented, drawing from the archives of official investigations of marine accidents (except *Estonia*). These seven accidents produced 908 deaths between 1979 and 1995. We believe that the situation could be improved by introducing nonlinear philosophy.

The ISM Code assigned the overriding authority to the master in cases of distress, and made the master's culture and attitudes of paramount importance for marine accidents. The master is left without proper education and preparation for these responsibilities, ignoring his culture or taking it for granted as coinciding with that of company, who moreover now has been burdened with the additional security duties. These, we believe, are not the proper ways to eliminate marine accidents.

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