Accident Analysis and Prevention 59 (2013) 26–37

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Human and organisational factors in maritime accidents: Analysis of collisions at sea using the HFACS

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ARTICLE INFO

Article history:
Received 19 June 2012
Received in revised form 19 April 2013
Accepted 10 May 2013

Keywords:
Accident investigation
Human error
Maritime accidents
Collisions at sea
Human Factors Analysis and Classification System (HFACS)

ABSTRACT

Over the last decade, the shipping industry has implemented a number of measures aimed at improving its safety level (such as new regulations or new forms of team training). Despite this evolution, shipping accidents, and particularly collisions, remain a major concern. This paper presents a modified version of the Human Factors Analysis and Classification System, which has been adapted to the maritime context and used to analyse human and organisational factors in collisions reported by the Marine Accident and Investigation Branch (UK) and the Transportation Safety Board (Canada).

The analysis shows that most collisions are due to decision errors. At the precondition level, it highlights the importance of the following factors: poor visibility and misuse of instruments (environmental factors), loss of situation awareness or deficit of attention (conditions of operators), deficits in inter-ship communications or Bridge Resource Management (personnel factors). At the leadership level, the analysis reveals the frequent planning of inappropriate operations and non-compliance with the Safety Management System (SMS). The Multiple Accident Analysis provides an important finding concerning three classes of accidents. Inter-ship communications problems and Bridge Resource Management deficiencies are closely linked to collisions occurring in restricted waters and involving pilot-carrying vessels. Another class of collisions is associated with situations of poor visibility, in open sea, and shows deficiencies at every level of the socio-technical system (technical environment, condition of operators, leadership level, and organisational level). The third class is characterised by non-compliance with the SMS.

This study shows the importance of Bridge Resource Management for situations of navigation with a pilot on board in restricted waters. It also points out the necessity to investigate, for situations of navigation in open sea, the masters' decisions in critical conditions as well as the causes of non-compliance with SMS.

1. Introduction

Around 90% of world trading is carried out by the shipping industry. Shipping is considered as a safe, economical, and environmentally benign form of commercial transport. Although increasing mediatisation draws public attention to accidents, the statistics show a slow but steady decline in maritime accidents over the past 10 years (Allianz Global Corporate & Speciality, 2013). This decade follows the general shipping safety improvement trend that took place over the 20th century. Records showed a rate of loss of 1% a year in 1910; this rate has improved to the figure of about one ship in every 670 in 2010 (Allianz Global Corporate and Speciality, 2012).

Shipping is also a highly regulated domain, and regulations have been reinforced in the last two decades. The main principles underlying shipping regulations are harmonized national rules based on international conventions and resolutions given by the International Maritime Organisation (IMO) (Kristiansen, 2008).

Among those regulations, the SOLAS[1] convention is seen as the most important of all international treaties concerning the safety of merchant ships. Its main objective is to specify minimum standards for the construction, equipment, and operation of ships. It is divided into 12 chapters. In response to the capsizing of the ferry Herald of Free Enterprise in March 1987, IMO adopted in 1993 the

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[1] SOLAS: International Convention for the Safety of Life at Sea, 1974, as amended.

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http://dx.doi.org/10.1016/j.aap.2013.05.006

International Safety Management (ISM) code through its resolution A.741 (18). The ISM code was added in 1994 as chapter IX of SOLAS, "*Management of the Safe Operation of Ships*". This chapter requires a Safety Management System to be established by the shipowner or any person in charge of a ship. According to Kristiansen (2008), this requirement represents a dramatic departure in regulatory thinking on the part of the IMO since it acknowledges that detailed prescriptive rules for design and manning have serious limitations and stimulates safety consciousness, both ashore and on board. With the ISM code, the shipping industry is slowly moving from an idea of safety as front line operator training and the use of check-lists to an industrial safety culture involving everybody in the trade, from the AB seaman[2] to the general manager of the company. The ISM code became mandatory for passenger and dangerous cargo ships in 1998, then for the rest of the fleet in 2002.

At the same time, the IMO's international convention on Standards of Training, Certification and Watchkeeping (STCW) for seafarers, in its 1995 revised version, adds in section B-VIII/2 recommendations on proper "Bridge Resource Management", that is to say, the correct allocation and use of all resources available on the bridge. The Manila amendments[3] to the STCW code, which came into force on January 1st, 2012, go a step further towards mastering the human factor by bringing Bridge Resource Management into the mandatory A section of the code, as well as a new Engine-room Resource Management competency. It also explicitly asks for leadership and teamwork skills both at the operational and at the management level.

This paper presents an analysis of maritime accidents that are posterior to 1998, i.e., posterior to the ISM code and the STCW95 advent. It deals with collisions at sea and uses a systemic approach to analyse the role of human and organisational factors in these recent events. Whereas collisions are the main cause of only 12% of total losses (Allianz Global Corporate and Speciality, 2012), they appear to be one of the three primary causes of "serious casualties" (Graham, 2012). Moreover, they account for some 50% of the total risk in busy waterways (Min Mou et al., 2010). Thus, collision and grounding represent 71% of accidents in European waters; it was reported in 2010 that the largest number of vessels involved in accidents (45%) were involved in collisions and contacts with infrastructure (EMSA, 2011).

Several studies have pointed out the role of human and organisational factors in maritime safety (Chauvin, 2011; Hetherington et al., 2006; Schröder-Hinrichs, 2010). The role of those factors is a central issue in collisions. In fact, "collisions should theoretically be avoided if every vessel abided by the International Rules for the Prevention of Collisions at Sea 1972, which came into force in 1977" (MAIB, 2004, p. 15). Studies dealing with collisions pointed out the role of the following factors: "poor lookout", "poor use of radar", "improper manning", "the poor employment of ratings on the bridge", "lack of competency", "communication or teamwork on the bridge", or "inter-ship communications". These studies yielded interesting findings, but they often put emphasis on some of these factors and did not provide a systemic approach of those accidents. Furthermore, they concerned events that were anterior to or occurred just after the introduction of the ISM code and the STCW95.

A MAIB report (MAIB, 2004), based on the analysis of 33 collisions involving 41 vessels during the period 1994–2003, showed that the most common contributory factors were poor lookout (for 65% of the vessels) and poor use of radar (73%). On 19% of the vessels involved in collisions, Officers Of the Watch (OOWs) were completely unaware of the other vessel until the collision, or in some cases even after the collision. In a further 24% of collisions, officers became aware of the other vessel's proximity only when it was too late for any avoiding action to be successful. Poor lookout itself might be linked to an improper manning, the poor employment of ratings on the bridge, or to incompetence. This study did not include vessels under pilotage.

In contrast, a TSB report (TSB, 1995) dealt with 273 occurrences involving vessels under the conduct of a pilot in Canadian pilotage waters between February 1981 and May 1992. Among these occurrences, there were 43 collisions with another vessel underway. The report pointed out that breakdowns in communication or teamwork on the bridge appeared to be implicated in many of these marine occurrences.

Several studies have investigated coordination and communication between vessels. The detailed analysis of several collision cases led Perrow (1999) to point out that difficulties of coordination (between two or more vessels or between members of the same crew) are the main causes of accidents. Perrow called these accidents "disconcerting" as the officers on board both vessels had perceived the risk of collision, and, in some of the cases, they had even communicated and agreed upon the manoeuvre needed. After analysing 59 collisions between merchant vessels, Pourzanjani (2001) observed a frequent lack of communication of manoeuvring intentions. Pourzanjani noted that 46% of the officers involved had not clearly indicated their intention to manoeuvre and that 23% of the officers had not detected or correctly interpreted the signal although it had been correctly given. One potential cause of these failures could be that different systems of rules exist: formal rules (collision regulations) on the one hand and informal rules shared between certain types of vessels and specific to certain zones of navigation on the other hand (Chauvin and Lardjane, 2008). In situations of interaction between people who do not know each other, the co-existence of formal and informal rules is, more often than not, a source of difficulties, uncertainty, and misunderstanding; the co-existence of two systems of different rules can, in fact, be the origin of accidents when two players or two groups of players interact while each referring to a different system.

This paper presents a systemic and multifactorial analysis of collision at sea, aimed at identifying different types of accidents, i.e., accidents characterised by different patterns of human and organisational factors. The analysis relies on a tool based upon Reason's model: the Human Factor Analysis and Classification System (HFACS). This tool is used to classify and analyse factors that are mentioned in accidents reports for 39 vessels involved in 27 collisions that occurred between 1998 and 2012. One objective of the study is to compare the causes of these recent accidents with accident causes identified in previous studies.

2. Theoretical framework

2.1. The need to choose a relevant accident model

Since the end of the 1990s, it has been acknowledged that accident analysis must rely on systemic and organisational models (Rasmussen, 1997; Reason, 1997) that are adapted to the context of the study, even if they still represent a simplified view of reality. Simple linear accident models (e.g., cause-effect models) can be used in specific contexts but remain limited when the structure of the socio-technical systems is complex. Complex linear accident models such as the "Swiss cheese" model (Reason, 1997) and systemic non-linear models such as FRAM (Hollnagel, 2004) have the

[2] Able-Bodied Seaman ("AB or ABS") is a qualified and trained merchant seaman who is certified so by a training authority.

[3] Final Act of the Conference of Parties to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, Manila, The Philippines, 21–25 June 2010.