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Towards the assessment of potential impact of unmanned vessels on maritime transportation safety

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ABSTRACT

The prototypes of unmanned merchant vessels are expected to come into service within the coming years. The main line of argument supporting their introduction pertains to the increase in navigational safety, which is expected to be achieved by reducing the frequency of human-related accidents on board ships, by removing the crews. On the other hand, the response of unmanned ship to potential accidents is still uncertain. With enthusiasm on one side and apprehension on the other, the literature lacks an objective study on the effect of unmanned ships on safety of maritime transportation.

This paper constitutes an attempt to bridge the aforementioned gap by applying a framework based on what-if analysis to a hundred maritime accident reports. The aim of the analysis is to assess whether the accident would have happened if the ship had been unmanned, and once the accident had happened - would its consequences have been different.

The results obtained reveal that the occurrence of navigational accidents (e.g. collision, grounding) can be expected to decrease with the development of unmanned ship. However the extent of consequences resulting particularly from non-navigational accidents (e.g. fire, ship loss due to structural failure) can be expected to be much larger for the unmanned ships when compared to the conventional ones.

1. Introduction

The concept of unmanned surface vehicle (USV) is not new. While its first demonstration was performed by Nikola Tesla in 1898 [1], the last decade of the 20th century has seen a large number of projects emerge. The vast majority of existing solutions pertain to the law-enforcement and naval units with displacement of up to 10 t [2], although some mine-sweepers can reach up to 100 t [3]. Due to technology advancements in recent years and experience gained in the operation of small- and medium-sized USVs, the aspiration appeared to develop an unmanned merchant vessel able to haul her cargo across the oceans. It is believed that the first unmanned ships will become operational within the next 10–15 years [4,5]. However, it must be ensured that those masterpieces of technology would indeed increase maritime safety or at least would not reduce it [6,7].

At present, there are several R & D projects aiming at the development of a proof of autonomous merchant vessels' concept [1,8–11]. Therein a hypothetical autonomous ship takes advantage of her ability of being operated in one of the three modes, as follows: fully manned, remote controlled or fully autonomous. The latter corresponds to autonomy level 5 (AL5) according to Lloyd's Register scale, defined as follows: '*Unsupervised or rarely supervised operation where decisions are made and actioned by the system, i.e. impact is at the total ship level*' [12]. She would traverse high seas autonomously with possibility of switching to remote control via satellite communication link in case the systems are unable to perform correctly in given circumstances or whenever a shore-based operator considers it necessary. Furthermore, a full complement of crew would embark prior to reaching the port of destination in order to perform mooring or any other demanding operations in a safe and efficient manner.

In the course of quantitative safety assessment of the unmanned bulk carrier concept carried out within MUNIN project [6,10] the authors claim that the unmanned ship can be expected to be safer than the conventional units despite acknowledging that they lack vital information pertaining to her design and operation [11]. Moreover, the majority of the hazards anticipated within that study are human-related and the effect of human absence on the development of the accident's aftermath does not appear to be properly accounted for. For

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instance, redundancy is claimed to be a primary means of reducing accident's consequences which can prove unfeasible in some cases like fire incidents where, as we conclude from our analysis, it would be extremely difficult to design a technical system capable of preventing or handling all the potential fire scenarios.

Furthermore, insurance companies are rather sceptical about the idea of unmanned ships. It is believed that it will take decades rather than years for the concept to become operational and legally acceptable, however it could offer an economically feasible alternative for short sea shipping, in a form of a convoy formation with manned vessels escorting and tracking the unmanned ships, [13].

From the scarce body of literature in the field of unmanned shipping it is evident that one of major issues related to the unmanned ship operations is their safety. The main line of argument supporting their introduction pertains to the increase in navigational safety. This is expected to be achieved by reducing the frequency of human-related accidents on board ships, simply by removing the crews. However, the crew will not be in fact completely removed but rather relocated to a remote command centre. This may create hazards that are yet to be identified. Furthermore, the response of unmanned ship to potential accidents is still uncertain. With enthusiasm on one side and apprehension on the other, the literature lacks scientific study on the effect of unmanned ships on the safety of maritime transportation.

To bridge this gap, or at least to reduce it, we made an attempt of applying a safety assessment framework based on what-if analysis over a hundred of maritime accident reports. The aim of the analysis was to assess whether the accident would have happened if the ship had been unmanned, and once it had - would its consequences have been different if there were no one on board to counteract them.

The assessment is based on the use of subjective two-step what-if analysis supported by Human Factors Analysis and Classification System for Marine Accidents (HFACS-MA) method and simple consequences check. Within such framework the available accident reports are studied with respect to the cause of an accident and its consequences. The first step was to assess whether the accidents were more (or less) likely to happen if the ship in question was unmanned (the question about the accident's likelihood). In the next step, given the accident did in fact occur, would the consequences be different (the question about the impact severity). To answer these two questions a qualitative scale is used as follows: 1) no influence, 2) occurrence or impact greater, 3) occurrence or impact lesser.

The obtained results show that if the unmanned ships are put into operation as per autonomy level 5, we may expect lower occurrence of typical, human-related maritime accidents, however there is no premise to expect the consequences of potential accident to be lower than observed nowadays. The assessment does not account for hazards that were not experienced in the shipping industry in the past, like cyber-piracy or terrorism [14]. If those appear, they may lead to devastating consequences significantly affecting the safety of navigation of unmanned ships and public perception of them.

The remainder of this paper is structured as follows: first materials and methods used in the assessment are introduced. Subsequently we present and discuss the obtained results as well as additional observations based on the analysis. Finally the conclusions are drawn and recommendations for future studies are given.

2. Materials and methods

This section elaborates on the available data used for the assessment of the potential unmanned ships' impact on the safety of navigation. Also, methods applied are introduced here. Finally, the section demonstrates the application of the method on a selected accident report as a case study.

2.1. Accident reports

Due to ongoing discussion regarding the manner in which the unmanned vessels would actually be operated [15,16], we assume that unmanned ships will operate in autonomous mode during ocean passage until a certain point before a port approach where the shore operator will take over. 'Conn to operator' point can vary for different ports or voyages depending on expected traffic, complexity of environmental conditions etc. but it may be expected that ships' managers would like to operate them in autonomous mode as long as possible in order to exploit full advantage of autonomy and not involve additional costs. In order to accommodate this uncertainty, we assume that the ship in question would operate autonomously until the point in which the Master took conn in a real event. It is also acknowledged that future unmanned ships might be forced to stay at the anchorage due to, for example, berthing crew's embarkation inability in severe weather.

In the study presented here, we analysed 100 maritime accidents involving 119 vessels based on publicly available investigation reports. Based on anticipated operational practice of unmanned ships, we selected only the accidents that occurred during those parts of voyage that are most likely to become unmanned in the future. The accidents that occurred in the other parts of the voyage (e.g. harbour navigation) are considered irrelevant for this study unless no connection between voyage phase and accident circumstances could be identified. The breakdown of accidents' number by voyage phase in which it occurred and special conditions prevailing is given in Table 1.

The accidents reports were retrieved from the following organizations: Australia Transport Safety Bureau [17], Accident Investigation Board of Norway [18], Danish Maritime Authority [19], European Maritime Safety Agency [20], Isle of Man Ship Registry [21], Japan Transport Safety Bureau [22], Marine Accident Investigation Branch in UK [23], The Federal Bureau for Maritime Casualty Investigation in Germany [24], The Bahamas Maritime Authority [25], The Government of Hong Kong Special Administrative Region [26], Transport Safety Board of Canada [27]. The list of the accidents analysed and sources of data is given in the Table A1.

In the course of the analysed accidents, 63 lives have been lost and 28 people have been injured. The numbers include rescuers wounded or perished while assisting endangered seafarers. Three cases resulted in serious environmental damage. Types of vessels involved in the accidents are presented in Fig. 1. We have included cargo ships' accidents in our analysis as a majority and other ships' types (Ro-Ro

Table 1
The breakdown of accidents' number by voyage phase in which they occurred.

Type of accident	Pilot station to berth	Coastal navigation	Ocean navigation	Anchorage	Restricted visibility	Wind Beaufort 5°+
Grounding	-	32	-	1	2	7
Fire, explosion	3	9	11	1	-	2
Collision	-	16	3	-	9	4
Flooding	-	7	2	-	-	5
Loss of stability	1	2	3	2	-	5
Damage to cargo	-	2	2	-	-	3
Loss of structural integrity	-	1	1	-	-	1
Loss of buoyancy	-	1	-	-	-	-