Uncrewed Ships and the Future of Passenger Transport

1 Introduction

There will come a time, in the near future, when a ship no longer requires the master and crew on the bridge. Recent developments show this potential: unmanned aerial vehicles, driverless cars, underwater and surface vehicles at sea. One of the greatest challenges for law and engineering in the maritime sector would be to create an uncrewed passenger ship.

The term 'uncrewed' is preferred by the writer, instead of 'unmanned', for passenger ships in order to make a distinction from the other unmanned ships. The distinction could also be useful as an unmanned ship could happen to have someone (non-crew member) on-board, but it is not a passenger ship. Although some literature treats 'unmanned' as the preferred term, this writer considers the 'uncrewed' as providing additional clarity for passenger ships, as it refers to crew members rather than to having any man (or woman) on-board.

All of the technological developments mentioned above involve more complex systems in the absence of a crew on-board, and different types of control depending on the task to be completed, ranging from remote-controlled (navigated and manoeuvred from shore or another ship) to fully autonomous. It is widely recognised that the technology exists to create unmanned ships, so they will be on the oceans soon (Sampson 2014). However, this technology needs to be adapted to the specific risks and regulations of shipping. Initially at least, it is expected that unmanned ships will be controlled remotely. In time, autonomous systems for ships will develop and they may be used alongside remote-control systems. Given the risks to property, people, and the environment, it is likely that ships will never become fully autonomous.

Although the additional risks posed by passenger transportation mean that there is currently a reluctance to state that passenger ships will become uncrewed, this writer argues that in time they will be uncrewed (Maritime Unmanned Navigation through Intelligence in Networks 2015b). This will depend on other forms of shipping (e.g. dry cargo) becoming unmanned first and proving the ability to operate without a crew, which other projects are trying to develop (although, as will be discussed later, testing on ferries could instead be a developmental stage for unmanned cargo ships (Advanced Autonomous Waterborne Applications 2016)). It will also depend on evidence gathered from other forms of transportation.

Unmanned metro systems are an important example due to the high number of passengers. The fact that people use these metro systems as they would a manned metro system is a strong indication of the ability of passengers to trust unmanned systems. Although being transported at sea does pose additional risks (e.g. isolation, waves, and extreme weather), unmanned metro systems do prove that it is possible to transport passengers without staff being there physically.

In addition, driverless cars are an interesting development due to the fact that people will be on-board, but they are not typically considered as passengers. However, it is possible that as the technology develops that they would be considered more akin to passengers. Also, as long as there is more than one person in the car there will be a passenger.

Through the development of remote-control and autonomous systems on other ships, and other forms of transportation, it becomes a matter of time before there are uncrewed passenger ships. Therefore, it is necessary to explore this issue now and not simply dismiss it as too removed.

2 Previous research, and the law

It is now necessary to consider existing research into unmanned ships specifically. There have been two main projects into unmanned ships: MUNIN (Maritime Unmanned Navigation through Intelligence in Networks), and the AAWA Initiative (Advanced Autonomous Waterborne Applications Initiative). Both of these consider the legal aspects of unmanned ships, as well as the associated engineering challenges.

2.1 The MUNIN Project

The MUNIN project was commissioned before the AAWA Initiative, and thus provides the first substantial findings on unmanned ships. MUNIN focused on the deep sea shipping of dry cargo through the use of slow steaming and unmanned ships. The combination of slow steaming (sailing at a reduced speed) and unmanned ships could make shipping more economical. By removing the crew and the crew facilities, coupled with slow steaming there is a considerable fuel saving, which means that transportation by sea can be made more environmentally friendly (Rødseth & Tjora 2014).

MUNIN did give consideration to the possibility of unmanned ships (including passenger ships) on a short sea shipping basis. However, this was considered unlikely in the authors' opinions. Passenger ships were specifically rejected due to the additional risks of personal injury and death to passengers (Maritime Unmanned Navigation through Intelligence in Networks 2015a).

As in the MUNIN project, this paper focuses on passenger ships for short sea shipping. Deep sea shipping would not be akin to passenger ship experiences of simple transportation, as most cruise ships stop regularly in port to allow shore visits, and will spend time near the coast for views. However, this paper does not focus on cruise ships, as they take longer journeys, and include additional services and challenges (e.g. entertainment and catering). Ferry crossings within a State or between States represent shorter journeys and are primarily concerned with transportation (not the experience). This paper will focus on crossings between States to discuss the applicability of international law.

2.2 The AAWA Initiative

While passenger ships did not have a role in MUNIN, they have been given more recent consideration in the AAWA Initiative. Although the AAWA Initiative asserted that passenger ships are not suited to being unmanned, passenger ships are a part of the research (Sampson, B 2014). For example, a ferry is being used to develop and test the sensors for an unmanned ship, but it is a simply a stage in the development of an unmanned dry cargo ship (Advanced Autonomous Waterborne Applications 2016). However, the testing could represent an important moment in the development of purpose built uncrewed passenger ships, as it could prove that a passenger ship could navigate with sensors instead of a crew.

The AAWA Initiative does go a step further than MUNIN, which advocated only being unmanned when doing deep sea shipping and bringing a pilotage crew on-board when near the coast (Rødseth &

Tjura 2014). The AAWA Initiative plans to develop a ship that will be unmanned for the duration of the journey, including when nearer the coast, and in port. This involves developing sensors and collision avoidance systems that are more advanced, and able to cope with additional obstacles and more complex environments. Importantly this will involve the gathering of data from multiple sensors, with the use of path planning, electronic mapping, and collision avoidance (Advanced Autonomous Waterborne Applications 2016).

If the AAWA Initiative is successful in the development of its unmanned ship, especially if it is as early as they predict, this will be an important moment in the development of unmanned ships, and for the future of uncrewed passenger ships.

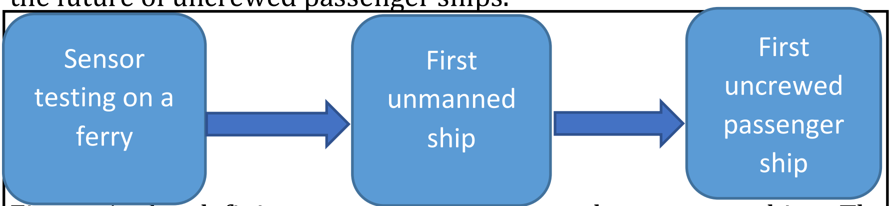

Figure 1, the defining moments of uncrewed passenger ships. The first key stage is the testing of sensors on a ferry by the AAWA Initiative. The second stage is the first purpose-built unmanned ship. The final stage is the first uncrewed passenger ship

For uncrewed passenger ships to develop, unmanned cargo ships need to first become a reality (unlike cars and freight lorries there will be no driver there as a back-up and still doing some driving). As technology improves, having passengers on uncrewed ships will become more feasible. It will also reduce the cost, making it more appealing to operators.

2.3 Legal overview

As ships develop, the law will need to as well. The law is currently behind the technology, and is trying to be prepared for when unmanned ships come into service. One of the most notable publications was made by Eric Van Hooydonk (2014). Van Hooydonk notes that given the difficulty of berthing a ship for a crew, a future of ships being completely unmanned is potentially unrealistic, irresponsible, and immoral. However, it is not impossible, and given the right legal and technical requirements it could be equally responsible and acceptable as the existing shipping industry.

Van Hooydonk discusses the widely accepted notion that most incidents are caused by human error, and thus developing unmanned ships would remove that factor. However, he notes that the systems will not be faultless, and remote-controllers will still introduce human error and may not be fully appraised of the situation, as they are not on-board. Remote-controllers, for instance, will be entirely dependent on technology, and if there is a failure then there will be no on-board solution. Therefore, the greatest challenge for engineering is to develop sensors and systems (and redundancy systems), which are sufficient to minimise error without introducing additional error. They will need to be able to make accurate decisions as quickly and effectively as they do on-board, in compliance with the law.

2.4 Regulation of passenger ships

It is not just the technological challenges specific to passenger ships that have to be met, but also the additional legal requirements – all of which are needed to ensure the safety of the ship, its passengers, and the surrounding area.

There are three main types of regulation that are applicable to passenger ships: safety, compensation, and environmental. In relation to safety there are many laws that apply, including *International Convention for the Safety of Life at Sea 2014* (SOLAS), and *International Safety Management Code 2012* (ISM Code). The primary example of compensation for passengers is the *Consolidated Text of the Athens Convention relating to the Carriage of Passengers and their Luggage by Sea 1974 and the Protocol of 2002 to the Convention*. There is a wide range of laws that apply to environmental liability, including the *International Convention on Civil Liability for Bunker Oil Pollution Damage 2001*. This paper will be focusing on SOLAS and ISM Code, as well as the Athens Convention 2002 when safety standards are not met or are insufficient to prevent harm.

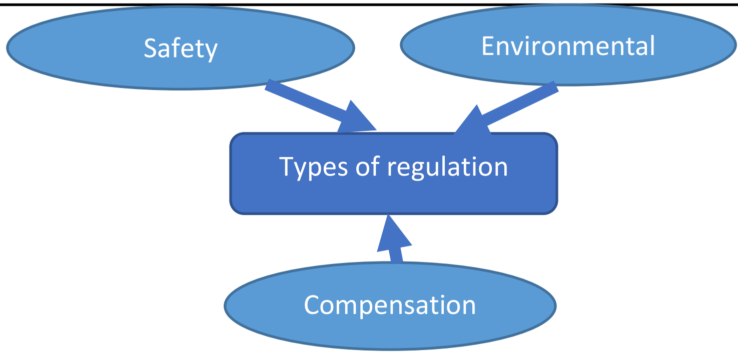

Figure 2, types of regulation. There are three main areas of regulation in maritime law: safety, environmental, and compensation.

2.5 Common issues with unmanned ships

There are also some issues that apply to all unmanned ships, including passenger ships. Primarily these concern the applicability of the law, and the risk of collision. One issue is whether an unmanned ship is, in fact, a ship. The use of broad definitions or lack of definitions in law has widely led to the conclusion that unmanned ships are encompassed by the conventions (Van Hooydonk 2014). The only contention has been whether the physical presence of the master and crew is integral to the essence of what a ship is. However, in law the ship is not defined by the crew. Thus, the absence of the master and crew should not, in law, present a problem.

Therefore, the law should apply to unmanned ships as it does to other ships (in the absence of amendments being made for unmanned ships). However, this does not mean that the application of the law will be without difficulty.

The starting point in maritime law is the *United Nations Convention on the Law of the Sea 1982* (UNCLOS). It is important to establish whether the unmanned ship will benefit from the rights conferred by UNCLOS (e.g. innocent passage in Article 17) and whether port states can impose construction, design, equipment, or manning regulations to foreign ships that would prevent innocent passage (Article 21). Problematically, there is no definition of 'ship' in UNCLOS. However, it is thought that UNCLOS will apply to unmanned ships (Advanced Autonomous Waterborne Applications 2016). Therefore, a port state will not be able to prevent the entry and thus the existence unmanned ships without international agreement.

Another problematic law is the *Convention on the International Regulations for Preventing Collisions at Sea 1972* (COLREGS). This is mainly due to requirements for look-out and good seamanship (COLREGS Rules 5 & 8). It is important to consider its requirements in developing collision-avoidance systems, and preventing a potential collision situation.

3 What is an uncrewed passenger ship?

It is important to consider what being an uncrewed passenger ship involves in regards to the operation of the ship, and for passengers. Ship design is informed by how systems operate, and whether there is remote-control. The lack of a crew on-board will affect the design of the ship to facilitate quick and safe evacuation (e.g. screens and lights to signal where to go).

3.1 Control

There are many ways in which unmanned ships can be controlled, and many combinations of control systems. For instance, there can be autonomous operation with remote-control, or a place of safety (sailing a predetermined location to wait for aid), as a way of addressing complications (Advanced Autonomous Waterborne Applications 2016). However, at first, it is likely that an uncrewed passenger ship would be operated remotely. One reason for this is to control communications between the uncrewed passenger ship, and other ships, crewed or not, in the absence of a communication system (Advanced Autonomous Waterborne Applications 2016).

It is thought that, by crews being shore-based, errors and causal relationships could change (Advanced Autonomous Waterborne Applications 2016). Therefore, it is possible that safety obligations, and liability regimes could also change.

3.2 What is 'uncrewed'?

In this paper, the focus is on the fact that the ship is uncrewed. In engineering the focus is on the systems, whether they are autonomous, remote-control, or somewhere in between. However, in law the important factor is the absence of people and not the differentiation in operating systems (as long as the systems are safe).

It becomes necessary in law to define 'uncrewed', and for engineers to understand what specific considerations the law will require of the uncrewed ships and their systems. Another term is also used, which is 'unmanned', and it must be asked whether the terms will have independent definitions, or whether they will be entirely synonymous. In this paper, 'uncrewed' is being used specifically for passenger ships, and 'unmanned' refers generally to ships that operate without a crew.

To this writer, 'uncrewed' and 'unmanned' should be considered as different; this differentiation could be part of a useful classification scheme. The use of the word 'unmanned' should mean that the ship is completely devoid of people on-board, whether they are categorised as passengers, crew, or other staff. 'Uncrewed', however, is more complicated and could involve subcategories. A ship could be uncrewed in the sense of having no personnel on-board, but have passengers on-board. Alternatively, it could mean that there are no crew in relation to the operation of the ship, but could have other staff on-board (e.g. security, catering, medical, or entertainment) – the distinction is based on who is needed for the ship to function as a ship, and those needed for hospitality. The two terms make the purpose of those board an uncrewed passenger ship clearer than simply using ‘unmanned’ for all. However, being unmanned or uncrewed does not preclude remote-operators, and thus does not mean that the ship is autonomous. It also does not preclude people getting on-board (e.g. stowaways, pirates, stowaways).

	Unmanned	**Uncrewed**
Definitions:	No people on-board.	1. Passengers on-board; or 2. Passengers and staff on-board, but no crew.
Remote-control possible:	Yes.	Yes.
Autonomous systems possible:	Yes.	Yes.

Table 1, terminology of ships without a crew. This table shows the potential range of ships without a crew, and indicates that it is important to distinguish between other ships and those with passengers.

3.3 Evacuation

Evacuation procedures aim to keep passengers safe, and are managed through the design of the ship and its life-saving features, and through the crew on-board. The design of life-saving features will change without a crew on-board. It has been argued how passengers behave is an overlooked feature, but how they behave may change without the guidance of crew members on-board (Ahola, Murto & Kujala 2014).

The study found that supervision through cameras, and clear alert systems of the situation on-board, are crucial factors in making passengers feel safe and helping them to evacuate in an orderly manner. The life-saving appliances should also be highly visible to reassure passengers, and for them to understand what to do. This links to the importance of good communication, which means that the remote-controller would need to make clear announcements and there should be directions (by sight and sound, and interactive screens) throughout the ship as to how passengers should evacuate (Ahola, Murto & Kujala 2014).

These factors are all the more important in the absence of the crew, as the crew also help passenger safety (Ahola, Murto & Kujala 2014). For instance, without clear information, it is likely that the passengers will become stressed and panicked, and thus slow an evacuation and reduce its effectiveness (Ahola & Kujala 2015).

4 Safety of passengers at sea

Most importantly, ships are designed to be safe, and the law, through SOLAS and the ISM Code, demands that they are safe. Both refer to manning requirements, which are important to consider when the aim of an uncrewed passenger ship is that it is not crewed.

The ISM Code is concerned with human aspects of ship safety (Maritime & Coastguard Agency 2015). It promotes safety at sea, and aims to prevent injury and death (ISM Code 1.2.1). The ISM Code applies to all passenger ships by virtue of Regulation 2 of Chapter IX of SOLAS. The broad terminology of 'all' will allow for uncrewed passenger ships. The ISM Code provides "an international standard for the safe management and operation of ships" (Preamble 1).

The ISM "Code is expressed in broad terms so that it can have widespread application. Clearly, different levels of management, whether shore-based or at sea, will require varying levels of knowledge and awareness of the items outlined" (Preamble 5). Thus, it would be within the purpose of the ISM Code for the safety of the ship to be managed by people from shore alone, and the technology to be on-board and on shore. This will require a wider understanding of shore-based management, including improving the skills of personnel on shore to be prepared for emergencies (ISM Code 1.2.2.3).

4.1 Manning requirements

The Maritime & Coastguard Agency considers that under the ISM Code the crew are responsible for all operations on-board the ship (2015). Every ship is required by ISM Code 6.2 to be ".1 manned with qualified, certificated and medically-fit seafarers… and .2 appropriately manned in order to encompass all aspects of maintaining safe operations on board."

SOLAS Chapter V Regulation 14 requires that ships be "sufficiently and efficiently manned." The flag state is required to determine the minimum level of safe manning. Therefore, it could be considered that zero is acceptable for ships with autonomous and/or remote-control systems (Veal et al. 2016).

Article 11(1) of the *Seafarers' Hours of Work and the Manning of Ships Convention 1996* requires that ships be "sufficiently, safely and efficiently manned, in accordance with the minimum safe manning document or an equivalent issued by the competent authority." This indicates that the minimum safe level of manning is determined by the flag state, thus it is possible zero crew on-board would fulfil Article 11(1). Through new technology, it may be possible that zero would be sufficient and efficient, and no humans on-board would be safe. Although this Convention is not in force in the United Kingdom, and the *Maritime Labour Convention 2006* is in force, it provides an additional indication on the concept of manning internationally.

The *Maritime Labour Convention 2006* itself includes Regulation 2.7, the purpose of which is to ensure that there are “sufficient personnel for the safe, efficient and secure operation of the ship.” The terminology used is very similar to Article 11(1) of the *Seafarers’ Hours of Work and the Manning of Ships Convention 1996*, with the addition of ‘secure’. Regulation 2.7 itself requires sufficient personnel to operate the ship “safely, efficiently and with due regard to security under all conditions, taking into account concerns about seafarer fatigue and the particular nature and conditions of the voyage.” The consideration given to fatigue is important (and fatigue and overworking are further emphasised in Standard A2.7(2)), and will be considered further later in section 4.2. Giving consideration to the voyage arguably could include consideration of the nature of how the ship operates, and would allow for no crew to operate ships with the requisite systems.

The question becomes whether the same will apply in relation to passenger ships. Given the additional risks of death and personal injury posed by the presence of passengers it could be considered impossible to have uncrewed passenger ships. However, through the use of remote-control and other technology, or other staff (if they are on-board), zero crew members could still ensure the safe operation of the ship.

4.2 Technology, personnel, and the uncrewed passenger ship

Technology will aid in making zero the minimum number of crew on uncrewed passenger ships acceptable. 'Dynamic autonomy' would allow autonomous operation in the open sea, and close-supervision or remote-control when closer to shore (Advanced Autonomous Waterborne Applications 2016). This illustrates how the systems can assist each other instead of the crew or pilot. Sensors and cameras will allow the remote-controllers to monitor the situation effectively. They will also allow the navigation and collision-avoidance systems to react to the situation, so that the crew is not needed to steer the ship. Alert systems will allow for instantaneous communication with passengers throughout the ship. This will allow for effective evacuation, and will keep passengers informed of the status of the ship (which will reassure them and develop trust).

It is not just the technology that will make uncrewed passenger ships safe and sufficiently manned, remote-controllers and other members of staff will have a role as well. There will be issues with ensuring that those staff are sufficient to make the ship safe (especially under the *International Convention on Standards of Training, Certification and*

Watchkeeping for Seafarers 1978). For instance, there must be enough remote-controllers to safely manage the ship from shore. When determining the safe number of remote-controllers and ships under their supervision, the International Maritime Organisation's guidelines on fatigue should be considered (2002).

There are other staff than remote-controllers that could have a role on an uncrewed passenger ship, if 'uncrewed' only refers to crew that operate the ship. There could be a member staff whose sole purpose is to coordinate the ship, and instruct passengers when there is an emergency. There could also be a doctor on-board for longer voyages, security staff if there is security risk or the ship is sailing in a dangerous area, or entertainment or catering staff for voyages that still want to provide those services. These members of staff would not operate the ship, but could be trained for emergencies (e.g. guide evacuation) but would not necessarily have to be trained if technological solutions can manage the emergency.

These people could be useful on-board for longer voyages, especially when the speed that lifeboats and the coastguard could reach the ship are deemed inadequate. Deciding which staff, and the combination of staff (whether on shore, or on-board), will be important in ensuring that the ship operates safely, and that when there is an emergency it is resolved in the best way. However, when there is an emergency there is no guarantee that no lives will be lost or harmed.

5 Passenger ship liability and compensation

So far this paper has focused on ensuring safety, but there is also the issue of compensation if there is an incident and a passenger is injured or killed. Safety is about setting standards before sailing and maintaining them during the voyage, whereas compensation tries to address situations when this standard has not been met or was not enough to prevent the harm suffered (a ship can meet safety standards, but the technology still fail).

The Athens Convention 2002 includes definitions of 'ship', 'shipping incident', and 'defect in the ship' (Articles 1(3), and 1(5)). As in other conventions and regulations this means that an uncrewed passenger ship will be considered a 'ship'. The terms 'shipping incident' and 'defect in the ship' are widely defined, which means they could include faults caused by autonomous or remote-control systems.

Athens Convention 2002 involves strict liability up to a limit (with a few exceptions), then fault-based liability for shipping incidents to a second limit, and fault-based liability for other losses (Article 3). A study by Li et al. found that an incident involving a driverless car means that the driver (as the person in the driver's seat who still does some driving) has less responsibility, and there is greater responsibility on the manufacturer and the government (2016). Liability is not likely to be imposed on the government, but it is possible that liability would be imposed on the manufacturer. Therefore, the liability system could change: there could be strict liability in all circumstances, and for all damage and losses, which would place the responsibility for any damage on the owner or manufacturer (Dahiyat 2011).

However, strict liability is usually applied to dangerous products, or those that do not meet minimum safety requirements, and the control systems of a ship are not innately dangerous and will hopefully meet the standards to which they are held (Dahiyat 2011). The dilemma is whether the liability should be on the owner, the manufacturer, or both. Strict liability could mean that any technical failure will result in liability, so the cause of the technical failure could indicate that it is most appropriate to place strict liability on the manufacturer. However, it is unlikely that the liability will be placed on the manufacturer, as the potential financial burden by prevent technological development. Considering the systems as instruments of the owner, and making the owner liable, may not be appropriate as the systems become more autonomous they cannot be considered mere tools (Dahiyat 2011). Therefore, it may not be best to apply strict liability for all incidents to the upper limit (*Athens Convention 2002* Article 7).

6 Conclusion

This paper has made it clear that there is a strong possibility of uncrewed passenger ships, which is currently being ignored as too risky. If this challenge is confronted, it is necessary to understand what 'uncrewed' means, and to highlight the differences between passenger ships and other unmanned ships. Manning requirements represent the main legal challenge, but control, passenger communication, and evacuation systems could potentially provide a solution to this problem. At times this will involve people, remote-controllers, or personnel on-board who do not operate the ship, which further emphasises the need to understand the meaning of 'uncrewed'. Although being uncrewed is hoped to reduce human error, being so does not mean that there will never be an incident, and thus the compensation system needs to be available, and the question will be 'who will pay?' Importantly, to become operational there need to be standards to ensure the safety of passengers, and to ensure that adequate compensation paid is when those standards have not been met or failed to prevent harm.

7 Bibliography

Advanced Autonomous Waterborne Applications 2016, *Remote and Autonomous Ships and the Next Steps*, Rolls Royce. Available from: http://www.rolls-royce.com/~/media/Files/R/Rolls-

Royce/documents/customers/marine/ship-intel/aawa-whitepaper-210616.pdf. [10 August 2016].

Ahola, M & Kujala, P 2015, ‘Modelling Passenger Ship Evacuation from Passenger Perspective’, *paper presented at Marine Design 2015*, London, 2-3 September. Available from ResearchGate. [5 July 2016].

Ahola, M, Mutro, P & Kujala, M 2014, ‘Perceiving Safety in Passenger Ships – User Studies in an Authentic Environment’, *Safety Science*, vol. 70, pp. 222-232.

Consolidated Text of the Athens Convention relating to the Carriage of Passengers and their Luggage by Sea, 1974 and the Protocol of 2002 to the Convention.

Convention on the International Regulations for Preventing Collisions at Sea 1972.

Dahiyat, EAR 2011, ‘Towards New Recognition of Liability in the Digital World: Should we be more Creative’, *International Journal of Law and IT*, vol. 19. No. 3, pp. 224-242.

International Convention for the Safety of Life at Sea 2014.

International Convention on Civil Liability for Bunker Oil Pollution Damage 2001.

International Maritime Organisation 2002, *Guidelines on Fatigue, 2002 Edition*, International Maritime Organisation, London.

International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978 (as amended in 2010).

International Safety Management Code 2012.

Li, J, Zhao, X, Ju, W & Malle, B 2016, 'From Trolley to Autonomous Vehicle: Perceptions of Responsibility and Moral Norms in Traffic Accidents with Self-Driving Cars', *paper presented at Society of Automotive Engineers World Congress 2016*, Detroit, 12-14 April. Available from ResearchGate. [7 June 2016].

Maritime & Coastguard Agency 2015, *International Management Code for the Safe Operation of Ships and for Pollution Prevention (The ISM Code): Instructions for the Guidance of Surveyors*, United Kingdom Government. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/508080/ISM_I2S_Feb_2015_Updated_150316.pdf. [10 August 2016].

Maritime Labour Convention 2006.

Maritime Unmanned Navigation through Intelligence in Networks 2015a, *D10.1: Impact on Short Sea Shipping*, European Commission. Available from: http://www.unmanned-ship.org/munin/wp-content/uploads/2015/10/MUNIN-D10-1-Impact-on-Short-Sea-Shipping-MRTK-final.pdf. [10 August 2016].

Maritime Unmanned Navigation through Intelligence in Networks 2015b, *D10.2 New Ship Designs for Autonomous Vessels*, European Commission. Available from: http://www.unmanned-ship.org/munin/wp-content/uploads/2015/10/MUNIN-D10-2-New-Ship-Designs-for-Autonomous-Vessels-MRTK-final.pdf. [12 August 2016].

Rødseth, OJ & Tjora, Å 2014, 'A System Architecture for an Unmanned Ship', *paper presented at COMPIT' 14*, Redworth, 14-17 April. Available from Maritime Unmanned Navigation through Intelligence in Networks. [12 August 2016].

Sampson, B 2014, 'Ships without a crew', *Professional Engineering*, vol. 27, pp. 58-61.

Seafarers' Hours of Work and the Manning of Ships Convention 1996.

United Nations Convention on the Law of the Sea 1982.

Van Hooydonk, E 2014, 'The Law of Unmanned Merchant Shipping – an Exploration', *Journal of International Maritime Law*, vol. 20, pp, 403-423.

Veal, R, Tsimplis, M, Serdy, A, Ntovas, A & Quinn, S 2016, ‘Liability for Operations in Unmanned Maritime Vehicles with Differing Levels of Autonomy’ (study performed by the University of Southampton on behalf of the European Defence Agency’s Group on Safety and Regulation of Unmanned Maritime Systems).