Grant Agreement number: 314286
Project acronym: MUNIN
Project title: Maritime Unmanned Navigation through Intelligence in Networks
Funding Scheme: SST.2012.5.2-5: E-guided vessels: the 'autonomous' ship

D9.2: Qualitative assessment

Due date of deliverable: 2015-07-31
Actual submission date: 2015-09-30

Start date of project: 2012-09-01 Project Duration: 36 months

Lead partner for deliverable: CML
Distribution date: 2015-09-30 Document revision: 1.0

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	**Public**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Document summary information

Deliverable	**D9.2: Qualitative assessment**
Classification	Public

Initials	**Author**	**Organisation**	**Role**
LK	Lutz Kretschmann	CML	Editor
ØJR	Ørnulf Rødseth	MRTK	Contributor
ÅT	Åsmund Tjora	MRTK	Contributor
BSF	Bénédicte Sage Fuller	UCC	Contributor
HN	Helen Noble	UCC	Contributor
JH	Jeffrey Horahan	UCC	Contributor

Rev.	**Who**	**Date**	**Comment**
0.1	LK	15/07/21	Initial table of contents distributed to partners
0.9	LK	15/08/26	First draft send to partners for review and input
0.91	LK	15/08/28	Draft final send to partners for last comments
0.92	LK	15/08/28	Version with comments from review
0.93	LK	15/08/28	Final draft version
0.94	ØJR	15/09/21	Final editorials from MRTK
0.95	BSF	15/09/28	Final editorials from UCC
1.0	LK	15/09/28	Final version

Internal review needed: **[ ] yes** **[x] no**

Initials	**Reviewer**	**Approved**	**Not approved**

Disclaimer

The content of the publication herein is the sole responsibility of the publishers and it does not necessarily represent the views expressed by the European Commission or its services.

While the information contained in the documents is believed to be accurate, the authors(s) or any other participant in the MUNIN consortium make no warranty of any kind with regard to this material including, but not limited to the implied warranties of merchantability and fitness for a particular purpose.

Neither the MUNIN Consortium nor any of its members, their officers, employees or agents shall be responsible or liable in negligence or otherwise howsoever in respect of any inaccuracy or omission herein.

Without derogating from the generality of the foregoing neither the MUNIN Consortium nor any of its members, their officers, employees or agents shall be liable for any direct or indirect or consequential loss or damage caused by or arising from any information advice or inaccuracy or omission herein.

Executive summary

This document is part of the assessment of the concept of an unmanned and autonomous bulk carrier as it has been developed in the project MUNIN. In particular it focuses on the external perspective on the innovation of an autonomous unmanned vessel. To this end the document is divided in three sections which cover

- the identification of main risks associated with autonomous vessel,
- the view of Flag States on autonomous ships and
- the external perspective of maritime stakeholders on autonomous ships.

The identification of safety and security hazards from different aspects of unmanned ship operation and the risk assessment of these hazards were done in workshops. 23 of the hazards identified were assessed to have an unacceptable high risk unless appropriate risk control means are implemented. Based on the research in the MUNIN project suitable risk control options are identified and discussed subsequently in this report.

Legally speaking, this report considers the point of view of States. It does so by looking at three related areas: social acceptability, technical issues, and political issues. A questionnaire was sent to several States in order to gather their views about this. This exercise provided interesting answers, some being similar, other opposite depending on the respondents.

Technological development is increasingly influenced by societal acceptance. Thus, an assessment which only relies on the opinion of experts without taking into consideration a wider perspective risks neglecting a crucial factor. Accordingly, as part of this report the results of a questionnaire are discussed in detail which aimed to capture the view of maritime stakeholder on the innovation of autonomous ships and key impacts associated therewith. It gives answers to the general attitude towards autonomous ships, covers safety and security aspects as well as social and environmental concerns, illustrates the view on technological aspects as well as main opportunities and challenges associated with autonomous ships. It turns out that respondents have a quite positive view on the innovation of autonomous ships overall and almost 80% expect a first appearance of autonomous ship concepts in merchant shipping within the next 10 years.

List of abbreviations

FI	Frequency Index
FSA	Formal Safety Assessment
POB	Person over board
RCO	Risk control options
RI	Risk Index
SAR	Search and rescue
SCC	Shore control center
SI	Severity Index

Table of contents

List of figures

List of tables

1. Introduction

In a first step the assessment focused on the identification and initial qualitative assessment of impacts associated with the concept of an autonomous ship as developed in the MUNIN project by relying on the knowledge of experts in the respective areas concerned. /1/ Hereby if fulfilled an important function of technology assessment as it is understood in the context of the project MUNIN: to identify main impacts associated with an innovation and create awareness about main challenges and available solutions to overcome these. A wide scope of technological aspects may be investigated in a technology assessment by employing a multitude of methods from different disciplines all of which are more or less prone to produce somewhat subjective results. A way to overcome this challenge is to bring together and consider different perspectives, backgrounds and value systems in the analysis. This becomes even more relevant regarding the fact that technological development is increasingly influenced by societal processes. An assessment that only relies on the opinion of experts without taking into consideration the view of main stakeholders and the wider public risks falling short of achieving an (optimal) alignment between technological and societal developments /2/. Accordingly it is crucial to integrate a wider external view on the innovation of autonomous ships in this report *Qualitative assessment of impacts.* This way the technology assessment in MUNIN is capable to fulfil the necessity to be a *"scientific, interactive and communicative process which aims to contribute to the formation of public and political opinion on societal aspects of science and technology"* /3/. Therefore this report includes the following aspects that complement each other:

- Hazard identification and risk rating to identify hazards with unacceptable high risks and discussion of appropriate risk control options,
- Consultation of flag states and Governments to determine and explain their views of the unmanned ship and
- Identification of wider external stakeholder perspective on the innovation of autonomous vessels by use of a structured questionnaire.

Taken together the results provide a more comprehensive qualitative assessment of the key impacts associated with autonomous ships which were identified in the first step of the assessment. Based on the outcome future technological development in the context of autonomous ships can be aligned to socially desirable solutions and thus the likeliness of developed innovations to make their way to the marked is increased.

2. Identification of main risks

During the project, work on identifying the main risks related to the operation of an unmanned dry bulk carrier has been performed. This work has been based on IMO's Formal Safety Assessment (FSA) framework /4/.

Hazards were identified in workshops; in these workshops, a division of the unmanned ship system in function groups was used to make sure that hazards from all aspects of the ship operation were identified. The main groups used were:

1. Voyage
2. Sailing
3. Observation
4. Safety and emergency
5. Security
6. Crew and passenger
7. Cargo, stability and strength
8. Technical
9. Special ship function
10. Administrative.

After hazards were identified, workshops for rating the expected frequencies and consequences of incidents related to the hazards were held. The risk can then be calculated as a function of frequency and consequence of an incident.

Three types of consequences of the incidents were used: Consequences for human life, consequences for material values, and consequences for the environment. As the risks are derived from the consequences, the risks will therefore also be divided into these categories.

For the rating, logarithmic scales, *Frequency Index* (FI) and *Severity Index* (SI), for frequencies and consequences were used. I.e. if the FI increases by one, the expected frequency of the incident becomes 10 times higher, and if the SI increases by one, the severity of the incident becomes 10 times worse. The *Risk Index* (RI) is calculated by adding FI and SI; this is equivalent of multiplying the frequency and severity if linear scales had been used.

Depending on the values of the risk indices, the risks are categorized in three groups. Unacceptable high risks (marked with red in tables) are risks that must be controlled for the system to be accepted. Risks that are acceptable (marked with green in tables) can be accepted without adding any control options. Risks between the two (yellow in tables) should be lowered as much as reasonably practicable (ALARP principle).

The risk assessment found that for 23 of the identified hazards, at least one risk index were unacceptable when no corrective measures were taken. These hazards were further analyzed to determine a set of suitable risk control options (RCO). These risks are summarized in Table 1 below, with risk control options (RCO) listed in Table 2. The MUNIN report *New ship designs for autonomous vessels* discusses constraints tied to these risk control options. /5/

A complete list of the identified hazards with the results of the risk rating work can be found in Annex B: HazId Analysis results.

Table 1: Hazards with unacceptable risks and corresponding RCO

	Human	Material	Environ
Human error in remote monitoring and control (e.g. through situation unawareness, data misinterpretation, SCC capacity overload) - collision	10	10	9
Human error in remote maintenance (e.g. through situation unawareness, data misinterpretation, SCC capacity overload) - foundering/loss	6	10	8
Foundering in heavy weather	4	8	6
Collision in low visibility	9	9	8
Collision with conventional ships in heavy traffic	9	9	8
Grounding after propulsion failure	5	8	8
Collision after sensor failure	9	9	8
Collision with floating objects	6	8	6
Embarkation and disembarkation of crew at a rendezvous point - injury	8	5	5
Failure in detection of small objects - fail to observe castaway/wreckage	9	6	6
Failure in detection of semi-submerged towed or floating devices (e.g. seismic gauges, fishing trawls or nets)	5	8	5
Fire loss of ship or systems	5	8	6
CO_2 application for firefighting purposes might compromise safety of individuals on board – stowaways	8	6	5
Jamming or spoofing of AIS or GPS signals - collision with other ship	8	8	8
Jamming or spoofing of communications, hacker attack, also on SCC (e.g. in case of pirate or terrorist attack) - collision with other ship	8	8	8
Hacker attack on system as above - grounding in critical areas (port appr.)	7	9	9
Loss of intact stability due to unfavourable ship responses (e.g. to waves)	6	10	8
Loss of intact stability due to shift/ liquification of cargo	5	9	7
Sensor failure - loss of control	7	8	7

	Human	Material	Environ
Temporary Loss of electricity (e.g. due to black-out) - loss of control	6	8	6
Failure of ship's IT structure (e.g. due to fire in the server room) - no control	6	10	8
Total loss of propulsion	4	8	4
Total loss of rudder function	4	8	4

Table 2: Risk Control Options

RCO	Risk Control Option
1	Careful design of SCC and SCC manning as well as training of personnel.
2	Design of on board systems for easy maintenance and accurate monitoring of maintenance state. Must also be fast to repair.
3	Ship should be unmanned at all times.
4	Need to avoid heavy or otherwise dangerous weather – use of weather routing
5	Need good sensor and avoidance systems. Selected systems must also be redundant so that a single failure does not disable critical functions.
6	Ship should be directly controlled in heavy or complex traffic.
7	Need redundant power generation, distribution, propulsion and steering
8	Automated fire extinguishing systems are required in all relevant areas. Note that no crew makes this simpler as areas are smaller and that CO_2 can be used more safely.
9	A ship without accommodation section is much easier to secure against stowaways in enclosed spaces.
10	Cybersecurity measures are important, including alternative position estimation based on non-GPS systems. The SCC may be particularly vulnerable. Data links must also have sufficient redundancy.
11	Improved cargo monitoring and planning is required.

The identified RCOs correspond to the main technical elements tested during the MUNIN proof of concept phase.

2.1 Unmanned ship and Shore Control Centre

RCO 1, 3, 6 and 9 refer to the unmanned ship and Shore Control Centre (SCC). These risk control options are all part of the overall concept of having an unmanned ship with a continuously manned shore control centre. The SCC design and operation concept have been described in other MUNIN reports (see e.g. /6//7/). It was also tested during the feasibility studies and the results were quite encouraging although not fully conclusive. One will need further investigation of the detailed SCC design when a more concrete unmanned ship case is proposed.

The original MUNIN concept included the use of a boarding crew for passage to and from port. However, this risk analysis indicates that one should perhaps aim for a fully unmanned ship and rather use direct remote control during port approach and departure. This could be from a shore station or from an escort boat. Near shore, it should be straight forward to implement high capacity communication links so this should be a feasible solution.

All in all, it is believed that the concepts shown in MUNIN and modified as discussed above should reduce risks sufficiently to get to an acceptable level.

2.2 Unmanned maintenance and technical operation principles

RCO 2, 7, 8 and 11 refer to unmanned maintenance and technical operation principles. These RCO fit together with the investigation into principles for unmanned maintenance and increased resilience of the technical systems. This is perhaps one of the most challenging issues of creating an unmanned ship for intercontinental voyages.

This discussion also points to a much simplified ship design where one should avoid as much sensitive technical systems as possible. This may also impact what cargo the ship carries. Cargo that needs intervention during the voyage that cannot easily be automated or remotely controlled may not be carried by an unmanned ship. Likewise, fire detection and extinguishing also needs to be fully automated in technical rooms as well as in cargo spaces, when relevant.

Also in this area the MUNIN results are very encouraging, but inconclusive in its details. One will need a full design to do the necessary assessments of reliability and availability. However, it seems clear that good technical solutions are available. Controlling the cost of these solutions is the main challenge.

2.3 Heavy weather

RCO 4 is deals with heavy weather. MUNIN has handled this issue partly with on board weather routing software to avoid heavy weather when possible and partly by dedicated algorithms for safe operation in heavy weather, if it should anyway occur. Testing of these systems has shown that the approach is feasible. Nevertheless, as stated in the MUNIN report *Autonomous deep-sea navigation concept* (see /8/) critical situations might occur in situations considered to be rather safe by IMO. In addition, critical phenomena are not strictly limited to situations covered by MSC.1/Circ. 1228, which provides the baseline of the heavy weather controller. Hence, at this point it should be mentioned again that the recommendations given by IMO only provide a very rough indication of dangerous situations and measures to avoid them.

One will also here need to test the interaction between specific ship designs and algorithms more thoroughly before any final conclusions can be drawn, but results indicate that also this issue is manageable.

2.4 Sensor systems

RCO 5 is related to the sensor system of the autonomous vessel. The MUNIN sensors and sensor fusion systems have been tested and shown to work as expected. Sensors are in rapid development and one should probably also investigate other systems to further increase detection and classification quality. However, the conclusion is that the development of satisfactory functionality has been demonstrated and is indeed feasible.

2.5 Cyber security

RCO 10 is related to cyber security threats. This issue has been investigated and it is clear that while this is a challenging issue, it can certainly be solved. MUNIN has mainly identified the critical parts of the infrastructure and indicated possible technical means to achieve a sufficiently high security and safety level. Cyber security is also a threat to conventional shipping so recent developments in IMO and international standards will also be of use to unmanned ships.

The conclusion is that this risk can be reduced to an acceptable level with proper technical solutions. One needs to keep in mind that this is as much a system design issue as a set of individual technical measures and that a system wide approach is required.

3. Flag States view on autonomous ships

This part of the legal analysis seeks to determine and explain the views of Governments on the unmanned ship. A legal analysis is provided in D9.1 and D9.3, and carried out from the point of view of an academic lawyer, and a practising maritime lawyer. However, it is important to also ascertain the point of view of States, particularly flag States, about the salient legal issues that the unmanned ship is likely to raise. To this end, a questionnaire has been drafted and sent to several national maritime administrations. The results of this consultation are discussed in this section.

A rather low response rate (2/5) was gathered. This can perhaps be explained by the highly sensitive issue that the unmanned ship represents at the moment, particularly in the context of SAR obligations and current events relating to migrants and refugees in the Mediterranean Sea, and acts of terrorism (raised in the questionnaire). In the context of their international relations and of international law, States may have been reluctant to provide their views about these issues, at a time when the migratory crisis is hitting Europe in full, and therefore may have preferred to stay away from the questionnaire altogether.

In order to obtain the two responses, full confidentiality was promised to the concerned people, therefore the section below does not name the countries in question. Their views remain nonetheless interesting, and provide leads as to what course of action to follow for the future development of the unmanned ship.

3.1 Legal issues stemming out of social acceptability of the unmanned ship

This first question contained in the questionnaire sought the recipients' views on the social acceptability of an unmanned ship. In response to this question the two respondents displayed divergent views.

One regarded the concept of an autonomous vessel as socially acceptable and attributed the reason simply to television and video games. It was conveyed that the use of remotely controlled sub-aqua equipment in marine documentaries for example and the use of remote control air and sea craft in children's video games would lead to an acceptance of the concept of an autonomous, unmanned ship.

Quite contrary to this another response expressed that the current biggest obstacle to the unmanned ship is social acceptability. It is suggested that a stigma would exist notwithstanding a resolution to all technical and legal issue arising from unmanned ships.

No consensus has emerged from the responses to this question. Two entirely opposite views were conveyed with the contrary view going so far as to suggest that social acceptability might never be forthcoming. However, this would appear to be quite extreme and stands on the absolute end of the spectrum. Given that such a small response was received to the questionnaire it is difficult to say how representative these views actually are and may not be reflective of the position of the several States which were unable to provide a response. The following Chapter 4 will add an interesting perspective to the issue above and the more detailed questions below as it illustrates the current view of maritime stakeholders regarding the acceptability of the unmanned ship.

3.1.1 Remote detection of operational spill or leak

Both respondents recognised the need for the detection of operational spills and leaks by the shore control center (SCC) but in conjunction, the imposition of some form of responsibility for any spills or leaks arising and the regulation of same. Divining the correct target for liability was emphasised by one participant as being of central importance. However, the common theme emerging was the need to have sufficient human resources to deal with any discharges. This would suggest that detection itself by the SCC is not likely to be considered enough and immediate remedial measures are necessary in the form of human responders.

3.1.2 Remote detection of accidental spill or leak

Accidental spills are caused by technical malfunctions in, e.g. pipelines, valves or pumps or by external damage to the ship or ship systems. Although it has a different causality than operational spills, the detection and management will be similar.

As with the previous question, the parties were in agreement that little could be done by an SCC in the event of a leak or spill however occurring. Their responses to this question mirrored their response to 3.1.1 above.

3.1.3 Piracy

Both parties agreed that an unmanned vessel could be easily commandeered by pirates. The perceived dangers posed by piracy are theft of the cargo; or the ship itself or its bulk cargo being held for ransom. However, the more worrying scenario for the respondents was the threat of hijackers. It was asserted that the unmanned vessel could be used as a weapon to ram other ships, structures at sea such as oil rigs, or even defended or undefended coastal facilities. It is believed that these risks are heightened in terms of unmanned vessels. One respondent did however, state that one assurance you would have in these situations is the knowledge that no innocent parties would be in danger when an unmanned ship is being taken over.

3.1.4 Cyber piracy

This is recognised as a problem by the participants but not one specific to unmanned vessels. All ships using computer software could potentially be the subject of cyber piracy. One respondent pointed out, as noted above, the risk to life is reduced should such an event transpire but it is not eliminated as other users of the sea will still be endangered.

This issue was also identified as an important hazard in the internal hazard identification exercise and is further discussed in section 2.5.

3.1.5 Search and Rescue obligations

In response to the proposition that an unmanned ship would not be in a position to assist those in distress at sea one party suggested that such a vessel could in fact provide assistance but went no further in elaborating on this. It simply called for new innovation.

The other participant highlighted two main issues. The first being political: the need for collective action and then, consensus among States. Attention was drawn to previous attempts to draft and implement international maritime conventions in the past and the difficulty and delays involved there. Second, it was stated that seafarers would be subject to further marginalisation. Seafarers it was argued will protest that the values of their lives do not outweigh the political and commercial costs involved in implementing new search and rescue measures. A disparity already exists between search and rescue facilities available on land and those available at sea. The unmanned vessel would erode one of the few protections seafarers have and further enlarge the gap between land and sea. It was also suggested that this could escalate to a human rights issue causing further political complexity.

3.2 "Human" look-out

Neither party to the questionnaire looked upon the replacement of the human lookout with 24/7 sensors and radar fusion with disapproval. So long as the systems employed on an unmanned vessel are functionally adequate neither party raised objection. One party cited the almost universal use by air and sea craft of electronic navigation as the norm and the absence of an actual human look out as being only observed in the breach.

One party questioned the ability to deal with malfunctions on board without any crew available to take a direct look at the problem and fix it there and then.[1] It was further argued that consideration should be given to the composition of the SCC: how an unmanned vessel will be controlled from shore, by whom and what qualifies them to do so.

To make way for the deployment of unmanned vessels the parties accepted the need for a revision of key international conventions like SOLAS, the Collision Regulations etc.

3.3 The ship master

The parties were here asked whether the absence of a master on board an unmanned vessel and this role now being undertaken by an individual in the SCC who would be in charge of several unmanned vessels simultaneously would affect liability rules in relation to the master, the ship owner, and the classification society.

One party answered this question in the affirmative with a succinct yes. The other framed its answer in terms of insurance liability. It was of the opinion that insurance premia would fall as there would be less human casualties should an accident occur. This respondent then drew attention to a potential difficulty when it comes to tendering evidence at judicial proceedings for collisions: how will the evidence of the unmanned vessel be tendered and is it admissible since it is electronic?

3.4 Other ideas

The respondents were finally asked whether they would like to make any other suggestions or comments about the position of an unmanned vessel.

In response to this one queried the extent of the compliance of an unmanned vessel with the various maritime conventions and stressed that careful consideration should be given to each to discern areas of compliance and areas of non-compliance. This course of action was regarded as necessary for determining what future amendments are required and how best to achieve them.

The other respondent suggested that the project might be proceeding too hastily. And that the progression from manned vessels to unmanned vessels was too great a step to take. Rather nostalgically it was pointed out that the unmanned vessel would signal the end of the era of manned ships and the seafarer. It was proposed that unmanned ships should sail in fleets with one manned ship present to deal with any emergencies should

[1] This issue is linked to the maintenance of the unmanned ship. The hypothesis of the MUNIN project is that the unmanned ship would actually be able to avert such issues by way of planned and predictive maintenance. It is interesting that it was raised as a potential problem by a flag State, and it shows the importance of demonstrating the safety and reliability of the MUNIN unmanned ship, in order to put to rest this kind of legitimate query.

they arise. It was put forward that this would ameliorate any political and social problems associated with the introduction of unmanned ships.

3.5 Conclusion

The views of Flag States on the operation of unmanned ships were sought in this report. Though the responses received are helpful in understanding the sentiment of those States which participated towards the concept of an unmanned ship they are not determinative. The low response rate only permits tentative conclusions to be drawn. This is most stark when it comes to determining whether these vessels will be accepted by Flag States. Two completely contrary views were expressed by the respondents. Thus, one cannot say how representative these views actually are; neither can it be said with certainty where exactly on the spectrum the consensus view of all Flag States would lie.

Notwithstanding, this was only one aspect of the unmanned ship on which the questionnaire sought an opinion. Several questions were asked, none of which depend on a high response rate for salient issues to be raised. Reservations were expressed by the respondents. The crux of these reservations is manning and the lack thereof. For example: inability to inspect the vessel and detect and deal with discharges; liability issues; lack of security personnel to prevent piracy; and compromised SAR capabilities. Furthermore, it was asserted that existing law will need to be amended to address any issues arising but this may prove a difficult task.

One of the conclusions from this survey is that more information about the technical capability and reliability of the unmanned ship will be required to convince flag States about their potential and feasibility. If States were more informed about an unmanned ship its design, operation, and legal position this may lead to a greater acceptance of the concept and any fears surrounding its operation would be allayed. This would permit more informed discussion and hopefully result in necessary legal amendment. The subsequent report on the assessment of the autonomous ship will provide an in-depth analysis of the relevant legal issues pertaining to the unmanned ship. Together with the analysis given here both reports give a good picture of what is needed to going forward, to move towards acceptance of the unmanned ship by interested parties, including flag States.

4. External stakeholder consultation

In the first step of the assessment an identification of impacts associated with the developed concept of an autonomous vessel and their respective assessment relied on the MUNIN expert panel. Following a Delphi-method approach, partners assessed the impacts of the MUNIN concept in two consecutive rounds /1/. However, the considered individual expertise in partners' respective organizations might give some bias to the results due to the limited scope of involved parties and an influence resulting from a close involvement in the developments of the MUNIN project. To complement the first internal analysis a wider scope of maritime stakeholders was integrated in the next step by conducting an external stakeholder consultation. The rational for this approach was twofold:

- The first step of the assessment has taken on a project internal perspective on the impacts of unmanned autonomous ships. In order to identify and assess relevant impacts the expert knowledge of involved partners was exploited. By adding the opinion of stakeholders from the maritime industry on key impacts an additional perspective can be added to the analysis.
- Furthermore, over the project duration the innovation of unmanned autonomous ships has caused significant attention from the maritime sector. Remarks and comments have been both positive and negative but were predominantly unstructured and focused on one rather narrow aspect associated with unmanned autonomous ships at a time. By conducting an external stakeholder consultation the view of maritime stakeholders on key aspects associated with autonomous ships – both in terms of the most important challenges as well as available opportunities – can be determined in a structured way.

Combining the results of the project internal identification of impacts and the external view of maritime stakeholders on the innovation of autonomous ships will make it possible to describe key impacts of autonomous ships more holistically.

4.1 Methodology

The primary goal of the external stakeholder consultation was to identify the attitude of a wider maritime stakeholder group on key aspects associated with the innovation of autonomous ships in a structured way. In order to realize this, a questionnaire with closed questions was given priority to a more open approach (e.g. open questions or interviews). The reason for this is as follows:

- The survey was supposed to cover explicitly defined issues (in terms of key impacts identified in the first step of the assessment); whereas in settings with

open questions or interviews participants tend to focus more on issues they are most familiar with.
- The purpose was to achieve a high comparability of results; here closed questions have certain advantages vs more open approaches.
- It was aimed to collect the feedback from high number of participants; thus for research economical reasons open questions or interviews are less suitable.

The questionnaire was designed in a way to ensure that questions would cover a wide area of effects and impacts associated with autonomous ships. The innovation of an autonomous ship is still in a very early stage of the innovation process. Thus, it was deemed appropriate to aim for feedback on a brought overview of relevant aspects from maritime stakeholders' perspective. Going into more depth with regard to the most important and critical aspects will be possible only as soon as the innovation of autonomous ships evolves out of its current early conceptual status.

One main input for the questionnaire design were the results of the impact matrix /1/. Those impacts that were identified as most relevant and/or controversial constitute the areas that are represented by items in the questionnaire. Further the selection of particular aspects covered in the questionnaire took into consideration aspects which were discussed vividly in ongoing public and scientific debates (e.g. comments of concerned / interested parties, topics under discussion in online forums, feedback and comments on dissemination events, news and media coverage of MUNIN).

The methodology used to capture the opinion of the respondents is via a rating scale approach. For each aspect the questionnaire was supposed to cover one (or more) item(s) containing a specific statement was provided. Following a Likert scaling approach the either positive or negative response of the participants to a given statement (which reflects a key impact of autonomous ships) is measured. /9/ Items are designed in such a way as to ensure an equidistant presentation of answer options. An example of the format of five-level Likert items used in the questionnaire is the following:

- Strongly disagree
- Disagree
- Indifferent
- Agree
- Strongly agree

In total the questionnaire contained 46 items assigned to eight content-related categories and was implemented as an online survey. Questioning took place between

15.06.2015 and 08.07.2015. An invitation to participate was forwarded to approximately 170 contacts gathered by Fraunhofer CML over the project duration. Further all MUNIN partners were asked to forward an invitation to suitable contacts as well and a link was posted online in the *LinkedIn Maritime Network* discussion forum on autonomous ships.

4.2 Results

4.2.1 Participants

In order to characterize the participants of the survey a number of demographic questions were provided at the end of the questionnaire. Besides polling general attitudes (e.g. age, gender) the main intention was to characterize the sample and thus gain insight whether the participants reflect the targeted group of maritime stakeholders.

In total 70 participants, with an average age of 48 years and predominantly male (90 %), completed the survey. Hereof 43.5 % have gained experience on board of a ship. Overall the respondents of the survey reflect a wide spectrum of different parts of the maritime sector and individual groups are quite well balanced (see Figure 1). Thus, despite the relatively small sample size a comparatively good representation of the target group *maritime stakeholders* can be achieved.

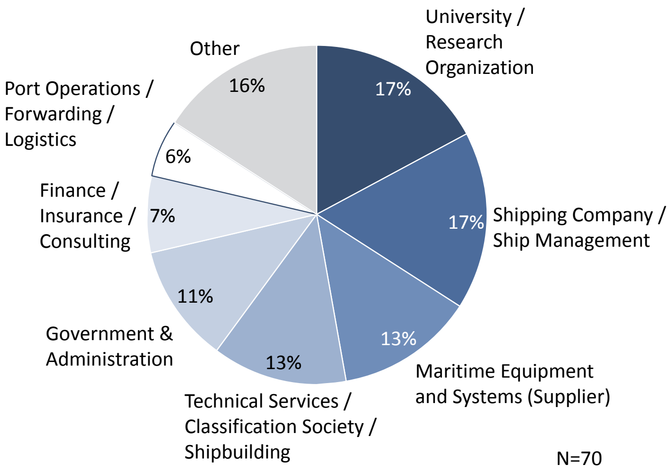

Figure 1: Background of survey participants

4.2.2 Descriptive analysis

Descriptive analysis is used to evaluate the results of the survey and highlight which impacts and effects associated with autonomous ships are seen as most relevant and critical by the participants. The analysis is divided into several sections covering aspects associated with autonomous ships respectively.

In order to derive valid findings from the given answers at least some knowledge of maritime transport and shipping as well as autonomous ships is required on the side of the participants. Thus the familiarity with the concept of autonomous ships as well as the research project MUNIN was polled. Overall the participants predominantly indicate to have at least some knowledge of the concept of autonomous ships. The specifics of the project MUNIN were less well but still sufficiently known (see Figure 2).

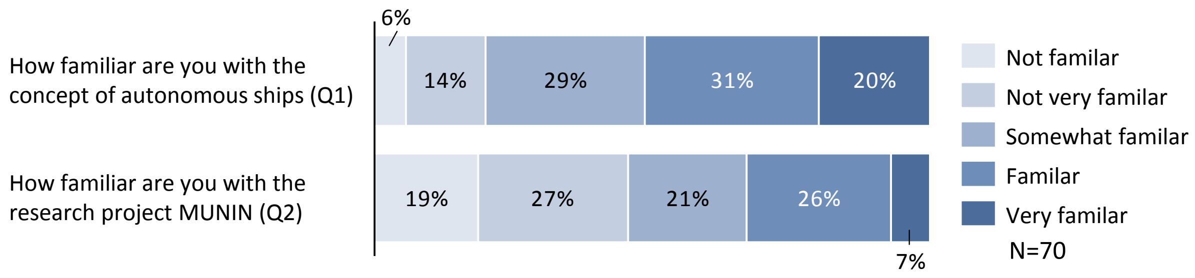

Figure 2: Respondents familiarity with the concept of autonomous ships

In order to improve the quality of results some of the respondents are excluded from further evaluation. This is the case if they were

- either *not familiar* with the concept of unmanned shipping
- or *not very familiar* with the concept of unmanned shipping while at the same time *not familiar* with the MUNIN project.

For this reason seven participants were excluded from the analysis. The remaining 63 are included in the following evaluation.

4.2.2.1 General attitude towards autonomous ships

First participants were asked about their general attitude towards autonomous ships. The same question was repeated after two thirds of the questionnaire. Overall a vast majority of maritime stakeholders in the survey indicate to have a *very positive* or *positive* perception of the concept (see Figure 3). As no consensus has emerged from the responses to the question of social acceptability in the consultation of Flag States in Chapter 0 with two entirely opposite views conveyed, this divide is mirrored in the results here as well with some respondents having a very negative attitude while others have a very positive. However, the positive attitude is much more common with the maritime stakeholders polled here.

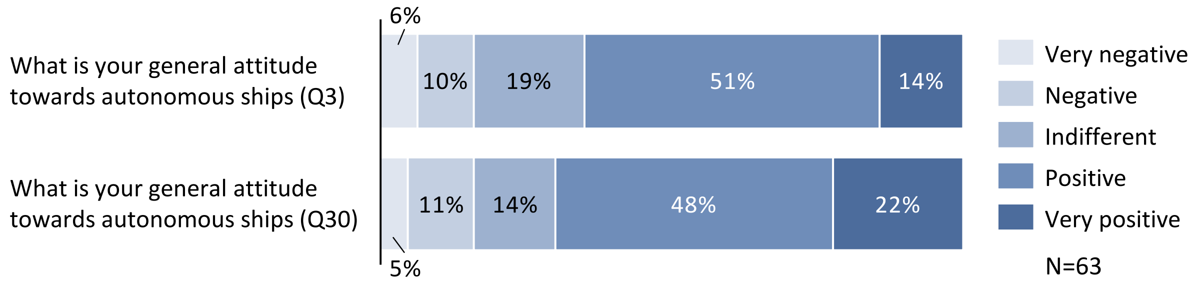

Figure 3: Respondents general attitude towards autonomous ships

The generally positive attitude even increased when the question was asked a second time. 12 participants changed their attitude to a more favourable assessment by one scale level after completing two thirds of the questionnaire while three indicated a less favourable level. No participant changed the general attitude statement by more than one level. It is noticeable that the response *indifferent* was reduced the most when asked for the second time and the share of *very positive* indications increased the most. A correlation between familiarity with the concept of autonomous ships (Figure 2 on previous page) and the general attitude cannot be observed in the data.

Furthermore, participants were asked to give an estimate when autonomous ships would first become a reality. Results show, that a first appearance autonomous ship concepts in merchant shipping are expected in a rather foreseeable future. Almost 80% expect them within the next 10 years. When asked about a common deployment of autonomous ships in merchant shipping the time horizon is somewhat longer with an average indication being 20 years from now. The share of participants that do not expect autonomous ships to become a reality – as a niche application or a regular part of the industry – is quite low overall (see Figure 4).

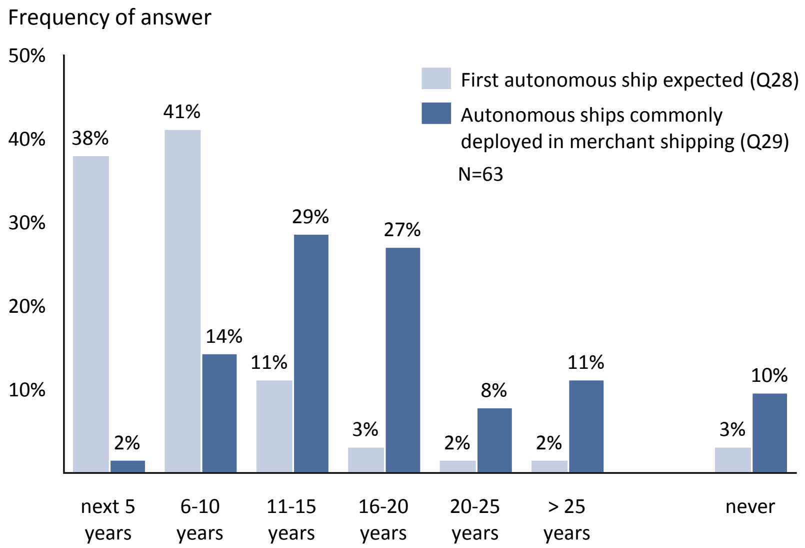

Figure 4: Respondents assessment of deployment date of autonomous ships

Finally, participants were asked to assess the impact of autonomous ships on the cost of maritime transport and the profitability of shipping companies. Both is seen to improve with 60% of respondents expecting transport costs to decrease with an introduction of autonomous ships and 43% anticipating a higher profitability for shipping companies. With regards to maritime legislation – seen as a major barrier for the introduction of autonomous ships – the respondents are quite optimistic as well. Here 67% believe that legislation will be adapted successfully in future to take into consideration the specific circumstances that autonomous ships bring along (see Figure 5).

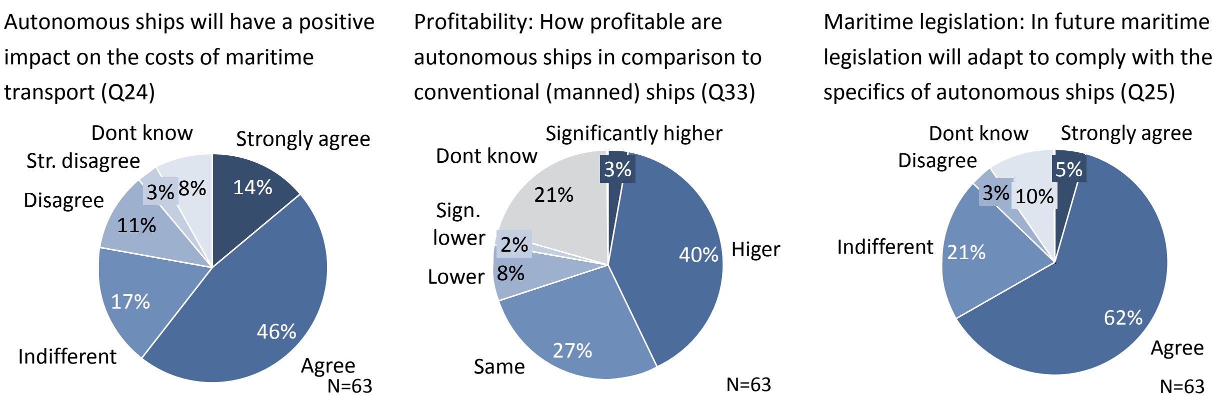

Figure 5: Respondents assessment of transport cost, profitability of shipping companies and adaptation of maritime legislation

4.2.2.2 Safety and security aspects

The general outcome of the impact identification and evaluation in the first step of the assessment was that the MUNIN modules and the MUNIN concept is expected to lead to a significant improvement of ship safety while security may pose a bigger problem.

When asked about the overall effect of autonomous ships on the safety of maritime transport a majority of stakeholders (52%) polled see a positive impact. A similar but slightly less favourable impact is expected for security of maritime transport, with 41% expecting a positive effect (see Figure 6).

Regarding ship safety advanced navigational support systems in combination with a positive impact of shore based monitoring of the ship are the main drivers. The stakeholders involved in the survey share this view. Better detection capabilities due to advanced sensor systems on board are seen as a significant benefit by 95% of respondents. Also human error, a main factor contributing to many maritime accidents (see /10/, /11/), will be diminished by using advanced sensor systems and automation technology on the bridge according to the results of the survey.

The discussion about the role that autonomous ships can play in SAR operations and in POB situations has been quite controversial during the project duration. Better sensors available on board and assistance from shore are likely to be an asset of autonomous ships in such situations. On the other hand current regulations include an obligation to provide assistance to save life at sea /1/. It has been brought forward by some parties though that the assistance an autonomous ship can provide will be limited at best and not equivalent to the level of assistance currently offered. At this point there is no clear indication whether an autonomous ship would actually need to be capable to rescue a person at sea in danger of being lost. Asked about their opinion in this regard respondents of the conducted survey show no consistent opinion either. About a quarter indicate that they do not see an absolute necessity for autonomous ship to be capable to rescue a person from the sea. On the other hand almost 50% feel autonomous ships should feature such a capability with the remaining being indifferent or undecided in their opinion.

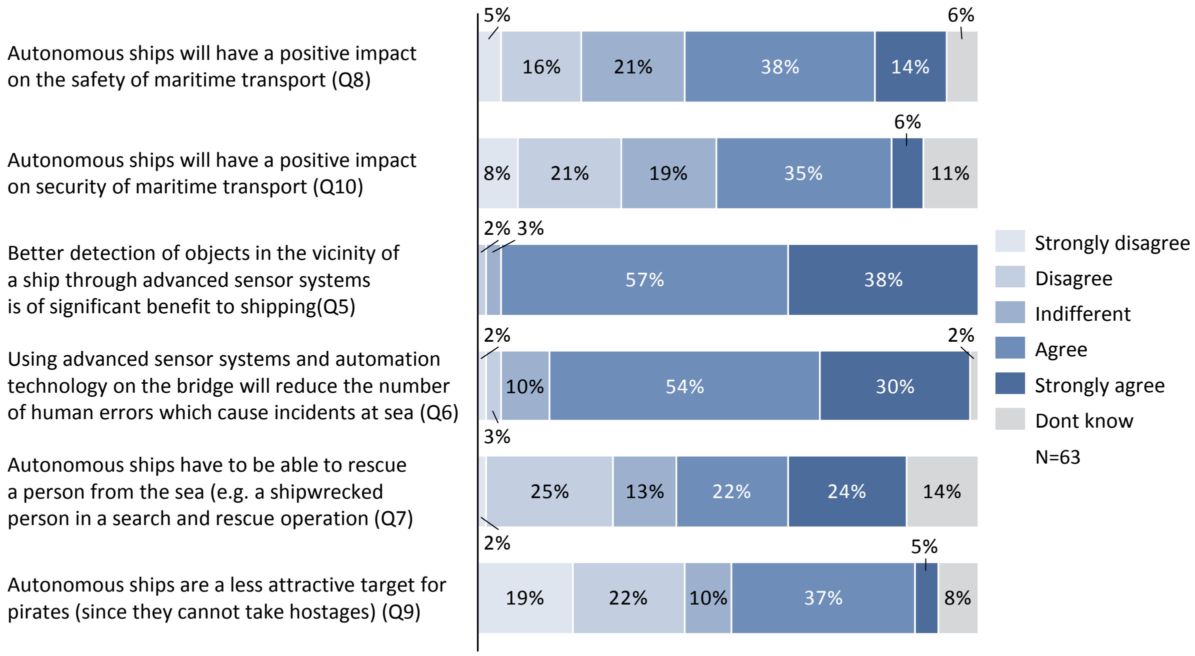

Figure 6: Respondents assessment of impact on main safety and security aspects

The initial assessment of impacts (see /1/) has revealed that particularly aspects associated with cyber security, i.e. that the unmanned ship can somehow be adversely influenced by hostile parties through the communication channels and computers used to monitor and control the ship, are relevant in the security dimension. As the maritime industry realizes higher degrees of automation overall – independent of autonomous ships – cyber-attacks pose relatively new threats compared to other industries where digitalization is already more widely spread. The sector is quite aware of the new threat and – since all programmable systems regardless of land based or ship board are equally vulnerable – might very well adapt best practices from other industry to mitigate emerging risks /12/. Nonetheless cyber security represents a major challenge with is also reflected in the results of the external stakeholder consultation (see Figure 7): two thirds of participants see cyber security as a more serious threat for autonomous ships than for comparable land based systems. Piracy – an issue frequently brought forward in discussions with stakeholders about the MUNIN concept – on the other hand is seen less clearly as a pertinent security threat for autonomous ships by the participants of the survey. Thus the stakeholder survey doesn't emphasize the results from the Flag States consultation in Chapter 3.1.3 where piracy was perceived as a quite worrying scenario.

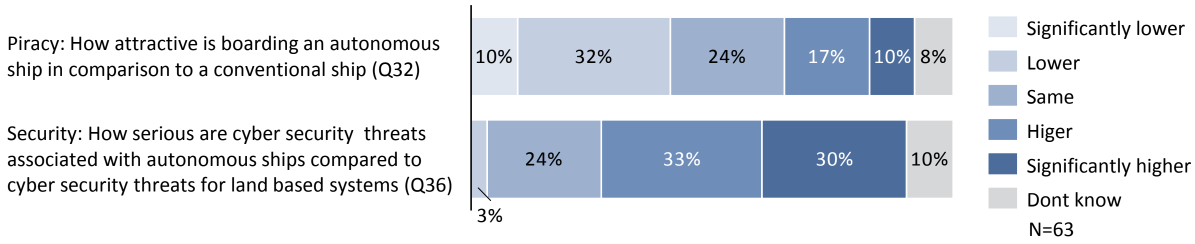

Figure 7: Respondents assessment of piracy and cyber security aspects

4.2.2.3 Social and environmental aspects

A main rational for autonomous ships is an increase in social sustainability by shifting maritime professions from an on board environment towards land based jobs. This would prevent the fact that mariners are somewhat disconnection from their social environment during the long time periods they spend on sea and accordingly increase the attractiveness of their work environment. While the overall assessment of social impacts associated with the concept of autonomous ships by the MUNIN expert panel in the first step of the assessment had proven to be rather difficult one aspect stood out: There was consensus that autonomous ships would have a positive impact on the work-life balance and increase the attractiveness of jobs in the maritime industry. This assumption was confirmed by the stakeholders involved in the questionnaire. A large majority of three-quarter agreed that being disconnected from their social environment for long periods of time is a disadvantage of the work of mariners. Almost as strong was the support for the statement that shifting maritime jobs to a shore control centre would influence the work-life balance positively and the attractiveness of the working on board a ship compared to a shore control centre was rated favourable only by one-quarter of all respondents (see Figure 8). Interestingly enough though, respondents that did or do work on board of a ship were less inclined to agree that shifting jobs from ship to shore would increase the attractiveness than those without on board experience. Of course it has to be considered that respondents with experience on board knew about the up- and downsides before they decided to work as mariners while respondents with no such experience might have chosen a nautical job, but decided otherwise, potentially due to lack in lack in social contact.

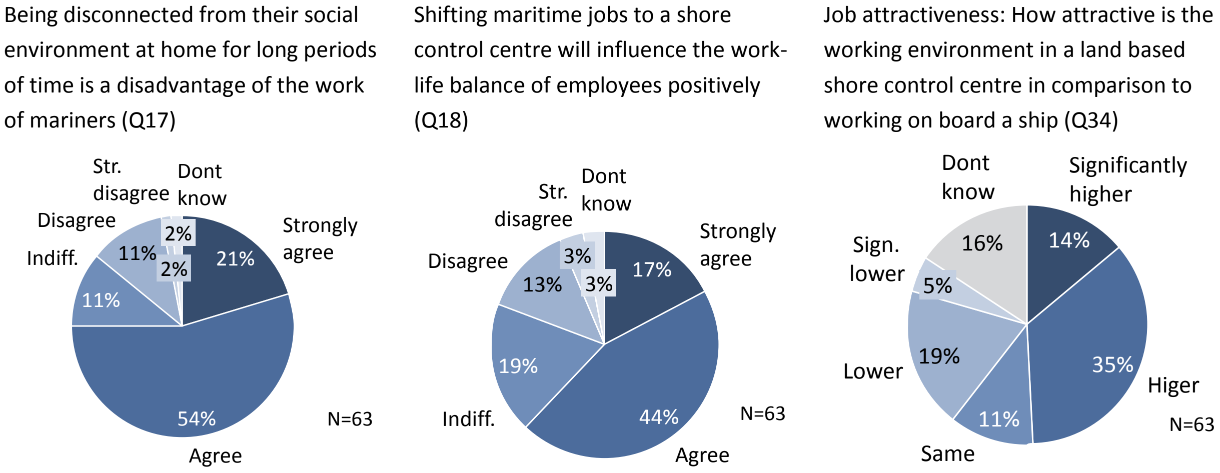

Figure 8: Respondents assessment of main social impacts

Environmental sustainability is of increasing importance for the shipping industry. In this context the development of autonomous ships is seen as one innovation that has the potential to contribute towards the industries commitment to reduce its environmental footprint in future. This view is shared by the polled maritime stakeholders: a majority associates a higher environmental sustainability with autonomous ships in comparison to conventional ships, although almost none sees a significant increase. The second largest group expects the same level of environmental sustainability for autonomous and conventional ships (see Figure 9).

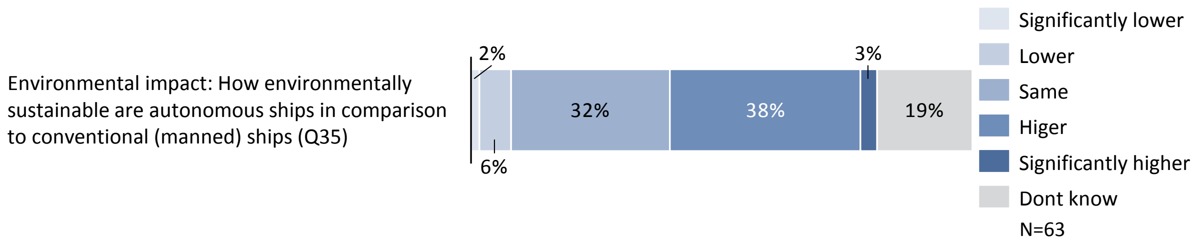

Figure 9: Respondents assessment of environmental sustainability

The main drivers behind an assumed increase in environmental sustainability of autonomous ships are twofold.

One the one hand discharges to sea can be reduced if the human element on board is taken out of the system: automation of processes and centralized monitoring in the shore control center reduce the probability of mistakes and thus accidental discharges. Moreover illegal intentional discharges become more difficult if data about the ships behaviour is stored centrally on shore with the possibility for governments to demand access to the data in case of doubt. The results of the conducted survey supports this argumentation: almost half of the respondents see human error as the main reason for illegal and accidental discharges to sea against less than 20% opposed to this assumption. Consistently the wide majority also expects a reduction of illegal and accidental discharges associated with autonomous ships (see Figure 10).

On the other hand, emissions to air can be reduced if autonomous ships are more fuel efficient than conventional ships. A further automation of the engine room, changes in ship design and an increase of the efficiency of ship operation have the potential to reduced fuel consumption for autonomous ships. According to the results of the survey a more widespread application of slow steaming concepts will play a significant role in this context as well. All in all 54% of respondents see an overall positive impact of autonomous ships on the environment with only 12% expecting negative effects (see Figure 10).

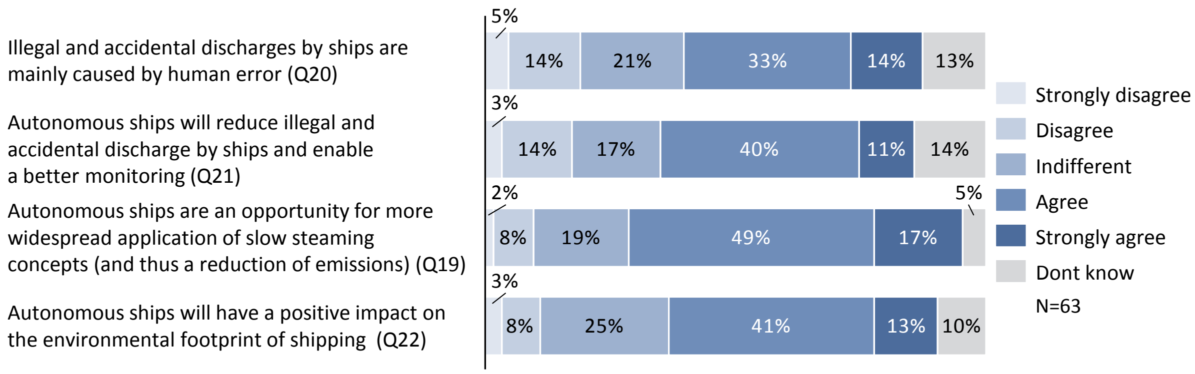

Figure 10: Respondents assessment of main environmental aspects

4.2.2.4 Technological aspects

Unmanned vehicles have been operated for a considerable amount of time in many fields of transport, for example as unmanned subways and trains or unmanned research submarines. Especially technological developments associated with self-driving cars are currently advancing rapidly getting autonomous cars out of the realm of science fiction. Cars offering basic autonomous capabilities are already on offer today and completely autonomous cars are expected to become reality before the end of the decade /13/. Accordingly a similar development might lie ahead for autonomous ships as well. As The Economist puts it: *"Civilian operations using unmanned aircraft are coming. Driverless cars are clocking up thousands of test miles. So why not let remote-controlled ships set sail without a crew?"*/14/. The maritime stakeholders in the survey concur with this judgement. A large majority (70%) expect the technology for autonomous ships to advance rapidly in future. 60% of respondents even go one step further by agreeing that from a technological perspective it would be feasible to build and operate autonomous ships already today. Thus a successful market introduction is one main challenge for future research and development on autonomous vessels. This will result in valuable new technologies available to applications in maritime transportation overall according to polled stakeholders' opinion (see Figure 11).

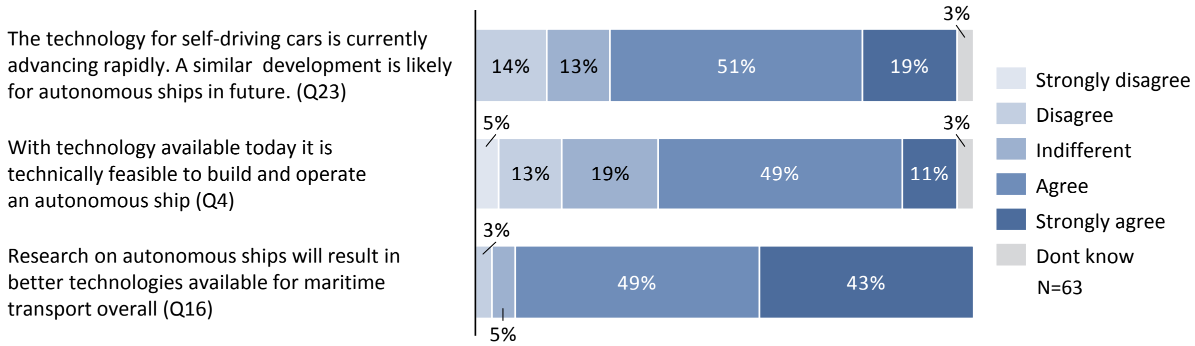

Figure 11: Respondents assessment of general technological aspects

Regarding technological research two of the MUNIN projects' priority areas were on the autonomous bridge and the autonomous engine room which were emphasized in the survey as well.

A critical functionality of the autonomous bridge is object detection. In order to implement reliable anti-collision functionalities on an autonomous vessel it needs to be equipped with advanced sensor systems which reliably detect obstacles in the ships surroundings. Current legislation requires that a "proper look-out" shall be maintained on the bridge at all times "by sight and hearing"/15/. This might be interpreted to imply that there must be a human per se to fulfil the function of proper look-out and thus would represent a major hurdle for the introduction of a further automation on the bridge. The participants of the survey do not see the human look out as an imperative though, with almost three quarters agreeing that sensors, if proven to work reliably, may take over the function. Further, regarding the effectiveness of object detection 72% of respondents expect a sensor systems to work as good or better that a human look-out. This paves the way for an intermediate step towards fully autonomous ship operation identified in the MUNIN project: the B0 scenario case (see /1/) where bridge crews will only work daylight hours, similar to engine crews on some vessel today. Based on the survey results this scenario finds approval with more than two thirds of respondents agreeing that bridge crews could only work daylight hours on certain vessels in future (see Figure 12).

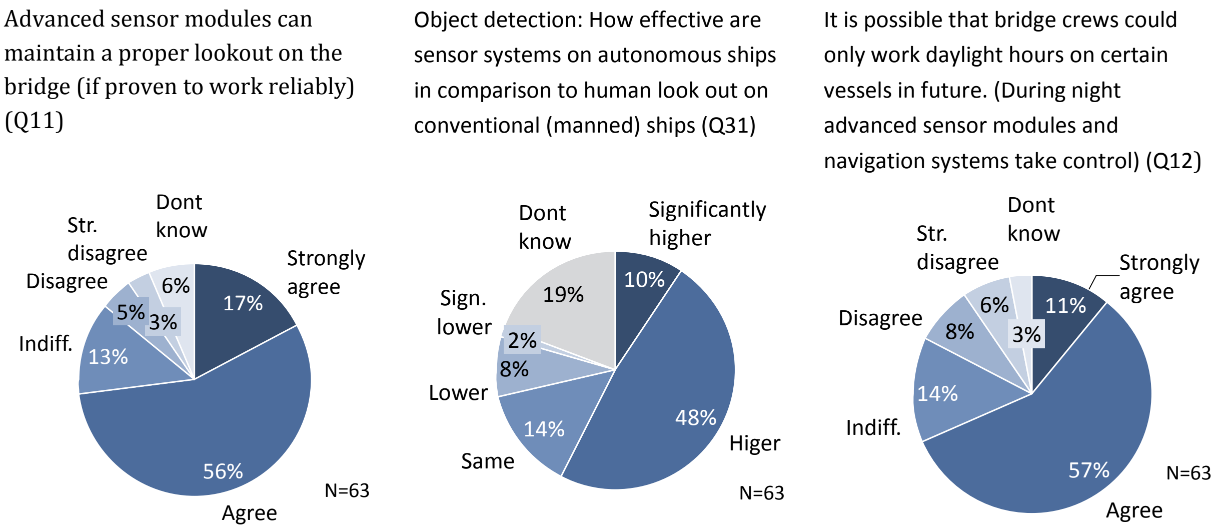

Figure 12: Respondents assessment of technological aspects associated with navigation

With regards to the autonomous engine room concept developed in the MUNIN project the goal was to enable the technical ship systems' functionality for a longer period of time without a need for manual human intervention. The aim was to achieve sufficient system robustness (reliable engine operation for 500 hours) and design an appropriate maintenance strategy /16/. That it feasible to have the engine room unmanned for a complete voyage finds wide agreement with those surveyed: only 20% express doubts in this regard. More caution prevails concerning the necessity to concentrate all necessary maintenance and repair work for an autonomous ship in the time the vessel spends in port. 30% consider this as a problem – but on the other hand still more than 50% agree that such an approach is feasible. Strong consensus exists, however, that maintenance concepts developed for autonomous ships will contribute to a reduction of costs associated with maintenance and repair and thus potentially benefit conventional (manned) ship operation as well (see Figure 13).

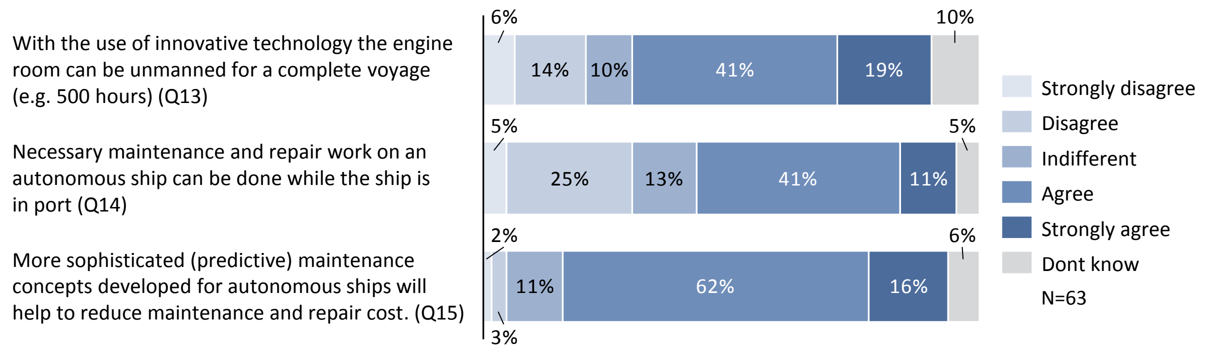

Figure 13: Respondents assessment of technological aspects associated with the engine

4.2.2.5 Opportunities and challenges

Waterborne TP identified the autonomous ship as a main opportunity for a competitive and sustainable maritime industry in Europe /17/. MUNIN started out to seize this opportunity by turning the vision of an autonomous vessel into an actual concept. Now, after the project is close to its end and has received significant media attention, how do maritime stakeholders evaluate the idea? Actually a very large majority shares the perception of autonomous ships being an important opportunity. On the other hand participants see associated benefits to outweigh risks less clearly (see Figure 14).

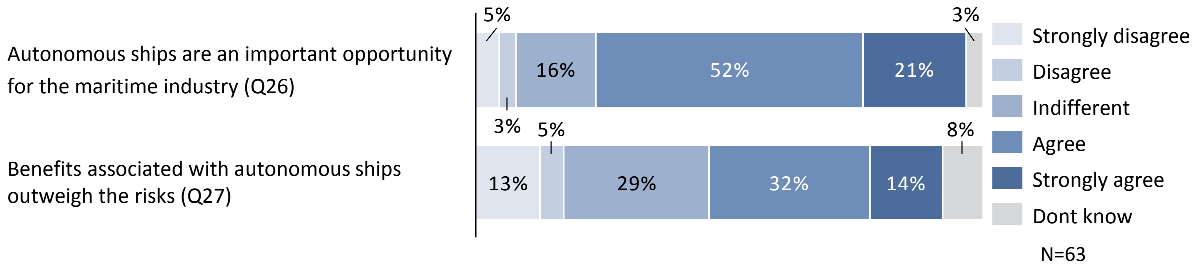

Figure 14: Respondents assessment of autonomous ships as an opportunity and the balance between benefit and risk involved

Besides their general view of autonomous ships being an opportunity overall maritime stakeholders were also asked where in particular they see the most important opportunities associated with autonomous ships and further what they regard as the principal challenges for an deployment of autonomous ships in merchant shipping. To this end they were supposed to identify their top three out of a given list of choices. The outcome of the assessment of main opportunities and challenges is shown in Figure 15. The most frequently mentioned opportunities were new innovative ship designs, a possible transfer of developed innovative technologies to conventional ships and lower maritime transport cost. Least frequently cited were a reduced environmental footprint of shipping, an increase of maritime security and an enhanced attractiveness of working in the maritime industry. With regards to challenges the participants ranked a prevention of accidents due to technology failures highest followed by an adaptation of maritime legislation for unmanned ships and the safe interaction of autonomous and conventional ships. Least frequently referred to were preventing unlawful boarding by unauthorized persons, ensuring high quality maritime personnel in future and assuring reliable satellite communication between ship and shore.

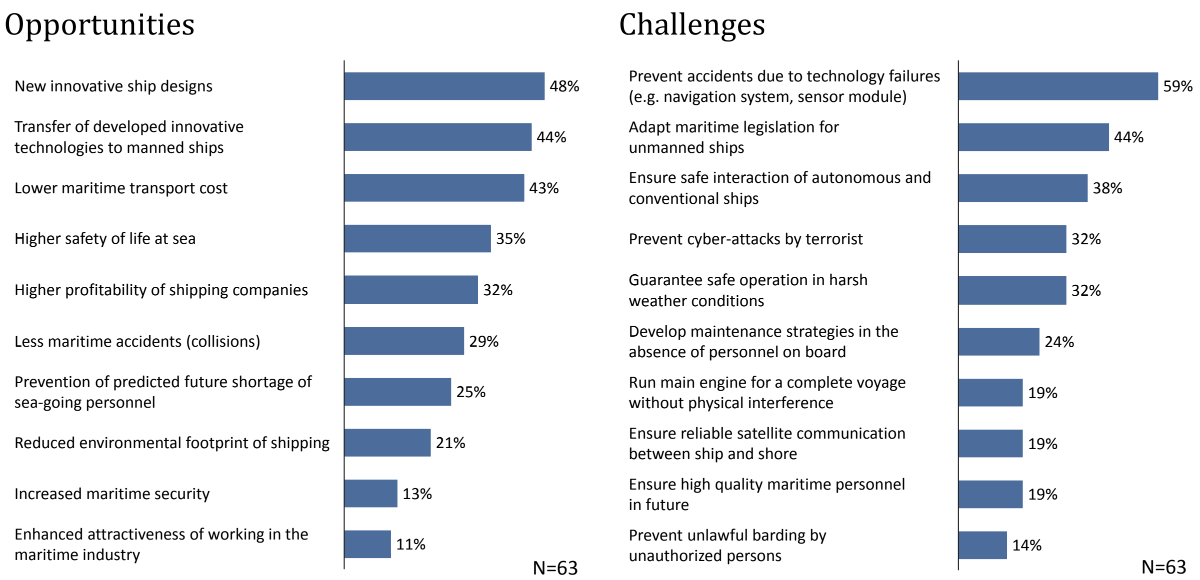

Figure 15: Respondents assessment of main opportunities and challenges associated with autonomous ships

4.3 Conclusion

In order to ensure the representation of a wider external view on the innovation of autonomous ships a questionnaire covering key impacts was drafted and forwarded to maritime stakeholders. This way an additional perspective is added to the technology assessment of the concept of an autonomous ship. Taken together with the results of the first step of the assessment (see /1/) this allows a more comprehensive qualitative assessment of the key impacts associated with autonomous ships to be accomplished.
The evaluation of the survey results has revealed that maritime stakeholders polled have a quite positive view on autonomous ships and expect a first deployment of respective concepts to take place within the next 10 years. Furthermore, 60% of respondents assume this will contribute to an overall decrease in transport cost.

Safety and security constitute an important precondition for autonomous ships. It has to be proven that autonomous ships are at least as safe as conventional ships. Participants of the survey are confident in this respect though. They predominantly agree that using advanced sensor systems and automation technology on the bridge will contribute to a reduction of human error – a main factor contributing to many accidents at sea. Consistently 52% of respondents agree that autonomous ships will have a positive impact on the safety of maritime transport as against 21% who disagree. Regarding maritime security cyber security constitutes a main challenge for autonomous ships as had already been identified in the previous internal impact identification (see /1/). The results of the survey could confirm this assumption.

As seagoing professions are increasingly perceived as unattractive today a main rational for autonomous ships is an associated improvement of social sustainability. This assumption is supported by the results of the questionnaire. Asked whether being disconnected from their social environment for long periods of time is a disadvantage of the work of mariners 75% of all participants agreed. Less clear of a consensus was reached whether the working environment in shore control centre is more attractive than working on board – half of participants saw a higher attractiveness while the other half didn't see a job in a shore control centre to be more appealing or didn't know. Regarding the environmental impact of autonomous ships the participants were quite confident: 73% expect autonomous ships to be more environmentally sustainable.

Furthermore, results of the poll show that a huge majority of more than 90% of maritime stakeholders expect research on autonomous ships to result in better technologies available for use in maritime transport overall. One starting point will certainly be the development of advanced sensor modules and navigation systems with the result that bridge crews could only work daylight hours on certain vessels which more than two thirds of respondents agree will be an option for the future.

The main opportunity of continued research on autonomous ships according to the respondents is technical developments– both completely new autonomous ship designs and individual modules developed for autonomous ships but available for conventional ships as well. Challenges are primarily seen in a prevention of accidents – both due to technical failures and an interaction of autonomous and conventional ships – and the adaptation of maritime legislation for autonomous ships.

5. Summary

In order to identify the main risks related to the operation of an unmanned ship, workshops were held to identify hazards and rate the risks associated with the identified hazards. The result of this work was the identification of several hazards from different aspects of the ship operation, where 23 of the hazards were rated to have risks that are unacceptable unless appropriate means for risk control are implemented. As part of the MUNIN project suitable risk mitigation measures and control options have been developed with very promising results which indicate that issues at hand are manageable. Controlling the cost of risk control options will be a main challenge. To be conclusive in detail one will need to continue to work on the issue. Particularly a full autonomous ship design would make the necessary assessments of RCO reliability possible.

In terms of legal issues, this report attempted to gather the views of flag States on the feasibility, acceptability and desirability of an unmanned ship. Flag States are the ones that will/would drive change at the international level, enable conventions amendments, and make the unmanned ship a reality, should they be convinced about it. Their views are therefore very important. What results from this questionnaire is that it appears that the most problematic technical point raised by respondent States was the lack of physical human presence on board to take care of specific problems, such as operational or accidental spills, or a sudden malfunction. To this point, one can answer that full and comprehensive information about the MUNIN proposals and solutions would go a long way towards convincing concerned parties that the unmanned ship can be, and actually is, at least as safe as a traditional manned ship. The most problematic political problem appears to relate to piracy and acts of terrorism, as well as SAR obligations. It is difficult to draw any firm conclusions in this respect, as the current migratory, refugee and terrorism crisis that is hitting Europe may have tainted responses from States (and prevented more State to respond). Finally, from a purely legal point of view, there does not appear to be any significant and unsurmountable problems that could not be resolved by amendments to existing conventions, and by innovative legal solutions. This point is addressed further in the subsequent report containing the *Quantitative assessment* of the MUNIN concept for an autonomous vessel.

To add another perspective to the technology assessment of the concept of an autonomous ship, external stakeholders were invited to participate in a structured questionnaire. The evaluation of the survey has revealed an overall quite positive view on autonomous ships. The development of autonomous ships and associated technologies is seen as an important opportunity for the maritime industry by a very large majority of respondents. On the other hand risks are also clearly seen in several areas by the participants who further have a less unanimous opinion whether benefits associated with autonomous ships will outweigh the risks. Thus, future research and development will need to place particular emphasis on main risks and obstacles that have been identified in order to achieve a wide social acceptability of the concept.

References

/1/ Kretschmann L. and Bruhn, W. (Ed) (2015). MUNIN Deliverable D9.1: Impact matrix and report

/2/ Van Den Ende, Jan et al. (1998). Traditional and Modern Technology Assessment: Toward a Toolkit. Technological Forecasting and Social Change 58, 5–21 (1998)

/3/ TAMI Technology Assessment in Europe - Between Method and Impact (2004). Final Report (12 month). Online at: https://www.ta-swiss.ch/?redirect=getfile.php&cmd[getfile][uid]=944 [accessed 08/07/2015]

/4/ International Maritime Organization: "MSC 83/INF.2 Formal Safety Assessment – Consolidated text of the Guidelines for Formal Safety Assessment (FSA) for use in the rule-making process (MSC/Circ.1023-MEPC/Circ.392)." 2007.

/5/ Rødseth, Ø. (2015). MUNIN Deliverable 10.2: New ship designs for autonomous vessels

/6/ Porathe, T., Costa, N., Tjora, Å. (2014) MUNIN Deliverable 7.4 Organizational lay-out of SOC

/7/ Porathe, T., Man, Y. (2014) MUNIN Deliverable 7.3: Technical layout of SCC

/8/ Burmeister, H.-C. et al. (2015) MUNIN Deliverable 5.4: Autonomous deep-sea navigation concept

/9/ Häder, M. (2015) Empirische Sozialforschung Eine Einführung. Wiesbaden Springer

/10/ Baker, C.C. and McCafferty, D.B. (2005). Accident Database Review of Human Element Concerns: What do the Results Mean for Classification? ABS Technical Papers 2005. Online at: https://www.eagle.org/eagleExternal PortalWEB/Show Property/BEA%20Repository/References/Technical%20Papers/2005/Accident DatabaseReview%20of%20HumanElementConcerns [accessed 08/07/2015]

/11/ Rothblum, Anita M. (2000). Human Error and Marine Safety. U.S. Coast Guard Research & Development Center. Online at: www.bowles-langley.com/wp-content/files_mf/humanerrorandmarinesafety26.pdf [accessed 11/09/2014]

/12/ Meyer, M. (2015). Schreckgespenst Cyberattacke. Hansa International Maritime Journal – 152. Jahrgang – 2015 – Nr. 5.

/13/ Shanker, R. et al. (2013). Autonomous Cars Self-Driving the New Auto Industry Paradigm. Morgan Stanly Blue Paper

/14/ The Economist (2014). Ghost Ships. The Economist Technology Quarterly: Q1 2014

/15/ Convention on the International Regulations for Preventing Collisions at Sea (COLREG), 20 October 1972

/16/ Fentzahn E. and Schmidt M. (2015). MUNIN Deliverable D6.9: Draft final report: Autonomous engine room

/17/ Waterborne (2011). Waterborne Transport & Operations - Key for Europe’s Development and Future,Strategic Research Agenda - Implementation - Route Map Issue 2 - May 2011

Annex A: Questionnaire MUNIN Stakeholder Survey

MUNIN Stakeholder Survey

MUNIN TUHH Technische Universität Hamburg-Harburg Fraunhofer CML

"Civilian operations using unmanned aircraft are coming. Driverless cars are clocking up thousands of test miles. So why not let remote-controlled ships set sail without a crew?"
The Economist

The research project MUNIN works on a future concept for a fully or partially unmanned merchant vessel.

An autonomous ship in the MUNIN concept is not designed for an unmanned voyage from berth to berth, but for unmanned deep sea transport. Approaching and berthing is still done by a conventional crew on board. Further, during deep sea voyage the vessel is constantly monitored by mariners ashore in a shore control center, which, in case of an emergency, can interact with the vessel at all times, thus ensuring a safe and efficient voyage.

MUNIN´s vision of an autonomous ship builds on innovative technology deployed on board and ashore:

- The autonomous ship will be equipped with advanced sensor systems to detect and avoid obstacles reliably. A positioning and navigation system allows determining and controlling exact location, speed and course as well as route. It determines COLREG-obligations between ships and conducts compliant collision avoidance manoeuvres while also operating the ship safely in harsh weather conditions.
- The engine is equipped with an advanced onboard control system which operates the vessel and its equipment. In combination with an indicator based maintenance interaction system the engine can operate reliably for one voyage without physical interference from a person in the engine room.
- In a shore-side control center qualified personnel monitors the autonomously operating vessels. In case of unintended and unforeseen events the shore control center has the capability to assist or even remotely operate the ship.
- Reliable communication links and a robust communication architecture ensure that onshore and offshore components are appropriately connected.

A note on privacy
This survey is anonymous.
The record of your survey responses does not contain any identifying information about you, unless a specific survey question explicitly asked for it. If you used an identifying token to access this survey, please rest assured that this token will not be stored together with your responses. It is managed in a separate database and will only be updated to indicate whether you did (or did not) complete this survey. There is no way of matching identification tokens with survey responses.

Load unfinished survey | Next | Exit and clear survey

0% 100%

General questions

* **Please rate the following statement.**

	Very familar	Familar	Somewhat familar	Not very familar	Not familar
How familiar are you with the concept of autonomous ships?	○	○	○	○	○
How familiar are you with the research project MUNIN?	○	○	○	○	○

* **Please rate the following statement.**

	Very positive	Positive	Indifferent	Negative	Very negative
What is your general attitude towards autonomous ships?	○	○	○	○	○

* Please rate the following statements.

	Strongly agree	Agree	Indifferent	Disagree	Strongly disagree	Don´t know
With technology available today it is technically feasible to build and operate an autonomous ship.	○	○	○	○	○	○

Resume later | Next | Exit and clear survey

0% 100%

Safety and Security

* Please rate the following statements.

	Strongly agree	Agree	Indifferent	Disagree	Strongly disagree	Don´t know
Better detection of objects in the vicinity of a ship through advanced sensor systems is of significant benefit to shipping.	○	○	○	○	○	○
Using advanced sensor systems and automation technology on the bridge will reduce the number of human errors which cause incidents at sea.	○	○	○	○	○	○
Autonomous ships have to be able to rescue a person from the sea (e.g. a shipwrecked person in a search and rescue operation).	○	○	○	○	○	○
Autonomous ships will have a positive impact on the safety of maritime transport.	○	○	○	○	○	○
Autonomous ships are a less attractive target for pirates (since they cannot take hostages).	○	○	○	○	○	○
Autonomous ships will have a positive impact on security of maritime transport.	○	○	○	○	○	○

Resume later | Next | Exit and clear survey

0% 100%

Technology

* Please rate the following statements

	Strongly agree	Agree	Indifferent	Disagree	Strongly disagree	Don´t know
Advanced sensor modules can maintain a proper lookout on the bridge (if proven to work reliably).	○	○	○	○	○	○
It is possible that bridge crews could only work daylight hours on certain vessels in future. (During night advanced sensor modules and navigation systems assisted by a shore-based entity take control. In case of an emergency, an alarm calls an officer to the bridge.)	○	○	○	○	○	○
With the use of innovative technology the engine room can be unmanned for a complete voyage (e.g. 500 hours).	○	○	○	○	○	○
Necessary maintenance and repair work on an autonomous ship can be done while the ship is in port.	○	○	○	○	○	○
More sophisticated (predictive) maintenance concepts developed for autonomous ships will help to reduce maintenance and repair cost.	○	○	○	○	○	○
Research on autonomous ships will result in better technologies available for maritime transport overall.	○	○	○	○	○	○

Resume later | Next | Exit and clear survey

0% 100%

Social & Environmental Aspects

* Please rate the following statements.

	Strongly agree	Agree	Indifferent	Disagree	Strongly disagree	Don´t know
Being disconnected from their social environment at home for long periods of time is a disadvantage of the work of mariners.	○	○	○	○	○	○
Shifting maritime jobs to a shore control centre will influence the work/life balance of employees positively.	○	○	○	○	○	○
Autonomous ships are an opportunity for more widespread application of slow steaming concepts (and thus a reduction of emissions).	○	○	○	○	○	○
Illegal and accidental discharges by ships are mainly caused by human error.	○	○	○	○	○	○
Autonomous ships will reduce illegal and accidental discharge by ships and enable a better monitoring.	○	○	○	○	○	○
Autonomous ships will have a positive impact on the environmental footprint of shipping.	○	○	○	○	○	○

Resume later | Next | Exit and clear survey

0% 100%

Outlook

* Please rate the following statements.

	Strongly agree	Agree	Indifferent	Disagree	Strongly disagree	Don´t know
The technology for self-driving cars is currently advancing rapidly. A similar development is likely for autonomous ships in future.	○	○	○	○	○	○
Autonomous ships will have a positive impact on the costs of maritime transport.	○	○	○	○	○	○
In future maritime legislation will adapt to comply with the specifics of autonomous ships.	○	○	○	○	○	○
Autonomous ships are an important opportunity for the maritime industry.	○	○	○	○	○	○
Benefits associated with autonomous ships outweigh the risks.	○	○	○	○	○	○

* How many years from now do you expect the first autonomous ship to be deployed in merchant shipping?
Choose one of the following answers

Please choose... ▼

* How many years from now do you expect autonomous ships to be commonly deployed in merchant shipping?
Choose one of the following answers

Please choose... ▼

* Please rate the following statement.

	Very positive	Positive	Indifferent	Negative	Very negative
What is your general attitude towards autonomous ships?	○	○	○	○	○

Resume later | Next | Exit and clear survey

0% 100%

Comparison

* Please rate the following questions.

	Significantly higher	Higher	Same	Lower	Significantly lower	Don´t know
Object detection: How effective are sensor systems on autonomous ships in comparison to human look out on conventional (manned) ships?	○	○	○	○	○	○
Piracy: How attractive is boarding an autonomous ship in comparison to a conventional (manned) ship?	○	○	○	○	○	○
Profitability: How profitable are autonomous ships in comparison to conventional (manned) ships?	○	○	○	○	○	○
Attractiveness of jobs: How attractive is the working environment in a land based shore control centre in comparison to working on board a ship?	○	○	○	○	○	○
Environmental impact: How environmentally sustainable are autonomous ships in comparison to conventional (manned) ships?	○	○	○	○	○	○
Security: How serious are cyber security threats associated with autonomous ships compared to cyber security threats for land based systems (e.g. IT systems of government/companies)?	○	○	○	○	○	○

Resume later | Next | Exit and clear survey

0% 100%

Voting

* What are the most important opportunities associated with autonomous ships?
Please select 3 answers

- ☐ New innovative ship designs
- ☐ Enhanced attractiveness of working in the maritime industry
- ☐ Lower maritime transport cost
- ☐ Prevention of predicted future shortage of sea-going personnel
- ☐ Transfer of developed innovative technologies to manned ships
- ☐ Less maritime accidents (collisions)
- ☐ Higher safety of life at sea
- ☐ Reduced environmental footprint of shipping
- ☐ Increased maritime security
- ☐ Higher profitability of shipping companies

* What do you regard as the principal challenges associated with autonomous ships?
Please select 3 answers

- ☐ Prevent accidents due to technology failures (e.g. navigation system, sensor module)
- ☐ Ensure reliable satellite communication between ship and shore
- ☐ Ensure safe interaction of autonomous and conventional ships
- ☐ Guarantee safe operation in harsh weather conditions
- ☐ Adapt maritime legislation for unmanned ships
- ☐ Develop maintenance strategies in the absence of personnel on board
- ☐ Ensure high quality maritime personnel in future
- ☐ Prevent cyber-attacks by terrorist
- ☐ Prevent unlawful barding by unauthorized persons
- ☐ Run main engine for a complete voyage without physical interference

Resume later | Next | Exit and clear survey

0% 100%

Demographics

What year were you born?
Choose one of the following answers

Please choose...

What is your gender?

Female   Male

What is your current occupation?

Are you employed in the maritime industry?

Yes   No

Do or did you work on board of a ship?

Yes   No

Resume later   Submit   Exit and clear survey

Thank you very much for your kind participation!
If you are interested in additional information on MUNIN please follow this link:
http://www.unmanned-ship.org/munin/

Annex B: HazId Analysis results

The results of the HazId and risk assessment are summarized hereafter. The columns represent risk to human health or life, material losses or negative environmental impact. Each unwanted event has been classified according to severity as shown in the table below.

Table 3: Severity index

		Personal	Ship	Environment
1	**Minor**	Minor injury	Local equipment	Local spill
2	**Significant**	Several injuries	Non-severe ship damage	Significant local spill
3	**Severe**	One fatality	Severe damage	Severe local spill
4	**Very severe**	10 fatalities	Total loss	Severe large spill
5	**Catastrophic**	100 fatalities or more	Loss of several ships	Very large spill

It has also been classified according to frequency so that we get a risk diagram as shown below.

Table 4: Frequency index and resulting risk

			Minor	Significant	Severe	Very severe	Catastrophic
		FI \ SI	1	2	3	4	5
Frequent	< 1 ship month	7	8	9	10	11	12
Common	< 1 ship year	6	7	8	9	10	11
Reasonably	< 10 ship year	5	6	7	8	9	10
Possible	< 100 ship year	4	5	6	7	8	9
Remote	< 1000 ship years	3	4	5	6	7	8
Unlikely	< 10000 ship year	2	3	4	5	6	7
Extermely unlikely	< 100000 ship years	1	2	3	4	5	6

The red areas represent not acceptable and the green are acceptable. The yellow areas should be analysed further to ensure that the risk can be made as low as reasonable practicable.

The resulting hazard identification and risk assessment is shown in the table below.

Table 5: Hazard identification and risk assessment

	RI/Human	RI/Material	RI/Environ
1. Voyage / Shore control centre			
Loss due to human error in input to voyage plan	6	6	6
Loss of ship-shore connection - loss of ship/foundering	2	6	4
Loss of ship-shore connection - collision	6	6	5
Failure of update (e.g. of nautical publications, weather forecasts) - foundering/grounding	3	7	5

	RI/Human	RI/Material	RI/Environ
Human error in remote monitoring and control (e.g. through situation unawareness, data misinterpretation, SCC capacity overload) - collision	10	10	9
Human error in remote maintenance (e.g. through situation unawareness, data misinterpretation, SCC capacity overload) - foundering/loss	6	10	8
2. Sailing			
Foundering in heavy weather	4	8	6
Collision in low visibility	9	9	8
Collision with conventional ships in heavy traffic	9	9	8
Grounding after propulsion failure	5	8	8
Collision after sensor failure	9	9	8
Collision after propulsion failure	7	7	6
Collision with marine wildlife (e.g. whales, squids, carcasses)	2	2	5
Collision with floating objects	6	8	6
Collision with offshore installations	5	6	5
Embarkation and disembarkation of crew at a rendezvous point - injury	8	5	5
Participation / assistance in SAR operation	5	5	4
Operation in fail-to-safe mode - unintended damage to ship	3	5	4
3. Observation			
Failure in detection of small objects - fail to observe castaway/wreckage	9	6	6
Failure in detection of collision targets - collision	7	7	6
Failure in detection of navigational marks - grounding	2	6	4
Failure in detection of ship lights and shapes - collision	7	7	6
Failure in detection of semi-submerged towed or floating devices (e.g. seismic gauges, fishing trawls or nets)	5	8	5
Detection of unforeseeable events (e.g. freak wave) - foundering	3	7	5
Detection of considerable data discrepancy between charted water depth and sounded water depth - grounding	3	6	4
Detection of considerable data discrepancy between weather forecast and weather situation – foundering	3	7	5
4. Safety / emergency			
Failure in position fixing (due to e.g. GPS selective availability) - collision	6	6	5
Communication failure in case of other ship in distress (e.g. message reception, relay, acknowledgement) - loss of other ship	6	6	5

	RI/Human	RI/Material	RI/Environ
Communication failure in case of own ship in distress (e.g. with SCC, relevant authorities, ships in vicinity) - loss of own ship	2	6	4
Fire loss of ship or systems	5	8	6
Water inrush - sudden hull damage - loss	3	7	5
CO_2 application for firefighting purposes might compromise safety of individuals on board - stowaways	8	6	5
5. Security			
Wilful damage to ship structures by others (e.g. pirates, terrorists)	3	5	3
Attempt of unauthorised ship boarding (e.g. pirates, terrorists, stowaways, smugglers) - hijack and loss of ship	3	7	3
Unauthorised individuals on board (e.g. pirates, terrorists, stowaways, smugglers, left-behind crew members) - illegal actions	3	6	3
Failure of ship's IT systems (e.g. due to bugs) - loss of ship	4	7	4
Jamming or spoofing of AIS or GPS signals - collision with other ship	8	8	8
Jamming or spoofing of communications, hacker attack, also on SCC (e.g. in case of pirate or terrorist attack) - collision with other ship	8	8	8
Hacker attack on system as above - grounding in critical areas (port appr.)	7	9	9
6. Crew / passenger			
not applicable			
7. Cargo / stability / ship strength			
Loss of intact stability due to structural damage - Foundering	3	7	5
Loss of intact stability due to unfavourable ship responses (e.g. to waves)	6	10	8
Loss of intact stability due to shift/liquification of cargo	5	9	7
Loss of intact stability due to icing	1	5	3
8. Technical			
Sensor failure - loss of control	7	8	7
Sensor failure due to ship icing - loss of observation/control	2	2	2
Temporary Loss of electricity (e.g. due to black-out) - loss of control	6	8	6
Permanent loss of electricity - loss of control	4	7	5
Failure of ship's IT structure (e.g. due to fire in the server room) - no control	6	10	8
Part failure of propulsion system - loss of control	5	7	5
Total loss of propulsion	4	8	4
Part failure of rudder function	5	7	5

	RI/Human	RI/Material	RI/Environ
Total loss of rudder function	4	8	4
Failure to drop anchor when drifting - grounding	2	6	4
Failure to heave anchor	4	6	4
9. Special ship functions			
no hazards identified			
10. Administrative			
Discharge of MARPOL-relevant substances (e.g. fuel tank overflow)	3	3	5
Denial of port access due to ISPS/ISM non-compliance - stowaway or other	6	7	6
Failure to comply with ship reporting regime - PSC detention	6	7	6
Failure to comply with administrative requirements - PSC detention	6	7	6