CHAPTER 18

The Societal Impacts of Autonomous Ships: The Norwegian Perspective

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1 Introduction

Autonomous ships have generated significant interest in researchers for a decade marked by the first large concept study, the EU-financed Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) project (Rødseth & Burmeister, 2012). Despite slower developments than initially expected, there are still high expectations and correspondingly

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high investments in ship autonomy around the world. Design projects examined in our research are the container ship "Yara Birkeland", the ASKO cargo ferries, the inland waterway vessel Seafar, and the container ship "Zhi Fei" (CNS, 2021; Kongsberg, 2020; Seafar, 2022; Yara, 2018). In addition, several large research projects are ongoing worldwide, e.g., the EU projects AUTOSHIP (2022) and AEGIS (2022), the Korean Autonomous Surface Ship project, and the Norwegian SFI AutoShip (KASS, 2022; NTNU, 2022). Figures published by these projects add up to research investments of close to 200 million Euros.

The definition of "an autonomous ship" is still debated with opinions ranging from decision support on conventional ships to fully uncrewed and automatic operations. In this chapter, we will only assess "constrained autonomy" which is defined as uncrewed operation with limited but relatively advanced automation onboard and supported in complex situations by operators in a remote-control center (RCC) (Rødseth, 2021). The focus is on uncrewed cargo transport, but autonomous passenger transport will also be investigated, where it is anticipated that there will be safety personnel onboard to assist passengers in normal operations as well as in emergencies while nautical operations, e.g., sailing and berthing, will be handled by constrained autonomy.

Section 2 details both actual and proposed use cases for autonomous ships in Norway with a brief qualitative description of expected societal effects also detailing what attributes of autonomous ship operations contribute to these effects. The concept of "societal impact" can be many-faceted, but in this chapter societal impact is specifically based on a selection of 8 of the 17 sustainable development goals (SDG) (detailed in Sect. 3). In Sect. 3 the SDGs will also be linked to concrete societal effects and to the autonomous ship attributes discussed in Sect. 2. Measuring societal impact depends on the delimitation of the system being assessed and therefore it can be complex and difficult to accurately measure with concrete key performance indicators (KPI). Section 4 will explore these issues in some detail and look at where quantitative KPIs can be used; and just as importantly where they are less useful. This section also describes some KPIs that have been developed in the writers' research projects. Section 5 summarizes the chapter and provides some conclusions.

2 Autonomous Shipping—The Norwegian Perspective

The general societal impacts are more context-dependent than environmental impacts alone. Thus, most of this chapter's analysis of societal benefits will be limited to Norway. Below is a set of key characteristics for Norway that are contextually significant for an assessment of societal impacts of autonomous shipping.

- High education, high costs: Norway has a highly educated workforce with high gender equality and high wages—only 10% of the workforce earning less than EUR 3000 per month and the average being EUR 5000 (SSB, 2022). Note: more than 50% of Norwegian seafarers are officers;
- Large and advanced maritime industry: The Norwegian maritime industry accounts for about 3% of gross domestic product and 29% of exports. It is a high-end industry, mainly focusing on various types of specialized ships (MTIF, 2020); and
- Long coast, sparse population: Norway has around 5.4 million people mostly spread along a long coast. The boundary to international waters is around 2600 km but the physical length is more than 25,000 km if the coast around major islands and fjords are counted. Sea transport is thus a critical part of the infrastructure in Norway (MTIF, 2020).

2.1 Some Relevant Attributes of Autonomous Ships

Smaller ships can be more cost-effective with autonomy than without. This is due to reduced crew cost and removal of accommodation. These benefits will be larger as ship sizes decrease (Gribkovskaia et al., 2019). Thus, autonomy is a promising innovation when considering new transport systems, based on many smaller ships, rather than larger ships which have been the predominate "economy of scale" trend. The main attributes of autonomous ships that make them an attractive option to solve certain specific societal problems are briefly described below. They are also included as the bottom row of Fig. 1.

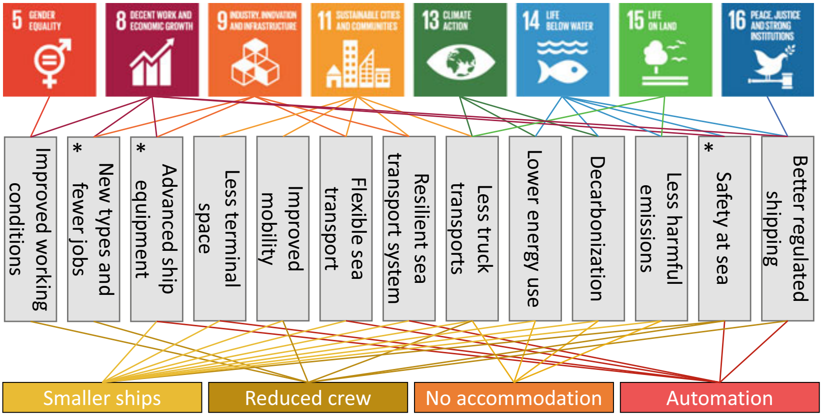

Fig. 1 Mapping between SDG, main societal effects, and autonomy attributes (*Source* Authors)

- Smaller ships give benefits in themselves in being more flexible, lower cost, and requiring less infrastructure than larger ships. On shorter voyages they are also suitable for battery operation;
- Reduced crew costs due to automation controlling the ship during most operations and only using RCC crew in more complex cases. It is likely that it will be possible to get below one crew per ship controlled when the RCC is designed to operate several ships (Kretschmann et al., 2017). This reduces operational costs, again more for smaller ships than larger ones;
- Removing crew accommodation reduces construction costs and eliminates energy consumption from the accommodation section. It also increases the cargo carrying capacity or reduces ship sizes. On the other hand, autonomous ships have additional costs related to new sensor systems and automation, but the authors believe it is likely that this is more than offset by the cost reductions; and
- Automation of the ship and its interfaces to the port, including cargo handling, makes it possible to operate around the clock without additional costs for, e.g., shore crew working at non-conventional times. This will be important for smaller ports where it may not be possible to always have a crew available. This is also an enabler for city center terminals with minimal real estate use and very fast turn-around for ship calls.

2.2 *Some Norwegian Examples*

2.2.1 *Yara Birkeland and ASKO—Reducing the Impact of Truck Transport*

Yara Birkeland (Yara, 2018) and the ASKO ferries are very different ship concepts, but one main societal effect quoted by both projects is reducing the negative impact of truck transport (Kongsberg, 2020). The ASKO ferries (two being built initially) are roll-on roll-off (RORO) ferries with a capacity of 16 EU standard trailers without tractor units. Yara Birkeland is a crane-operated ship with a capacity of 120 20-foot containers. The ships are electric powered with batteries and are completely emission free. Cargo handling will be fully automated and can in principle take place around the clock. For the ASKO project specifically, resilience is also an important factor. The main transport road today goes through the Oslo-fjord tunnel. The tunnel is frequently closed, requiring a longer detour with significant delays and increased environmental impact, which the ferries will help mitigate.

2.2.2 *Passenger and Car Transport in Rural areas—The Need for On-Demand Operations*

Norway is a country with a sparse population where many live along the coast. Many small communities are on islands or separated by deep fjords. Passenger and car ferries play an important role where bridges or tunnels cannot be built or are too expensive. To keep operational costs at a reasonable level, these ferries will normally not operate during the night. Autonomy may make it cost-effective to have a small safety crew onboard also during night operations. For very small populations, e.g., less than 100 persons on an island, one may even consider training the residents to operate safety equipment themselves. This may make it possible to offer around the clock, with fully uncrewed, and on-demand services. Some projects are now developing concepts for such operations in Norway. In Finland, the operation of an autonomous ferry was demonstrated in 2018 (FinFerries, 2018).

2.2.3 *Cargo Transport in Urban and Rural Areas—Low Real-Estate Impact*

Urban areas have high real estate costs and low tolerance for, e.g., noise from port areas. This means that port areas are in many cases being moved out of the city. This often also brings increased truck transport from the new port areas to the city. Smaller and highly automated ships offer an option to serve city centers with minimal requirements to infrastructure and demand for high-value real estate for cargo storage. This requires that cargo immediately be moved from the landing site to its destination. This could be based on palletized cargo or RORO solutions for containers or similar concepts (AEGIS, 2022).

2.2.4 Passenger Transport in Inner-City Areas—Flexible and Low Cost

Many cities have internal waterways in the form of rivers and canals. Normally, these are passed with bridges, but bridges are expensive and may also hinder waterway traffic. In the same way, as described in Sect. 2.2.2, ferries without a crew or with only a safety operator can be a good substitute for a bridge, possibly offering 24-hour services without excessive operational costs (Hyke, 2022; Zeabuz, 2022).

3 Societal Impacts and How to Measure It

3.1 Defining Societal Impact

In 2015, the United Nations defined the 17 sustainable development goals (SDG) to be a "blueprint to achieve a better and more sustainable future for all" (UN, 2022). Sea transport is relevant for most of these goals (Alamoush et al., 2021), but in the context of automation and autonomy, we have selected eight of them, as illustrated in the top row of Fig. 1.

The second row of boxes shows the more concrete societal effects that we have been investigating in our projects and how they are linked to the SDGs. These will be further discussed in Sect. 4. The third and final row shows the four attributes of autonomous ships that are considered the main contributors to the effects in row 2. These were discussed in Sect. 2.2.

3.2 Measuring Societal Impact

Key performance indicators (KPIs) are quantifiable, measurable indicators of performance. They allow for statistical analysis, qualitative snapshots, historical trends, and benchmarks between comparable concepts. At first glance, they seem very well suited toward assessing the impact of autonomous shipping. Unfortunately, when assessing the societal benefits from autonomous shipping, we need to consider the nature and complexity of societal impact.

"While environmental objectives and criteria can be based on science, a social taxonomy has to be based on international authoritative standards of topical relevance [...]" (EU, 2022).

This statement sums up two key aspects related to societal impact: It is difficult to quantify, and it is more susceptible to context. Trying to create a generic set of societal KPIs which are quantifiable and universally relevant, carries the risk of focusing on what is possible to quantify rather than what is relevant to express.

Recognizing these challenges, the results from two EU H2020 projects for autonomous ships conducting cargo transport operations, the AEGIS (2022) and AUTOSHIP (2022) are presented below. In addition, KPIs relevant within the context of passenger transport are also included (project Smarter Transport) (Smartere Transport, 2018).

The KPIs listed in Tables 1, 2, and 3 were developed as tools for assessing autonomous-ships and transport systems at the conceptual stage and to exemplify how quantitative societal impact assessments can be done. Each of the KPIs listed is mapped to the UN's sustainable development goals from Fig. 15. Note that KPIs related to GHG emissions (SDG 13) are not included in the tables as these are extensively discussed in other papers (e.g. Lindstad et al., 2021).

Tables 1, 2 and 3 have been assembled by the authors based on internal and non-published reports from the respective projects.

4 Main Societal Effects of Autonomous Shipping

In the following, each of the societal effects indicated in the middle row of Fig. 1 is discussed in detail. Most effects are generally positive, but those that may have negative effects are marked with a star in the upper left corner in Fig. 1. In cases where the Norwegian perspective is specifically relevant for the analysis, a brief discussion of why is included.

4.1 Improved Working Conditions

Autonomy and automation are often applied to tasks that are "3D": Dirty, Dangerous, or Dull. One can question which onboard jobs fall into the 3D category, but it has been shown that working on a ship is much more

Table 1 Societal KPIs from AEGIS (2022)

KPI name	*KPI description*	*SDG*
Accident rate	Number of incidents resulting in damage or injury	SDG8
Fatality rate	Number of occurrences of death by accident	SDG8
Fire incidents	Number of incidents involving smoke, heat and flames causing damage	SDG8, SDG11
Crime	All actions which constitute an offence and is punishable by Law	SDG16
Labour conditions	Quality of working environment	SDG8
Employment	Influence on the occupational rate	SDG8
Income	Influence on earnings	SDG8
Worker commuting time	Total journey employees take from home to work and back again	SDG8, SDG11
Training	Time invested in teaching an employee a particular working Skill	SDG5, SDG8 SDG16
Acoustic emissions	Amount of noise emitted by AEGIS vessels to society	SDG8, SDG15
Traffic	Amount of goods transported in ports/terminals	SDG11
Citizen complaints	Total number of societies protests against some of the AEGIS proposals' activities	SDG11
Area used for port operations	Total amount of surface needed to operate AEGIS proposals successfully	SDG11

Source Authors

dangerous than working in similar jobs on land. This is mainly due to work-related accidents onboard (Roberts et al., 2014). Thus, removing crew from the ship should improve occupational safety for the workers.

Shifting crew from ship to shore provides the potential for more standard working hours in the RCC rather than exhausting shifts on board (Jepsen et al., 2015). Shore-based work and more ordered working conditions may also encourage more women to seek maritime jobs (Kim et al., 2019).

At the height of the recent Covid-19 pandemic, an estimated 400,000 seafarers were stranded on vessels around the world with extended time on board, and often with no opportunity to go ashore during port stays (Lucas et al., 2021). In addition, the pandemic led to a lack of sufficient

Table 2 Societal KPIs from AUTOSHIP (2022)

KPI name	*KPI description*	*SDG*
Reduction in tonne-km transported on road	The reduction in tonne-km transported on road is found by calculating the distance a truck would have to drive to transport the goods between the same two points as if the ship is transporting the goods (D_{truck}), and multiplying with the total transported weight (M)	SDG11, SDG15
Reduction in truck transport km	Reduction in truck-km is estimated by first calculating how many trucks would be needed if the autonomous ship is not performing the freight n_{truck}. Then calculating how far each truck would need to drive D_{truck} and finally the total reduced truck transport distance	SDG11, SDG15
Number of hours of tasks at dangerous areas removed	Removing people from manual tasks such as cargo handling, mooring and deck operations, improves safety by reducing the risk of personnel injury from moving equipment. n is the number of locations visited in the time period for measuring number of reduced manual tasks, $t_{\text{task}}(j)$ is the duration of the task at location j	SDG8

Source Authors

healthcare onboard and restricted access to onshore healthcare. While this type of crisis hopefully is rare, it shows how vulnerable ship crews can be to external international disruptions.

4.2 *New Types of Jobs and Fewer Jobs*

So far, the effects of autonomy on the employment of Norwegian seafarers are positive, as both ASKO and Yara replace trucks with new ships operated from an RCC by licenced ship officers. However, automation will likely reduce the number of jobs, but also likely have more effect on lower qualified workers than on the higher. Shipping has already seen

Table 3 Societal KPIs from Smartere Transport (2018), assembled by authors

KPI name	*KPI description*	*SDG*
Transport cost for passenger, expressed as *generalized travel cost*	Estimated travel time- and cost, expressed by the sum of the monetary and non-monetary costs of a journey for a specific transport operation	SDG11
Total travel time	Total travel time consist of travel time in rush hours between starting point and end destination. Calculated from time spent getting to starting point for commuting service, actual waiting time at bus stop/ quay, potential waiting time divided by the factor of two, and time spent on the actual commuting service	SDG11
Service regularity	Number of delayed departures/trips per annum, expressed in % of all scheduled trips Number of cancelled departures/trips per annum, expressed in % of all scheduled trips	SDG11
Passenger comfort	Noise level in passenger area, measured in dB (decibel)	SDG11

Source Authors

a dramatic reduction in crew sizes from the 1970s when computerized automation systems were introduced on ships. It is to be expected that this trend will continue, although not at the same speed. One limiting factor is port operations where the most demanding tasks still require ship crews (Kooij & Hekkenberg, 2021). More ship maintenance work in port or dry dock is expected, which may also increase the number of jobs in this part of the maritime sector. Therefore, it is difficult to estimate the actual impact on future jobs that autonomy will bring. As noted initially, it is also to be expected that many smaller autonomous ships both in short sea and inland waterways will replace truck transport (AEGIS, 2022) which most likely will reduce the total number of transport jobs. For Norwegian policymakers, this may be less of a problem as much of the truck transport is by foreign drivers and trucks, either doing cabotage or being employed by foreign customers.

The reduction of jobs may also have geographic differences. As the RCC will be on land, the owner of the ship may prefer to have it under the same jurisdiction as the ship. This may also become a requirement from the ship's flag state authority. As the qualification of the operators most likely will be at least on the level of today's officers, the savings in using convenience flags and foreign ratings will be lower. Thus, one may see that owners will flag home their ships as well as the RCC crew. For some countries, like Norway, this may increase the number of jobs in the maritime sector, particularly when seen together with cargo being transferred from truck to ship. However, there is little doubt that it will have a negative impact on countries that traditionally provide many ratings to the world fleet.

The jobs will also be substantially different. While today's concepts for RCC operations focus on remote control from a "virtual bridge", this will not be feasible in the longer perspective. More autonomy onboard will create an environment where one operator supervises several ships and relies on automation to control those ships which are not immediately under attention (Porathe, 2014). This will require dramatically new workstation designs and job profiles. On the other hand, it is also likely that basic maritime skills will be necessary, and that it is primarily a question of supplementing current officer training with new skills to operate advanced automation systems (Rødseth, 2021). In Norway, such courses are already under development for RCC operators (USN, 2021).

4.3 Advanced Ship Equipment

The higher degree of automation will require much more advanced ship and RCC equipment than what is the norm today. New sensors and anti-collision decision support, as well as continuous connectivity to land will be required. This will likely give benefits to the high-end ship equipment industry, such as the Norwegian. However, this may also reduce the market share or prices for some other countries' industries, therefore there may be a drawback for the latter.

4.4 Less Terminal Space

Areas close to the shoreline are now seen as among the most valuable, especially in urban areas. Public demand for moving ports and terminals from city centers is ever-increasing. This will increase last-mile truck transport as cargo now will be landed farther from the city. Autonomy may make it possible to use several smaller ships rather than the large ships used today. By automating cargo handling, e.g., in combination with RORO solutions as in ASKO (Kongsberg, 2020), very little land-based infrastructure will be required. If this is combined with just-in-time arrival and departure of cargo, one can set up waterborne transport solutions directly into city centers or to small rural quays with minimal requirements on terminal infrastructure. This could emerge as an attractive alternative to truck transport. The introduction of autonomous ships may also have an impact on more conventional port operations. As the demand for intermodal connections is expected to increase, including smaller autonomous ships and barges for hinterland and last-mile transport, cargo can be expected to spend less time at the terminal and thus reduce the need for terminal storage area.

4.5 Improved Mobility

As discussed in Sects. 2.2.2 and 2.2.4, autonomous ships and passenger ferries carry the potential of revitalizing mobility in both urban and rural areas. This can help to answer the increased demand for new transport solutions, while minimizing environmental impact through zero-emission propulsion technologies. With operations without crew or only safety personnel onboard, a significant cost element in short-distance transport at sea is removed. This allows realization of new and high-frequency services as viable alternatives to high-cost investments in land-based transport infrastructure. In addition, with the opportunity to provide around-the-clock services to the public, such solutions can easily be connected to other modes of public transport and thereby support more sustainable living and commuting services. Likewise, as discussed in Sect. 2.2.3, the same mechanism may be used in sparsely populated areas to provide, e.g., on-demand car and passenger ferry services. In addition, many small autonomous ferries can reduce waiting times on higher traffic fjord crossings and may prove a good alternative to bridges or tunnels.

4.6 Flexible Sea Transport

Autonomy may make it cost-effective to use many smaller ships instead of fewer and larger ships. This concept can also be used for large seagoing ships on intercontinental voyages. Smaller ships, e.g., 2000 to 4000 TEU capacity, will put less pressure on the ports and their hinterland transport and may significantly reduce investments in cargo handling equipment

(Van Es, 2019). Ships can use smaller ports and cargo can be moved closer to the final destination and reduce transhipments and overall transport costs. The viability of this concept is supported by an investigation by McKinsey (Glave & Saxon, 2015) that reports that at calls in a certain European port, an 18,000 TEU ship on average only moves around 2 500 containers during the port call (Glave & Saxon, 2015).

4.7 Resilient Sea Transport Systems

A larger fleet of smaller ships can also increase transport system resilience as smaller ships are easier to operate, occupy a smaller space in narrow passages, and are less dependent on large and complex ports and terminals. The 2021 Ever Given incident in the Suez Canal is a prime example of one of the risks associated with large ships in narrow passages. Similar risks are also applicable to short-sea shipping and inland waterways. Additionally, uncrewed ships are minimally impacted by quarantine or other restrictions related to persons either onboard the ship or in the terminals. This may make it easier to operate in adverse circumstances such as during the COVID-19 pandemic.

4.8 Less Truck Transports

The traditional advantages of road transport versus ships are frequency, flexibility, and customization (door-to-door) via small batch sizes. Increasing vessel size or reducing operational speeds are two well-known principles for reducing fuel consumption and cost per transported unit on ships. However, this may further increase the disadvantages relative to truck transport: frequency and flexibility. An economic analysis by Akbar et al. (2021) of a hub-and-spoke shipping network composed of conventional mother ships and autonomous daughter ships performing cargo transhipment at specific ports, shows that autonomous ships can contribute to considerable cost savings—11% on average of operating costs savings, and up to 20% cost reduction when introducing an autonomous mother ship to the network. A similar study of a liner shipping network serving 13 ports along the Norwegian coastline using autonomous ships estimated a cost reduction of 13% compared to conventional ships (Msakni et al., 2020). Thus, autonomous vessels, conveying operational cost savings combined with an innovative hub and spoke system, can serve as a game changer to make waterborne transport much more competitive compared to trucks (Lindstad, 2020).

The estimated benefit of shifting cargo from road to sea and rail, based on the removal of all Norwegian road shipments longer than 300 km, is about 0.48 mill MT CO2 eq. over the period 2021–2030 (Miljødirektoratet, 2020). The Yara Birkeland autonomous ship transport alone is estimated to reduce diesel-powered truck haulage by 40,000 journeys a year (Kongsberg, 2020). In addition to GHG emission reductions, we foresee few accidents, less congestion, less noise, and less dust and particulate matter emissions.

4.9 Lower Energy Consumption

In theory, shipping can fully decarbonize through electro-fuels produced using renewable energy. However, the use of electro-fuels require about 2.5 times more energy than conventional fuels on a well-to-wake perspective. This makes them inevitably costly, and heavily dependent on a large ramp-up of renewable electricity (Lindstad et al., 2021). Improving energy efficiency and reducing abatement cost is therefore key to the viable adoption of electro-fuels. Uncrewed and autonomous ships can reduce energy use through the removal of accommodation and other spaces for human occupation. Based on a study of a 230-m long bulk carrier from the MUNIN project, Kretschmann et al. (2017) have estimated an overall 6% energy saving from removing the deckhouse and hotel system. For small vessels, engaged in a shorter distance and high-frequency services, batteries can provide the most energy-efficient power source. From well to wake, the energy intensity of an electric battery is about 1.5, compared to 2.4 for conventional fuels (Lindstad et al., 2021). Finally, uncrewed operation can enable new and more energy-efficient hull designs, as some constraints related to crew comfort and safety onboard may be reduced or removed. This could also include designs for more efficient cargo handling or adaptions to, e.g., wind propulsion.

4.10 Decarbonization

As discussed in Sect. 4.9, the least energy-intense solution and most mature technology for zero-emission ship propulsion is electric batteries. While this option is limited for larger ocean-going vessels, it is highly compatible with smaller vessels in short-range and high-frequency shuttle systems. Autonomy, enabling the cost-effective deployment of smaller vessels, represents a real opportunity to expand the electrification of nearshore shipping activity, and a direct contribution to reducing both GHG emissions and other harmful air emissions, as demonstrated by the Yara Birkeland and the ASKO ferries (Yara, 2018; Kongsberg, 2020).

Additional solutions for reducing a ship's carbon intensity may also be developed from autonomy. First, considering conventional combustion systems, the reduced energy needs of smaller ships, without compromising the carrying capacity for vessels of a certain size, allow for the drop-in of more expensive but zero-emissions electro-fuels; second, considering novel fuel systems, the freed space onboard can enable the implementation of alternative fuels requiring larger and heavier tank systems such as green ammonia or green hydrogen, without compromising the shipload capacity; third, assuming full autonomous control of the machinery system, the available space could in theory be considered for an onboard carbon-capture system (CCShip, 2021; Feenstra et al., 2019).

4.11 Less Harmful Emissions

Decarbonization often means the use of electric energy from batteries or from fuel cells as discussed in Sects. 4.9 and 4.10. In many cases, and always for batteries, this will totally remove emissions to air from ship transport (excluding the production process of the batteries themselves). This includes particulate matter, NOx, SOx, or any other exhaust-associated emissions. This can have significant positive effects on life on land and under sea, particularly in short sea or inland waterways transport and has been used, as such, to justify both the Yara and ASKO projects' advances of autonomous shipping.

4.12 Safety at Sea

As discussed in Sect. 4.1, an uncrewed ship, by definition, eliminates onboard human injuries and fatalities while at sea. Automating cargo operations will also remove safety risks associated with port operations.

Regarding human errors resulting in safety incidents at sea, Galieriková (2019) states that studies of maritime accidents identify human error as the primary contributing cause for up to 70% of accidents. Many of these incidents are attributable to fatigue, badly designed systems, or faulty safety management procedures. While autonomous ships still will have a crew in the RCC, it can reasonably be expected that many of the contributing factors to today's incident scenarios, will be removed. Normal work schedules can be used, eliminating some of the fatigue problems, while design requirements, procedures, and equipment standards are expected to be stricter than on today's ships. Thus, it is reasonable to expect that the operators' contributions to marine accidents will be heavily reduced (de Vos et al., 2021).

Conversely, human intervention can play a major role in reducing the consequences of incidents, though it is difficult to clearly quantify these effects even on conventional vessels. Wróbel et al. (2017) concludes that the net effect may be negative for uncrewed ships. The design of the autonomous ships and what roles the RCC operators are assigned will have an impact here. What is even more difficult to assess is the number of safety incidents which were worsened through human intervention.

4.13 Better Regulated Shipping

Ships sailing under flags of convenience are sometimes a challenge in today's shipping industry. One of the main reasons for owners choosing this option is to reduce costs, but it can also be to minimize technical requirements and regulation of crew working conditions (ITF, 2022). The authors assess it unlikely that autonomous ships will be under a convenience flag both for cost reasons (see Sect. 4.1) and because the high complexity of such ships requires more competent flag state authorities for the necessary risk and reliability analysis.

Autonomous ships will also be digitalized throughout, and all information about the ship and its operations can be recorded in the RCC. This may enable flag and coastal state authorities to oversee normal operations and more detailed investigate incidents. This should also improve operators' compliance with flag, coast, and port state requirements. One can also expect that insurers will scrutinize how ships are operated and the relationship the operator has to authorities' requirements.

5 Conclusions

In this chapter, our focus has been on "constrained autonomy", i.e., relatively advanced automation on an uncrewed ship which is supported by RCC personnel in more complex situations. Other levels of autonomy may have a different societal impact, but we foresee such differences as a matter of degree rather than on the "types" of impact.

The societal impact created by autonomous shipping is foreseen as largely positive, especially from a Norwegian perspective where no significant negative impacts have been found. Some aspects of societal benefits are very context-dependent, such as the effect on the job market, while others are more generic, such as reduced emissions. Overall, we see a clear link between UN's Sustainable Development Goals and the main attributes of autonomous shipping, although the quantification of these relationships is difficult to define. Currently, several initiatives are developing KPIs for assessing societal impact but we foresee there will always be a need for qualitative assessments in addition to KPIs.

Some of the societal benefits from autonomous ships are what we may call indirect, as autonomous ships in some cases can be seen as an enabler of other measures. This is particularly true in the case of reduced GHG emissions from shipping where the main effect of autonomy is related to the possibility to run on alternative and low-carbon fuels and not autonomous operation per se. Nevertheless, we see this indirect contribution from autonomous shipping as vital for the achievement of the International Maritime Organization (IMO)2030 and IMO2050 goals.

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