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Analyzing the economic benefit of unmanned autonomous ships: An exploratory cost-comparison between an autonomous and a conventional bulk carrier

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ABSTRACT

Unmanned autonomous ships are seen as a key element of a competitive and sustainable European shipping industry in future. But even if the technology to further automate ships will principally be available at some point, this does not imply that autonomous vessels are also the superior choice for the ship owner. In the end the success of autonomous vessels depends on their impact on the profitability of shipping companies. Following a structured approach this paper analyzes the costs of running an autonomous bulker and compares them against a conventional vessel in a cost-benefit analysis. Hereby it provides insights on the (economic) benefit of autonomous vessels for a first-time. Results principally confirm an economic potential. The expected present value of cost of owning and operating the autonomous bulker over a 25-year period is mUSD 4.3 lower than for a conventionally manned ship. Assuming identical cargo carrying capacity this means that the required freight rate of the autonomous bulker which produces a zero net present value is 3.4% lower than the required freight rate of the conventional vessel. This advantageousness is based on one aspect in particular as the paper argues. Besides cost savings associated with reducing crew levels an autonomous ship brings along additional benefits due to changes in ship design.

1. Introduction

Shipping is one of the few truly global industries. In principle, competition between all states and nations is possible in maritime international trade due to the freedom of the seas and international regulations. In terms of making international shipping more efficient, several fields of innovation showed a rapid development in the recent past (see Table 1).

With the advent of autonomous technology in train and car industries in the last decade, unmanned and autonomous vessels have become of popular interest in latest maritime research and innovation studies as well. The fundament of this kind of vessel lies within the European Waterborne Technologies Platform (Waterborne TP) Implementation Plan from 2011, which defines an autonomous vessel as a ship with "*next generation modular control systems and communications technology [that] will enable wireless monitoring and control functions both on and off board. These will include advanced decision support systems to provide a capability to operate ships remotely under semi or fully autonomous control*" (Waterborne TP, 2011).

Against this background, the intention behind the development of autonomous vessels is to contribute to all main dimensions of sustainability (e.g. Burmeister, Bruhn, & Rødseth, 2014; Rødseth & Burmeister, 2012):

- Economic sustainability by keeping operational expenses low, especially crew-related costs, to facilitate efficient international trade,
- Ecological sustainability by enabling new and innovative ways to reduce overall fuel consumption e.g. due to the absence of life-support systems on board, and
- Social sustainability by increasing safety due to moving trivial operational tasks from fatigue crew to onboard automation and by enabling shore-based and family friendly monitoring jobs for nautical personnel ashore.

Of course, individual developments in waterborne transport often relate to more than one field of innovation making a clear attribution difficult. The concept for an autonomous vessel is a good example. Besides a higher automation on board it also covers several aspects closely related to the intelligent ship such as optimized (weather)

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Table 1
Selected fields of innovation in waterborne transport.
Source: authors.

Field of innovation	Related to e.g.
Efficient ship: innovations focusing on efficiency improvements	– Hull form optimization – Energy-saving devices – Machinery technology
Intelligent ship: innovations that make use of evermore data generated on board in smart applications	– Optimized (weather) routing – On-board energy efficiency management – Voyage performance management – Condition monitoring and management
Autonomous ship: innovations that aim for a higher degree of automation on board	– Reduced crew – New ship designs – Improved safety

routing or on-board energy efficiency management. For a brief review of the history on unmanned and autonomous vessel projects, it is referred to Bertram (2016).

Nowadays there are several public-funded research projects in Europe aiming to develop appropriate technology and business concepts that can be mainly attributed to unmanned and autonomous vessels, e.g.:

- AAWA - The Advanced Autonomous Waterborne Applications Initiative: A Finish funded project led by Rolls-Royce investigating principle factors and designs enabling autonomous ships (Rolls-Royce, n.d).
- ReVolt: A Norwegian-funded concept study conducted by DNV-GL about an unmanned and battery powered short-sea container vessel for the Norwegian fjords (DNV GL, 2015).
- MUNIN – Maritime Unmanned Navigation through Intelligence in Networks: A European FP7 funded feasibility study about unmanned dry bulk shipping in deep-sea (Fraunhofer CML, n.d.).

While the first project is basically about technical design according to the project description, the latter two also include research on the commercial feasibility of the developed concepts. This represents a key issue in the context of industrial autonomous system design, as one of the first questions asked is going be "*Can the [vehicle] do the job, and if so, at a lower cost?*" (Stokey et al., 1999). In other words: unless an innovation is commercially viable it will not find its way into practice. Surprisingly, so far little attention has been given to the economy of unmanned autonomous ships (Bertram, 2016). Against this background the paper intends to open up the discussion on economic issues associated with unmanned autonomous ships.

The commercial attractiveness for pure retro-fitting of existing vessels might not be given (Rødseth & Burmeister, 2015a). Thus, the paper focuses on the economics of newly designed autonomous ships according to the MUNIN concept. The analysis primarily looks at benefits associated directly with unmanned ships. Benefits associated with ship intelligence, even though part of the MUNIN project to some point, are not considered since they are available for both conventional vessels and unmanned autonomous ships. Further the analysis focusses on costs of owning and operating a ship while revenue is not considered.

The analysis in this paper deals primarily with technical and commercial aspects of unmanned autonomous ships. However, it should be noted that unmanned autonomous ships don't appear to pose an unsurmountable substantial obstacle in legal terms and bring along the potential to increase maritime safety. In this context the interested reader is referred to e.g. IMO (2015), Kretschmann et al. (2015a, 2015b), Rødseth and Burmeister (2015a), Safari and Sage (2013), Ringbom, Felix, and Viljanen (2016) and Van Hooydonk (2014), where also effects of unmanned ships on flag state regulations and registrations are discussed.

The remainder of this paper is structured as follows. To give an a priori understanding of the subject of investigation, Section 2 outlines the principal concept and operations of the autonomous vessel as developed in MUNIN. Subsequently the methodology of the analysis is introduced in Section 3 and a reference cost model for a conventional bulker is described in Section 4. Section 5 identifies changes in cost of owning and operating an autonomous vessel and gives quantitative estimations of their extent. Finally Section 6 outlines results of the comparative cost-benefit analysis for three scenarios and conclusions are given in Section 7.

2. MUNIN concept of the unmanned autonomous vessel

The use case investigated in MUNIN is a partly unmanned dry bulk carrier. In the principal operational concept of MUNIN, the vessel is fully unmanned during deep sea voyages, which is operated by autonomous onboard navigation and lookout systems while being monitored from a shore side control center (see also Fig. 1). In the taxonomy of MUNIN, the above described vessel is part of the class of Unmanned Maritime System, as it is a "*maritime system that operates full or part time without humans in direct control*" (Rødseth, Tjora, & Burmeister, 2014). Only during port approach and berthing an onboard control team is on the vessel and directly operates it from the bridge. During the main deep-sea leg, an Autonomous Navigation System acts as the officer-of-the-watch with regards to operative decision-making, while the lookout

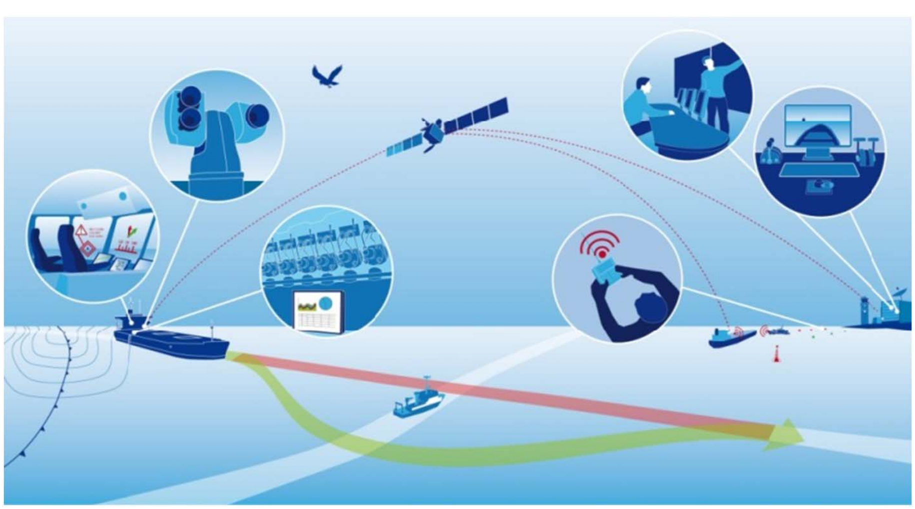

Fig. 1. MUNIN vision.
Source: Burmeister, Bruhn et al., 2014.