

Research paper

# Creating value through product-service-software systems in institutionalized ecosystems – The case of autonomous ships

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## ARTICLE INFO

### Keywords:

Autonomous ship  
Sea shipping  
Institutional theory  
Value creation  
Product-service-software system  
Business ecosystem

## ABSTRACT

Introducing product-service-software systems (PSSS) to the market requires forming an enabling ecosystem, which can be largely based on incumbent business ecosystems. Creating value through PSSS with autonomous capabilities will likely encounter numerous challenges related to the lock-ins in current ecosystem structure. We use institutional theory as a lens and autonomous ships as the case to shed some light on types and impacts of these barriers. We identify a set of institutional barriers pertinent to regulatory, normative and cultural-cognitive pillars of institutions. We further analyze how institutional barriers affect creating, delivering, and capturing value of autonomous ships, ultimately shaping the ecosystem formation around PSSS. The main contribution of the paper is the depiction of early ecosystem dynamics as the mutual adaptation of the PSSS value proposition and the structure of the incumbent ecosystem.

## 1. Introduction

Autonomous solutions continue the range of smart product-service-software system (PSSS) offerings and business models that product suppliers adopt (Hsuan, Jovanovic, & Clemente, 2021; Kohtamäki, Parida, Oghazi, Gebauer, & Baines, 2019; Tukker, 2004, 2015). Developing such PSSS requires innovative technologies and new digital servitization business models employed by their innovators (Aas, Breunig, Hellström, & Hydle, 2020) but also an enabling business ecosystem that aligns the actions and value propositions of many actors needed to deliver the promised “system” value of autonomous solutions (Jovanovic, Sjödin, & Parida, 2021; Kohtamäki et al., 2019; Reim, Sjödin, & Parida, 2018).

The challenge of creating such an enabling ecosystem is that the numerous actors have varying goals, and even their perceptions of autonomous solutions’ value can differ. At the same time, incumbent ecosystems build on established roles and power positions, values and ways of working—that is, an institutionalized structure of production (Jacobides & Winter, 2005). This can be problematic if the current value creation structure and established industry norms inhibit adoption of emerging technologies due to systemic lock-ins or institutionalized practices (Arthur, 1989). Studies on the tensions between new and

incumbent ecosystems draw attention to the orchestrating activities of ‘keystone’ actors (Adner, 2017; Autio, 2021; Jovanovic et al., 2021; Snihur, Thomas, & Burgelman, 2018). However, two key aspects remain unclear. Firstly, what is the role of institutions, which go beyond the agency of a single firm, be it an incumbent or a disruptor, in the dynamics of business ecosystem transition. Secondly, in light of institutional character of value co-creation structure of business ecosystems (Thomas and Thomas & Autio, 2014), it is important to understand how the innovative value propositions introduced in incumbent ecosystems are adapted not only in relation to the incumbents’ value propositions and competition between ecosystems, but also under the effect of the institutional barriers to their value creation logic.

Autonomous ships (also called maritime autonomous surface ships—MASS) seen as PSSS are an illustrative case in point (Siggelkow, 2007), with tension between the well-established structure of the incumbent sea logistics ecosystem and the new logic and possibilities of MASS. While there are studies of how MASS will enable new business models (Munim, 2019) and how their introduction will potentially affect logistic and supply chains (Kim, Joung, Jeong, & Park, 2020), we are researching the dynamics of the underlying business ecosystem required for creating value through MASS, and specifically, how institutions underlying incumbent business ecosystems create barriers for value

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<https://doi.org/10.1016/j.indmarman.2021.09.007>

Received 15 September 2020; Received in revised form 23 July 2021; Accepted 28 September 2021

Available online 6 October 2021

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creation and how this affects new ecosystem formation. To achieve that, we use institutional theory and the three-pillar framework proposed by Scott (2014) to analyze various regulative, normative and cultural-cognitive barriers for system value creation, delivery and capture enabled by MASS.

We explore early dynamics of business ecosystem formation and tensions between the incumbent and new logic and division of roles, thus adding to literature addressing the institutional character of business ecosystems (Gawer & Phillips, 2013; Thomas & Autio, 2014) and the coevolution perspective on business ecosystems (Hou & Shi, 2021; Moore, 1996). As with identifying organizational lock-ins to avoid firm-level inefficiencies and limitations on innovation (Sydow, Schreyögg, & Koch, 2009), barriers to delivering the value of PSSS must be identified at a business ecosystem level in order to enable transforming the business ecosystem and altering the prevailing industry recipe (Spender, 1986). Thus, our theoretical contribution concerns the role of institutional barriers in affecting business ecosystem dynamics. Empirically, we contribute by providing a detailed account of the multitude of institutional barriers for MASS implementation and their impact on how both the incumbent ecosystem and the PSSS adjust during this ecosystem transition.

The article is structured as follows. We start by discussing the concept of business ecosystems as an appropriate lens for analyzing complex value creation through PSSS. Then we present an institutional perspective on business ecosystems using theories from both fields and reviewing research attempting to connect these fields. In the Method section, we present the shipping industry's empirical context. We then describe the qualitative research design we adopted by presenting our primary and secondary data sources and how we analyzed the data through content analysis. We next discuss institutional barriers and their impact on the business ecosystem and value creation potential of MASS. We conclude by discussing the theoretical and practical contribution of this paper, its limitations, and ideas for further research.

## 2. Literature review

### 2.1. Business ecosystem as a lens for analyzing system value creation

The notion of business ecosystems captures the fact that industries, as traditionally known, are converging and evolving, their boundaries constantly redrawn. Simultaneously, business actors are elements in complex value creation systems whose survival depends on the “health” of the ecosystem (Iansiti & Levien, 2004; Moore, 1996). Business ecosystems have received much attention since Moore's original work (Moore, 1996), where he described a business ecosystem as an economic community of interacting organizations and individuals producing goods and services of value to customers. Given the growing body of business ecosystem knowledge, attempts have been made to review this stream of literature, creating a comprehensive “theory of ecosystems” (Adner, 2017; Fuller, Jacobides, & Reeves, 2019; Jacobides, Cennamo, & Gawer, 2018; Tsujimoto, Kajikawa, Tomita, & Matsumoto, 2018). While commonly agreed that the defining feature of business ecosystems is value co-creation (often based on technological and activity complementarities) and coevolution of interdependent organizations (Adner, 2017; Jacobides et al., 2018; Jovanovic et al., 2021;), applying the ecosystem lens differently can direct attention to key characteristics of business ecosystems.

One of the most influential works by Adner (2017) highlights two distinct views of business ecosystems in management and organizational studies. In the actor-centric view, ecosystem-as-affiliation emphasizes the network characteristics of ecosystems, such as changing industry boundaries, increased interdependence of business actors, and potential for symbiotic relationships. In the activity-centric view, ecosystems are analyzed as “the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize” (Adner, 2017: p. 40). With our explicit focus on value creation, we

adhere to the latter, but additionally there are explicit changes regarding actors, activities, positions and transfers—according to Adner (2017), a necessary condition for making the ecosystem perspective relevant in the first place. In a recent study, Hou and Shi (2021) draw attention to a somewhat overlooked facet of business ecosystems: *coevolution*. They propose to extend Adner's (2017) structure vs affiliation framing with structure vs coevolution framing, with affiliation as a linking concept by reintroducing the focus on coevolution within ecosystems. Thus, they call for paying attention not only to how value is co-created in ecosystems, structured by interdependencies and interconnected activities, but also, importantly, to the dynamics of business ecosystem formation and evolution.

With MASS, we observe a business ecosystem emerging around the PSSS, at the intersection of the mature maritime transportation industry and the rapidly developing IT industry and artificial intelligence. The boundaries of the ecosystem remain unclear, because the actual system value proposition—autonomous shipping—is in early development, and the value it creates and for whom is unclear. In addition, emerging technologies and connected business models face challenges when entering the market and appropriating value created by the innovation unless they fit the incumbent ecosystem structure (Christensen, Rory, McDonald, Altman, & Palmer, 2017); they need a different structure to the activities of the ecosystem to fully realize their inherent value creation potential. Moreover, to ensure the willingness of ecosystem actors to contribute to the ecosystem value proposition, each actor has to be able to capture a fair share of the commonly created value (Hellström, Tsvetkova, Gustafsson, & Wikström, 2015; Talmar, Walrave, Podoy-nitsyna, Holmström, & Romme, 2018; Tsvetkova, Nokelainen, Gustafsson, & Eriksson, 2017). For example, in the maritime industry, it is not always obvious who is to gain from an investment in the fleet: the owner of the vessel, its operator, the shipyard who builds it or the supplier who provides the technology.

In this study, we gauge how value creation in an emerging business ecosystem around MASS is bound by the institutions underlying the incumbent business ecosystem structure. The tension between old and new provides valuable insight into dynamics of ecosystems at early stages when industries start converging, such as when digital technologies increasingly factor in ship designs and operations. Such convergence of two industries can be viewed from the perspective of moving from product-service systems (PSS) to PSSS.

A PSS may be defined as “a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs” (Tukker & Tischner, 2006, p. 1552). The concept denotes the general transition towards service-oriented business models (Tukker, 2015). The essence of such models is moving from ownership to utility and outcomes, perhaps best conceptualized as a continuum of offerings ranging from pure products to result-oriented services (Tukker, 2004) and whether the ownership of the product is transferred or not (Aas et al., 2020). This is in line with the common definition that a business model delineates how value is created, delivered and captured in a firm (see, e.g., Amit & Zott, 2001; Zott & Amit, 2010; Teece, 2010). Value creation concerns the customer focus and value proposition targeted at them, while value capture identifies how this value is monetized. Value delivery is the set of linkages between identifying value creation potential for customers and monetization (Baden-Fuller & Haefliger, 2013). As business ecosystems can be analyzed as a system of interconnected business models (Tsvetkova, Gustafsson, & Wikström, 2014), we focus on the value creation structure, which can be perceived as a complex system of interconnected models for value creation, capture and delivery. This also concerns the required alignment of value creation and capture in business model innovation relationships (Sjödin, Parida, Jovanovic, & Visnjic, 2020), such as ecosystems.

With the introduction of digital technologies (smartness), it seems that the role of the ecosystem in developing new PSSS increases as companies collect data and seek new revenue streams beyond

traditional buyer-supplier relationships (Aas et al., 2020; Kohtamäki et al., 2019; Sklyar, Kowalkowski, Tronvoll, & Sörhammar, 2019). Although not a necessary condition for making the ecosystem perspective relevant, digitalization tends to evoke changes (even disruptions) in institutionalized ecosystems, as seen over the two last decades in many consumer markets. For example, ships can be considered a type of PSS where ownership is not (necessarily) transferred. Ships are typically either chartered for an agreed time with operation of the ship (as in a time charter) and are thus an example of ship-as-a-service (Duru, 2019), or, in a voyage charter, transportation service is provided from a port to another port using a vessel that can be time chartered from another party. With the addition of ship intelligence, autonomous ships can be considered a PSSS where smart vessel operations are the ultimate service. We discuss the value that can be created through this PSSS in detail in Section 3.1 where we present the empirical context.

## 2.2. Business ecosystems as institutionalized structures

While business ecosystems are dynamic, they are also inert and institutionalized to a certain extent through differentiation and specialization processes (Hagel & Singer, 1999; Porter, 1980). As mature industry structures become settled and increasingly constrained by explicit or implicit industry logic, the “ways of working” become locked into narrowing path of action options (Sydow et al., 2009). This resonates with the early argument of neoinstitutional theory (see e.g. DiMaggio & Powell, 1983, 1991; Meyer & Rowan, 1977) that organizations often adopt new structures and practices because they provide them legitimacy rather than because of their particular efficiency or effectiveness (Alvesson & Spicer, 2019). In an attempt to relate the concept of business ecosystems to the study of organizational collectivities within institutional theory, Thomas and Thomas and Autio (2014) concluded that ecosystems can be perceived as a fifth facet of organizational fields (in addition to common industry and technology, social issues, and market,). Further, Autio (2021) draws attention to the need for institutional orchestration efforts for defining roles in emerging ecosystems, resolving conflicts and ensuring regulatory embedding as the ecosystem stabilizes. These studies point to the institutionalized structure of systemic value co-creation and the fact that institutions impact ecosystem development.

Institutions can be defined as “multifaceted, durable social structures, made up of symbolic elements, social activities, and material resources” (Scott, 2014: 57). These include both more formal structures, like political and economic rules and contracts, and informal structures such as taboos and traditions (Jepperson, 1991). Within organizational studies, Scott (2014) draws on the vast but often dispersed (see e.g. critique by Alvesson & Spicer, 2019) body of existing knowledge under the umbrella of institutional theory and identifies three pillars of institutions: regulative, normative and cultural-cognitive. These pillars reinforce each other in providing stimulus, guidelines and resources for acting, prohibit and constrain actions, but rely on various mechanisms for legitimizing actions, which is the reason for differentiating among them. These mechanisms vary from coercive (compliance with rules to avoid punishment), to normative (compliance to common norms and standards of behavior), and further to mimetic (taken for granted and shared logics of action) respectively (DiMaggio & Powell, 1983). We choose Scott’s framework to study a business ecosystem in this paper, because it provides a holistic and robust, yet structured, approach to analyzing different institutional barriers to business transformation.

The research into the regulative institutions pays prominent attention to regulatory processes, such as rule setting, monitoring and sanctioning, which are meant to influence future behavior (Scott, 2014). Institutional economists like North (1990) stress the coercive mechanisms behind regulative institutions, which rely mainly on written rules and unwritten codes of conducts, on the one hand, and enforcement mechanisms, on the other hand. In the study of the impact of such institutions on organizations and industrial change, researchers explored,

for example, how national-level institutions shape innovation processes in firms (Hage & Hollingsworth, 2000; Whitley, 2000) or how regulative institutions such as product market regulation, labour market regulation and judicial system, among others, create barriers for business entry in different countries (Kosi & Bojnec, 2013).

Normative institutions define ‘rules of the game’ in a different manner compared to regulative institutions – through defining goals and objectives, such as making a profit, and designating appropriate ways to pursue them (Scott, 2014). The key carriers of such institutions are norms, values and standards, which together define the appropriateness of certain actions and are embedded in the expectations behind the roles of a focal actor held by other salient actors. Several studies focused on the tensions between existing institutional logics and new logics induced by a business model innovation. For instance, Gawer and Phillips (2013) followed Intel in its transition from a traditional supply chain logic to a new platform economy and explicated how the company has both been affected by and actively influenced the logics shift. In their study of shifts in healthcare in Alberta, Reay and Hinings (2005) depicted the tension between ‘business-like healthcare’ and ‘medical-professional’ logic, which resulted in an ‘uneasy truce’ between the two logics (Alvesson & Spicer, 2019). It is worth mentioning a study by Töytäri, Rajala, and Alejandro (2015) on the barriers to value-based pricing in industrial relationships. The authors discover that the strong industrial culture favoring aggressive buying and cost-based pricing have become a norm that buyers refuse to deviate from, despite the potential for a win-win model for purchasing enabled by value-based selling.

Finally, cultural-cognitive institutions are manifested in carriers such as identities, frames and schemas that create shared meaning that underpins the nature of social reality (Scott, 2014). Often, organizations abide by cultural-cognitive institutions without conscious thought (Zucker, 1983). Thus, they both enable meaningful interactions, but also create certain limiting frames, which can become apparent, for example, when industrial transformations take place. The attention to cultural-cognitive institutions is a distinguishing feature of neoinstitutional theory within organizational studies (Scott, 2014) and is therefore an integral part of many studies concerning normative and regulative institutions (Beckert, 2010; Dhalla & Oliver, 2013). To provide an example, in their study of Scottish textile industry, Porac and Thomas (1990) demonstrate that taxonomic mental models of the managers guided and limited their understanding of the competition and question the ability of strategists to reconceptualize competitive environments when patterns of interorganizational relationships change.

As in the activity-centric view ecosystems are seen from a functional perspective (Adner, 2017; Tsvetkova et al., 2017), much attention has been paid to the agency of business ecosystem actors such keystone players (Iansiti & Levien, 2004) or ecosystem orchestrators (Autio, 2021), disruptors and incumbents (Snihur et al., 2018) in affecting business ecosystem structure. The introduction of PSSS with autonomous capability like MASS in an industry with long tradition calls not only for identifying complementors and aligning activities for creating the value of the PSSS but also understanding which institutional barriers the emerging ecosystem faces, which might not be pertinent to the agency of any certain actor. “This is how we have always done it” is the rhetoric we aim to address in this paper. Linking the theory of institutions and business ecosystems, we aim to understand better the complex process of shaping value creation, capture and delivery structures underpinning business ecosystems during early formation. Specifically, we explore how institutions pertinent to the three pillars described above limit and shape the transition of maritime industry triggered by the introduction of MASS.

## 3. Method

### 3.1. Empirical context

Shipping has adapted to technological change many times during its

5000-year history. Despite revolutions such as the switch to iron hulls and containerization of general cargo (Levinson, 2016; Stopford, 2008), ships recently have mostly seen incremental development alongside increasing specialization and vessel size. The basic economics of the sector have changed little, remaining clearly driven by the laws of supply and demand (Stopford, 2008).

However, autonomous ships are part of a broader digitalization expected to change the conduct of business (Porter & Heppelmann, 2015). It creates space for PSSS through smart, interconnected vessels operated remotely or with little human intervention. In this paper, we explore the case of autonomous ships, or MASS, which, “to a varying degree, can operate independently of human interaction” (IMO, 2018). Given such a broad definition, we separate two key aspects of the development towards MASS: onboard manning and level of autonomy (Ringbom, 2019). For example, a remotely controlled ship is not operating autonomously if a human navigator is making decisions. Both aspects exist to a varying degree, when only some functions are operated remotely or autonomously. Fig. 1 highlights the distinction between manning level and level of autonomy, including the gliding scale that features in both aspects.

The most commonly mentioned benefits include reduced operational, voyage, and crew costs; increased safety of operations; and earning potential from new vessel designs (Ghaderi, 2020; Hogg & Ghosh, 2016; Kim et al., 2020; Kretschmann, Burmeister, & Jahn, 2017; Levander, 2017). Realizing these benefits depends on levels of manning and autonomy. Vessels connecting to the Internet of Things in logistic and supply chains is yet another significant source of potential benefits (Ghaderi, 2020).

Given the complex and fragmented structure of sea logistics (Gustafsson et al., 2015; Gustafsson, Nokelainen, Tsvetkova, & Wikström, 2016), what and whose value will eventually be created is unclear. This warrants taking an ecosystem perspective on how MASS can create value beyond dyadic supplier-buyer relationships, to include ship systems providers, shipbuilders (shipyards), shipowners, ship operators, freight forwarders and brokers who organize shipping, and shippers (usually shippers are buyers or suppliers of commodities that are shipped).

The benefits of implementing MASS will be enjoyed by the ecosystem actors to varying degrees and in different ways. Delivering autonomous ships as PSSS will largely create benefits for ship operators and shippers. At the same time, shipowners make the investment in autonomous capability on ships, though they may not operate the vessels. The problem of creating value through PSS on ships has been highlighted before (Ghaderi, 2020; Rivas-Hermann, Köhler, & Scheepens, 2015). The logic in building and operating conventional ships has been maximizing financial benefits through cost reduction (Ghaderi, 2020). Hence the shipbuilding industry focuses on standard designs for vessels carrying specific types of cargo (liquid or dry bulk, general or

containerized). Minimizing capital investment in vessels while maximizing cargo capacity aims at reducing transportation cost and thus offering low freight rates to shippers. With MASS, new types of value may be created, especially for ship operators and shippers. Unmanning vessels can help solve problems ship operators face, such as rising crew costs (up to 45% of total operating cost; Kretschmann et al., 2017) and shortage of seafarers (Ghaderi, 2020; Hogg & Ghosh, 2016). For shippers, opportunities to optimize supply chains may arise from increased ship intelligence and higher operational flexibility of vessels without crew onboard (Ghaderi, 2020). In Fig. 2, we compare value creation in shipping ecosystems enabled by conventional ships and by MASS.

### 3.2. Case selection

The implementation of MASS is a topical and illustrative case. Firstly, this innovation involves a multitude of actors to implement it and thus calls for an enabling business ecosystem and a system change. Secondly, it faces several challenges involving the structure and logics of the current maritime logistics business, from legal and policy issues to changes in business logics and mindsets. These challenges represent barriers pertinent to all three of Scott’s (2014) institutional pillars.

Thirdly, introducing autonomous ships can be considered an extreme case (Pratt, 2009) of tensions between incumbent and emerging business ecosystems when traditional maritime transportation industry converges with the fast-moving ICT industry. It is, therefore, suitable for studying how institutional barriers affect system value creation in ecosystems. Lastly, it is possible to gain insight into early ecosystem formation and rely on current opinions rather than study historical documents and recollections of this period. Later studies can explore the resulting structure of the stabilized business ecosystem and draw conclusions on how barriers identified in this paper shaped the path for the PSSS.

### 3.3. Data collection

Studying a business ecosystem in early development is challenging, because not much evidence of its structure can be found. Since our aim was to identify barriers to value creation, we sought opinions from actors involved in the ecosystem on its development and challenges. Certain barriers mentioned might have little effect on ecosystem transformation in the end, yet because they are discussed by the practitioners, they are at least cognitively limiting and thus can be considered

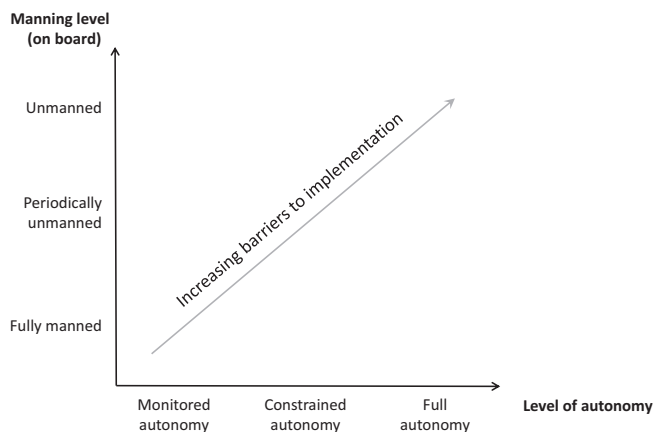


Fig. 1. Separation of aspects of automation (Adapted from Ringbom, 2019).

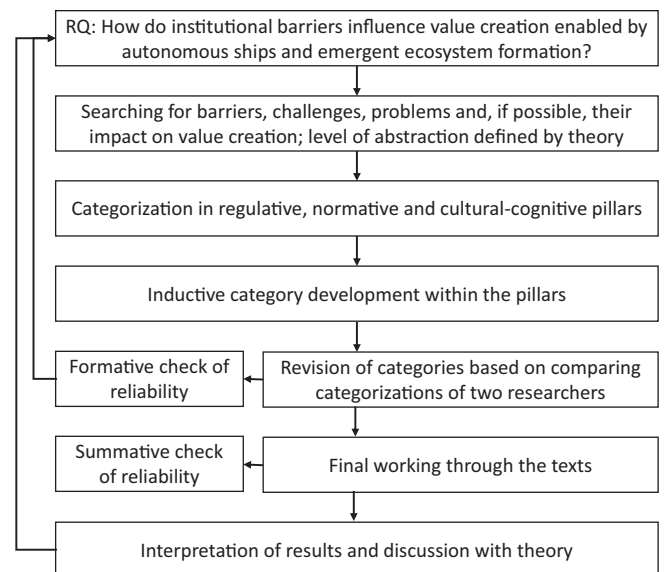


Fig. 2. Additional value creation enabled by autonomous ships.

institutional barriers.

The data for this study are twofold. Firstly, we have collected information through desktop analysis of secondary sources including scientific literature, news and trade magazines, and industry reports on the challenges of introducing MASS. We have focused on organizations listed as leaders in maritime technology, such as ABB Marine and Ports, DNV GL, Kongsberg, Rolls Royce Marine, and Wärtsilä (Lloyd’s List, 2017). The summary of secondary sources analyzed in this study is presented in Table 1.

Secondly, to address the three institutional pillars, we interviewed industry participants, consultants, and academics in business, regulation, technology, and ship navigation and operations, as well as naval school educators and trainers. Autonomous shipping is not yet an established industry, which makes it challenging to find knowledgeable experts. The criterion for choosing the interviewees was their involvement in autonomous shipping for several years (e.g. in piloting autonomous vessels, developing technology for them or training seafarers for autonomous shipping). We searched for most relevant organizations in Finland, which is one of the leading companies in the development of autonomous shipping, and attempted to interview stakeholders representing different types of actors in the ecosystem: not only technology developers who promote autonomous shipping, but also ship operators who are the ultimate users, and, for example, naval educators which have a better knowledge on ‘the human factor’. This helped us gain the perspective of different actors in the focal business ecosystem and validate barriers identified in the desktop analysis. The anonymized list of interviewees can be found in.

Table 2. Each interview lasted around 1–1.5 h and was either recorded or, in case interviewees did not give permission to record the interview, documented by the researchers as detailed notes. In addition to interviews, we conducted a workshop on insuring autonomous ships, with two ship insurance companies, a technology provider and two ship operators. Although we interviewed 12 persons and had a discussion with five more during the workshop, we have reached category saturation (Glaser & Strauss, 1967) for the barriers pertinent to all three pillars as no new topics arose during last interviews.

3.4. Data analysis

The secondary data and interviews are analyzed using content analysis with deductive category application and further inductive category development (Mayring, 2004), because we are guided by the approach of Scott (2014) presented earlier. This can be labeled a directed approach to content analysis, aimed at supporting or extending the theory (Hsieh & Shannon, 2005).

In order to reach reliable category development, two researchers independently analyzed the secondary data and interview notes, assigning the barriers to one of the three categories of institutional pillars. Thus, the main criterion for coding a particular statement as a barrier was mention of a challenge, a factor slowing down adoption of MASS, or a clearly stated barrier to value creation by this innovation.

Table 1  
Secondary sources for collected data.

Type of secondary source	Number of sources	Examples
News item on web portals	12	maritime-executive.com, company webpages
Podcasts, webinars, blogs	6	Webinar on smart shipping, podcasts by maritime educational institutions
Reports, research and trade magazine articles and papers	23	Technical articles, reports from research projects, consultancy reports
Laws, regulations, guidelines	10	International Convention on Standards of Training, Certification and Watchkeeping, Regulation VIII/2 (2)(1)

Table 2  
The list of interviewed people.

ID	Type of business actor	Position of the interviewee	Comments
1	Digital platform provider	Project manager	Involved in developing smart ports that to harbor MASS
2	Research organization	Researcher	Expert in workforce changes from automation
3	Technology company	Client executive	Involved in many digitalization projects in the maritime industry
4	Shipowner and operator	Captain, HSSEQ manager	Involved in many automation efforts related to tugboat operations
5	Naval school	Lecturer, educator	Involved in educating seafarers
6	Technology provider	Product manager	Involved in first MASS development
7	Innovation consultant	Senior ecosystem lead	Leading many national initiatives on autonomous shipping
8	Technology provider	CEO	Developing autonomous capability for mobility systems
9	Technology provider	Engineer	Expert in developing autonomous solutions
10	Consulting company	Partner	Involved in a project about using MASS in commercial cargo shipping
11	Consulting company	Senior consultant	Involved in a project about using MASS in commercial cargo shipping
12	Ship operator	Project manager	Manager of the project for piloting an autonomous ship

The researchers defined whether each barrier was pertinent to the regulative, normative or cultural-cognitive pillar from Scott’s (2014) framework. Then, they compared notes and agreed on the categories within each pillar by merging some of them and revisiting the original texts in case of dissimilarities in identified barriers. The process for such deductive category application and subsequent inductive category development is depicted in Fig. 3.

Finally, we cross-analyzed the barriers pertinent to the three institutional pillars and analyzed how they impact value creation that can be enabled by MASS, aiming at understanding how the formation of an enabling ecosystem is shaped by institutional structures inherent in the incumbent business ecosystem.

4. Analysis and findings

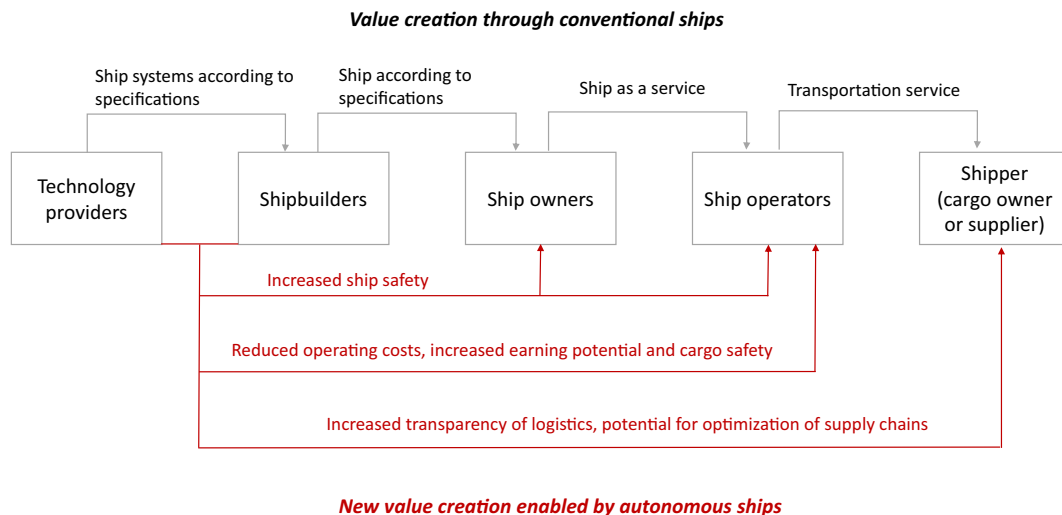
4.1. Barriers pertinent to the regulative pillar

4.1.1. Requirements for physical presence of crew

Reducing ship’s crew gives rise to different regulatory issues. For onboard manning, the clearest legal barriers are the rules requiring crew members to be physically present onboard ships and the rules of safe manning (International Convention on Standards of Training, Certification and Watchkeeping, Regulation VIII/2(2,1); International Convention for the Safety of Life at Sea, Regulation V/14).

The ship’s flag state has an important role in deciding whether technological solutions may replace functions traditionally performed by onboard crew. For example, the flag state eventually issues the “certificate of safe manning” for an individual ship. If it is satisfied that the safety level is not compromised and its legal obligations are maintained, the flag state has broad discretion to accept that onboard functions may be replaced by technology. Thus, the first autonomous ships for cargo shipping are intended for operating in the waters of a single state (as in the case of Yara Birkeland; see Munim, 2019) to avoid the challenges of complying with regulations in the short-term. In the words of one interviewee:

When we start talking about the first cases that will have a good business case, then we see short sea shipping, because there we don’t



**Fig. 3.** The process of deductive category application and subsequent inductive category development used in the study (visualization inspired by Mayring, 2000).

have these legislative barriers, you don't have international laws that you should first change before you move to remote controlled operations.

However, limiting areas of operation diminishes potential for value creation. As another interviewee stated, the use of MASS in deep sea shipping could create more value than in short sea shipping through removing crew from long, isolating voyages. The interviewee also noted that autonomy could be a solution for ship operators challenged to find seafarers and reduce crew costs. The results of the survey regarding the future of autonomous shipping, reported by the Institute of Marine Engineering, Science and Technology, suggest container deep-sea shipping may benefit most from autonomous operations (Meadow, Ridgwell, & Kelly, 2018).

#### 4.1.2. Requirements for humans in the decision-making loop

Increasing levels of automation give rise to different regulatory challenges. In particular, certain rules require a human in the navigational decision-making loop. For example, the collision avoidance rules (2 and 8) of the International Regulations for the Preventing of Collisions at Sea presume a human presence by referring to decision-makers' "good seamanship" and by specifying that navigational decisions accord with the "ordinary practice of seamen."

Longer-term, accommodating MASS into existing international and national regulatory frameworks requires some regulatory amendments, notably at the global level by the IMO. Meanwhile, the extent of autonomous solutions depends on several issues, including the level of automation and crew reduction. The approach taken by the ship's flag state will also be decisive for certain issues, while regulatory barriers will depend on the ship's operating areas. Furthermore, in many jurisdictions the regulatory barriers will depend on whether or not the MASS operation is characterized as a trial (IMO, 2019). Initial attempts to implement MASS in commercial cargo shipping are directly affected by such regulatory barriers and lead to focusing on those user segments (short sea shipping within the territory of one state) where value might not be fully realized or will not outweigh investments.

#### 4.1.3. Liability issues

Finally, a different but very relevant regulatory hurdle relates to civil liability of persons involved in developing and operating MASS. Exposure to liability for damage is an important factor influencing how actively those developing MASS will wish to be involved. As several interviewees noted, important questions about how far the shipowner's vicarious liability extends (is the shipyard or the developer of the faulty

software covered by the shipowner's liability or by a separate liability regime, such as product liability?) and how to establish fault to trigger liability when all decisions were made autonomously. For such questions, an additional challenge is that liability rules, unlike safety standards, differ largely between countries, with no generally applicable convention.

Given how liability is currently attributed in case of accidents at sea, its redistribution will impact the value creation potential for MASS. If shipowners are always liable for damages in case of an accident on an autonomous ship, incentives to invest in MASS will be diminished. That is, the value created for the shipowners might not compensate for the risks. Then, the new, "unusual" distribution of liability might affect the perception of the value of increased safety attributed to MASS. Trust in software developers will have to overtake trust in mariners (Chambers, 2016), a significant shift for the industry.

## 4.2. Barriers pertinent to the normative pillar

### 4.2.1. Industry logics behind sea logistics

Introducing MASS has the potential to change the business logic behind sea logistics in several ways. As several interviewees indicated, it can enable "distributed economies" (Johansson, Kisch and Mirata, 2005) and "network effects" (Katz & Shapiro, 1985) through coordinating many smaller vessels delivering goods from the origin port to the destination port, which also can save time. Current logistics aim rather for "economies of scale" through increasing vessel size and enlarging the capacity of ports and fairways, through so-called hub-and-spoke transportation systems. According to an interviewee, distributed economies in the context of shipping would have implications for shipbuilding (smaller vessels) and cooperation between actors in the value chain (integrating production planning with logistical planning more transparently). Data sharing and availability are crucial for such optimization, but changing the business models of different actors is paramount to make use of these data. However, as one interviewee put it:

It's very expensive to change your existing business. That is the root cause, where it [difficulty in implementing autonomous ships] really comes from—why would you change your existing business model just for the sake of aiming to autonomy in two decades in the future. ...You have to maintain the existing business and just solve the problems you get. So it's very difficult for people to start thinking is there any other way to do this.

Without shifts in industry logics and respective changes in the

business models of many actors, system-level value that could be enabled by MASS will not be realized.

#### 4.2.2. Contractual models and incentives for efficient ship operations

Autonomous ships can create value through fuel savings and consequent emission reductions, because such ships are easily adjusted to slow steaming and generally sail more optimally. Barriers in such cases include current freight contracts and lack of coordination of port arrival. Voyage optimization, technology with fuel savings potential, and other energy management systems require changing business operations in the logistics chain (Johnson et al., 2014). Realizing such benefits also depends on the type of ship charter used. If the ship operator does not pay for the fuel (as with time charters), incentives to save are obviously small (Gustafsson et al., 2015).

#### 4.2.3. Standardization

Many interviewees brought up standardization as a major barrier. Current standards assume there is always crew onboard a vessel, and developing standards for safe navigation of autonomous ships is a challenge. One interviewee argued that creating standards for systems on MASS is not difficult, but expensive:

Your hands are not tied to make the new solutions; the classification society allows you to do that, the legislation allows you to do that, but it is just much more expensive when you need to do classification by yourself, you need to prove that it works... nobody wants to do that... you don't want to invest too much money at this point by yourself, you want that the whole industry will obey the same rules, and you are again fighting in that business with the same rules.

Such wait-and-see behavior slows down implementing autonomous ships and questions the value of their safety and reliability.

#### 4.2.4. Development of complementary assets and activities

From a structural viewpoint, autonomous ships need complementary innovations around them. Insuring autonomous ships is as yet an unsolved problem. Some of the new risks discussed in Section 4.1 regarding liability may be possible to integrate into existing marine insurance policies, but with respect to insurance, too, autonomous ships bring about certain novel elements that may turn out to be barriers for ship-owners (See Viljanen, 2021; Wilhelmsen & Bull, 2021).

Additionally, MASS might create more value if implemented with smart ports and intelligent fairways. Greater automation in ports would unleash the value potential of MASS. As an interviewee mentioned, ports will need to be equipped to handle MASS, including automated docking and cargo handling. Since ports must provide a wider range of services (British Ports Association, 2018), more collaboration will be required to align the ports' offerings with MASS (Ghaderi, 2020). However, actors that cannot directly benefit from the operation of autonomous ships make investments in port infrastructure, creating a barrier to developing complementary activities and making investments.

Additionally, challenges arise related to new roles that do not exist in the incumbent ecosystem structure. For example, who will develop and maintain shore-based control centers: the shipbuilder or technology provider (Ghaderi, 2020)?

#### 4.2.5. Transparency in ship operations

The higher degree of digitalization underpinning autonomous shipping would naturally require increased data sharing and transparency within the shipping ecosystem. While system benefits are apparent for many actors (more efficient logistical chain, fast ship turnaround, optimized shipping, etc.), the way certain actors work and interact with others will be affected. Moreover, a more transparent logistics chain may also shift the industry power constellation towards the shipper.

Regarding liability for accidents, detailed logs of vessel movements and decisions made by AI reduce ambiguity regarding the cause. There

will be no language problems and no discretion in decisions. However, some actors might see this as an unwanted scenario. For instance, Jim Scorer from the International Federation of Shipmasters Associations mentioned in his interview that there are many instances of unreported incidents and casualties at sea (Gibraltar Shipping, 2017). Also, as an interviewee indicated, certain actors might be against the idea of high transparency because currently they can manipulate cases of unclear liability.

Better monitoring of cargo conditions could exist, thanks to improved resolving of time-consuming claims (machines keep a log of what they do). However, as the CEO of a ship operator explained:

You do not want to argue about every single claim, but instead ensure a continued good relationship with your client cargo owner.

#### 4.2.6. Traditional role and skills of ship crew

One immediate association of automation and autonomy envisioned by economists (Arntz, Gregory, & Zierahn, 2016; Frey & Osborne, 2017) and leading consulting firms (McKinsey Global Institute, 2017) is the direct impact on employment, immediately reducing staff onboard a vessel. Hence, an expected barrier would be the reaction from labor unions. However, currently the transportation sector confronts quite another problem: attracting young people (see Section 4.3). So far, unions have mounted no major interventions.

In the normative sense, however, the changing roles of the crew may constitute a big barrier to adoption. Arguably, operating a ship from a bridge or a machinery room and oversee its operations from shore are quite different. According to UNCTAD (2019), the shift towards MASS will require less physical strength and more ICT skills. Moreover, the lack of training in operating ships remotely and of skilled people are brought up as barriers by some interviewees and experts. According to the study by Hogg and Ghosh (2016), while certain experts argue that the attractiveness of maritime jobs will increase with the advent of MASS, those who work or have worked onboard a ship are less likely to take this view.

### 4.3. Barriers pertinent to the cultural-cognitive pillar

#### 4.3.1. Culture of "good seamanship" vs digitalization

While many companies in shipping are forward-looking and eager for innovation, several interviewees mentioned that it is unadvisable to go against shipping's long legacy by denying the importance of seafarers in the business. Every ongoing industrial revolution shares discourse concerning the fact that humans—and their jobs—will be replaced by machines. Resistance to change and giving up established roles can create a formidable barrier to the introduction of MASS, at least in the short run. In particular, it creates challenges related to transferring the tacit knowledge required to develop adequate ship intelligence for MASS. As one interviewee explained:

The first thing we should do while we still have the amazing experience onboard the vessel, while we have captains and seafarers that have been doing this for decades, and they have been in all kinds of situations, so somehow we should harness that experience.

The tensions between the tradition-heavy seafaring culture and the fast-moving IT industry are noted by some experts, stating, for example, that technology providers—drivers behind the introduction of MASS—do not understand the maritime industry (Meadow et al., 2018). Also, the emphasis on the technical side of MASS might have adversely affected legitimizing the innovation. As one interviewee put it:

When the discussion about autonomous ships started, it was more of a science fiction type of marketing, which might have made people

cautious. Now we need to restart the discussion and make it [the transition to autonomous ships] more real and incremental.

#### 4.3.2. Values and identity connected to seafarers

There are particularly difficult cultural shifts required when decision-making is fully transferred to the equipment. The idea of “good seamanship,” which implies the high value of an officer’s experience for safety and ship operations, will be abandoned. Several interviewees and experts predicted that “seafarers of the future” will operate ships remotely or form much smaller crews due to increased automation. Such skills as flexibility, creativity, problem-solving and rapid analysis will be increasingly needed, as opposed to highly specialized mechanical knowledge. Thus, autonomous shipping needs to attract people with a different set of values, skills and job expectations (Björkroth, 2020). Further, new jobs will be created by automation, such as high-skilled route operators, different kinds of pilots, and riding gangs (Wise, 2018). Seafarers’ training needs to reflect this shift, too.

#### 4.3.3. Framing the concept of autonomous ships

Autonomous shipping was initially almost single-handedly developed by Rolls-Royce’s marine division, showcasing a tugboat trial in Copenhagen in 2017 and a remotely operated ferry in Turku, Finland, in 2018 (Rolls Royce, 2018). Kongsberg has also been active with its Yara Birkeland project, the world’s first fully autonomous and zero-emission container ship, and acquired Rolls-Royce’s marine business in 2019. For more traction, the technology would likely need more suppliers. However, other leading ship technology suppliers, such as ABB and Wärtsilä, have remained cautious,<sup>1</sup> referring to “Smart Marine”<sup>2</sup> and “conditionally and periodically unmanned bridge.”<sup>3</sup> Similarly, in the recent *Maritime Trends* report, autonomous ships are seen as a future technology for naval and research applications, with “smart ships” for commercial shipping (Lloyd’s Register et al., 2015). The discourse is shaped by incumbent actors suggesting automation makes conventional ships smarter, undermining or at least postponing the potential to create value from fully unmanned ships (e.g., through a different ship design). This can be explained by the “existing power constellation,” as formulated by one of the interviewees, and incumbent actors’ “very strong opinion about how to develop [the] maritime sector.” This leads the development of the focal ecosystem towards incremental change, heavily relying on the current structure of the sea logistics ecosystem.

## 5. Discussion

### 5.1. Impact of institutional barriers on value creation through autonomous ships

We set out to study how institutions underlying incumbent business ecosystems create barriers to value creation through autonomous ships. Adding software to a PSS is often depicted in terms of associated changes in capability (e.g. Kohtamäki et al., 2019; Porter & Heppelmann, 2015). Such is the case for MASS. Increased automation provides ships with new capabilities, especially business models that can be applied at various stages. PSS are traditionally illustrated according to different offerings that can be categorized along the continuum between pure products and pure services (Aas et al., 2020; Tukker, 2004). Therefore, we have portrayed autonomous ships as a different PSSS offering and, therefore, analyzed the barriers for their effect foremost on value creation but also value delivery or value capture in the ecosystem. The list of

barriers identified in previous sections is not exhaustive but gives a good idea of the main issues for autonomous shipping and allows us to interpret how institutions from incumbent ecosystems might impact emergent ecosystems. In Table 3, we list the institutional barriers to creating value through MASS from Section 4 and analyze whether they obstruct value creation, delivery or capture (Amit & Zott, 2001; Teece, 2010). Further, we discuss impacts on the three facets of value creation structure in more detail.

A number of institutional barriers affect the value creation potential of MASS. First, the benefits related to fully unmanned ships, such as increased safety, optimized vessel design and reduced crewing costs, cannot be realized unless current international legislation is changed. This seems to be a kind of ‘tipping point’ in the transition towards autonomous shipping. While it is still possible to create value through ship intelligence, this may not compensate for higher investments in MASS. The PSSS in question has taken a path around this barrier by focusing on market segments where MASS is allowed (i.e., within the territorial waters of one state). This creates a certain mismatch between the potential for value creation and targeted customer segments. Thus, the regulative barriers seem to direct the value proposition of MASS along the path of least resistance, at least at early stages.

Second, the ecosystem-level value that can be enabled by MASS stems from redefining logistics and changing the industry logics (Gawer & Phillips, 2013) towards economies of distribution and network effects (Katz & Shapiro, 1985). This shift is bound by the structure of the business ecosystem, manifested in a system of interconnected business models (Tsvetkova et al., 2014), contractual models, industry standards and norms (Spender, 1986), and interorganizational complementarities (Jacobides et al., 2018). While the more drastic shift to fully autonomous operations can create system value that outweighs related investments and risks, the tension between the incumbent and emerging ecosystems leads the PSSS to adjust the value proposition of MASS to be rather similar to conventional ships by adding an element of smartness. This seems to be another ‘tipping point’ in the transition to ecosystem where value creation potential of autonomous ships can be unleashed. Additionally, the skepticism and discourse around “smart ships” instead of autonomous ships downsizes the value that can be achieved only through full unmanning and full or partial autonomy. Thus, we can conclude that while “smartness” of a PSSS can define how its value is delivered (Aas et al., 2020), the degree of smartness is also to be understood in light of the potential for full unmanning when it comes to MASS.

The structure of the incumbent business ecosystem also affects the potential for providers of MASS (technology providers and/or shipyards) as well as other developers of complementary activities, resources and capabilities (Talmar et al., 2018) to capture the system-level value of MASS: increased transparency in logistic chains and consequent optimization possibilities. As concerns value delivery, a number of cultural-cognitive barriers can potentially obstruct the transfer of knowledge necessary for “training” MASS and attracting new types of professionals. These could decelerate the development of necessary human resources and organizational capabilities for delivering the value of MASS.

To summarize, value creation potential of a PSSS such as autonomous ships depends not only on its potential to create value for the end customer but also on the value co-creation structure in the ecosystem (Reim et al., 2018). The findings of this paper indicate that value creation is also affected by regulative and cultural-cognitive institutions (Scott, 2014) spanning the ecosystem structure to its wider foundation (Hou and Shi, 2021) and impact how the value proposition of the PSSS is formed. This is an important insight on the impact of ecosystems on digital servitization (Kohtamäki et al., 2019).

### 5.2. Business ecosystem transition in institutionalized environments

The second aspect of our study was concerned with how institutions

<sup>1</sup> <https://www.wartsila.com/twentyfour7/innovation/maritime-autonomy-a-bridge-too-far>

<sup>2</sup> <https://www.wartsila.com/marine/smartmarine/cases/case-smart-marine>

<sup>3</sup> <https://new.abb.com/marine/media-center/press-releases-and-articles/articles-and-highlights/b0-a-conditionally-and-periodically-unmanned-bridge>



**Table 3**  
Institutional barriers to value creation enabled by autonomous ships.

Institutional barriers	Impact on			Description of the impact
	Value creation	Value delivery	Value capture	
<b>Regulative pillar</b>				
1	Requirements for physical presence of crew	X		Limited reach to segments that would enjoy higher value from autonomous shipping; difficulty to generate system-level value that can be enabled by MASS.
2	Requirements for humans in the decision-making loop	X		Limited reach to segments that would enjoy higher value from autonomous shipping; difficulty to generate system-level value that can be enabled by MASS.
3	Liability issues		X	Value of safety is questionable when established liability distribution is changed and might not outweigh new risks transferred to some actors.
<b>Normative pillar</b>				
4	Industry logics behind sea logistics	X	X	Value of network effects that can be enabled by employing many autonomous ships at once is difficult to achieve given the current “linear” logic of sea logistics relying on economies of scale.
5	Contractual models and incentives for efficient ship operation		X	Value that can be created by MASS (e.g., fuel savings) cannot be captured by actors due to existing contractual agreements.
6	Standardization	X	X	Higher financial investments for new standards that are not based on human presence on board.
7	Development of complementary assets and activities	X	X	Lack of incentives for other ecosystem actors to develop complementary assets and activities required for MASS to operate efficiently.
8	Transparency of ship operations	X		Increased transparency affects business models and way of working of certain ecosystem actors.
9		X		

**Table 3 (continued)**

Institutional barriers	Impact on			Description of the impact
	Value creation	Value delivery	Value capture	
	Traditional role and skills of ship crew			Potential resistance from labor unions, deficit in skills when changing work tasks, and difficulties in transferring tacit knowledge.
<b>Cultural-cognitive pillar</b>				
10	Culture of “good seamanship” vs digitalization	X	X	Transition from traditional maritime culture to “digitalized transportation” can create resistance and lead to losing tacit knowledge on safe ship operations.
11	Values and identities connected to seafaring		X	Challenges in defining requirements and attracting new type of professionals in ship operations that are required to create value through MASS.
12	Skepticism about MASS	X	X	Value delivery is redirected and postponed due to slow adoption.

underlying incumbent business ecosystems affect the dynamics of ecosystem formation. We can see from the analysis institutional barriers interacting with the value creation potential of autonomous ships that there is an ongoing adjustment both of the incumbent ecosystem and the PSSS, depending on the barriers created by the incompatibility of the existing and required structure of the business ecosystem. We attempt to depict these dynamics in Fig. 4.

To address the barriers pertinent to the regulative pillar, ecosystem actors employ two strategies. First, they attempt to remove barriers through engaging policy-makers to change current legislation to accommodate MASS. Second, they adjust the value proposition to focus on segments where implementing MASS is currently possible. While the first strategy will eventually allow wide adoption of MASS, enabling system benefits, legislative changes take considerable time, and until then, institutional barriers pertinent to the normative pillar will persist as well. The ecosystem participants wait for conditions to change for everyone before making significant investments and changes required for autonomous shipping.

Similarly, the slowness to change in complementary activities of ecosystem actors directs ecosystem formation towards adjusting the value proposition of the PSSS to fit with the current structure. A more proactive strategy would be affecting value capture structure in the ecosystem, at least temporarily, through vertically integrating logistic chains so that logistic operators could control both port and ship operations. Introducing MASS would be easier and financially viable because the logistic operator would capture the value of investments and changes required for implementing autonomous ships. Thus, a change in affiliations within the business ecosystem can enable the change in value creation structure (Hou & Shi, 2020).

Summing up, it appears that autonomous ships as PSSS are undergoing incremental innovation in the conventional shipping ecosystem. Only further legal changes will allow for architectural innovations (Henderson & Clark, 1990) that may unleash a significant value creation

### Structure of value co-creation activities in institutionalized environment

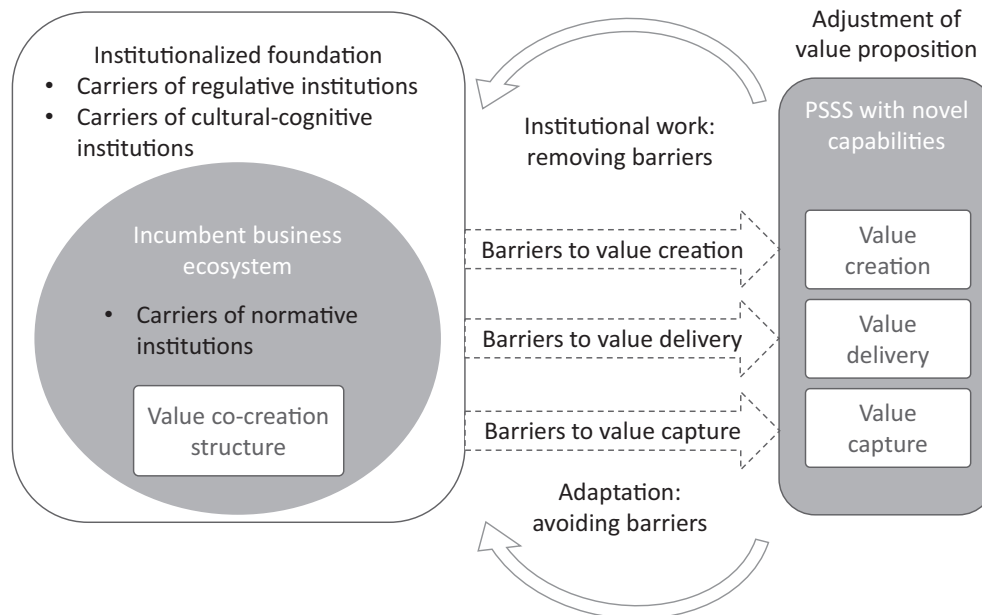


Fig. 4. Dynamics of early ecosystem formation around PSSS with autonomous capability.

and capture potential. Only passing these ‘tipping points’ we may witness a true system transition (Geels, 2005) towards platform ecosystems (Gawer & Phillips, 2013) and more transparent value chains (Kim et al., 2020). These are significantly different from conventional supply chains and may alter the existing power constellations in the transportation sector (Ghaderi, 2020). Sustainability concerns can be yet another driver of this transition if the value of autonomous ships aligns with the goals sustainable development. As policy aimed at sustainable development can create motivation to e.g. save fuel in shipping or to increase transparency in ship operations, the value of smart, autonomous vessels can become more apparent and easy to monetize. Before such system transition is achieved, incumbent institutions will have a significant impact on which path the PSSS will take.

## 6. Conclusions

### 6.1. Research contribution

This paper sheds light on how emerging business ecosystems for PSSS are bound by institutional barriers. This extends the perspective of a business ecosystem from purely business interactions and interdependent activities of business actors to achieve system value creation (Adner, 2017; Jacobides et al., 2018; Kapoor, 2018) to how they are affected by institutional structures within business ecosystems and outside them. This is an important insight for transforming and shaping business ecosystems (Autio, 2021; Möller & Halinen, 2017; Tsvetkova et al., 2017). The case of introducing PSSS, which can reduce human effort to operate products and provide services, seems especially complicated, as our study has shown. Earlier studies have laid out the modular properties of business model dependencies between actors in an ecosystem (Hellström et al., 2015; Talmar et al., 2018), which we extend in two ways. Firstly, we demonstrate how institutions underlying business ecosystems can affect value creation potential of PSSS introduced to the ecosystems in how value is created, delivered and captured among ecosystem participants. Earlier studies have used other theoretical lenses, such as transaction cost economics, the resource-based view, agency theory, and identity and power theories, but not institutional

theory to explain the dynamics of ecosystems around PSSS (Kohtamäki et al., 2019; Reim et al., 2018). Secondly, we reveal the two-way dynamic between the formation of PSSS and resistance of the incumbent ecosystem, which is a unique depiction of the dynamics of ecosystem formation (Hou & Shi, 2020) on the grounds of an incumbent ecosystem. We provide an array of empirical observations to support our view of a phenomenon in the making. While such a listing may not fully explain the phenomenon at hand, it is a true theorizing attempt (Weick, 1995).

### 6.2. Practical implications

Understanding the limitations created by existing institutional structures inherent in incumbent business ecosystems enables business ecosystems to fully realize the value of emerging technologies. This study is relevant for those actors involved in delivering the value proposition of MASS. This includes, most importantly, the providers of autonomous capability of the ships as well as shipbuilders. Understanding how MASS fit the current maritime industry and the implications of their introduction is crucial to smoothly transitioning towards their extensive use in global supply chains (Ghaderi, 2020) and requires a systematic approach (Baldauf, Kitada, Mehdi, & Dalaklis, 2018). The results of this study indicate that besides developing adequate technology, the value creation structure of the incumbent ecosystem must be addressed, as well as how its institutionalized structure can shape the resultant value proposition of MASS.

The findings of this study are also useful for policy-makers to lead the maritime transportation industry towards sustainable development. To lead such development, they must understand the different challenges of implementing autonomous ships. As Kim et al. (2020) argue, the disparity between developing a mature autonomous ship industry and the relevant regulations and practices may negatively impact their timely adoption. In this paper, we reveal the complex interaction between the barriers pertinent to regulative, normative and cultural-cognitive institutions and development of the potential of MASS to create their intended value.

### 6.3. Research limitations and further research

Researching a business ecosystem that does not yet exist is a challenge. The findings of this paper are based on the analysis of recent efforts of some actors implementing autonomous shipping as well as the opinions and discourse of actors embedded in the ecosystem. We attempted to collect the facts on both sides for an inclusive picture of what this emerging innovation is facing. It is likely, however, that some of the institutional barriers we identified will be overcome easily, while others will persist and new ones arise. The lists of institutional barriers and value created by autonomous solutions in shipping are by no means exhaustive, and deeper insight and certain categorization can be an avenue for further research.

Another interesting avenue for further research would be an in-depth analysis of possible strategic responses to these barriers (Lawrence & Suddaby, 2006; Lawrence, Suddaby, & Leca, 2011). The analysis of institutional work aimed at transforming institutions could consider the complex interplay among the three institutional pillars.

### Acknowledgements

We acknowledge the funding provided by Academy of Finland, grant number 301843 (The Sea). We also want to thank the practitioners whose insights helped us develop this paper as well as four anonymous reviewers whose insightful comments contributed greatly to improving the quality of this paper. As always, all the remaining mistakes are authors' own.

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