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A Tripartite Model of Shipping Digitalization: Findings from a Multi-Case Study

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Abstract

Digital transformation is one of the most topical themes for the shipping industry, today. Academics and practitioners investigate this transformation, in specific how it affects shipping companies' service and strategic, operational and tactical level practices, as well as how digital technologies enable new entrepreneurial orientations and lead to changes in shipping markets and maritime sector organizations. However, the implementation of new digital technologies, as well as the actualization of the associated business and management possibilities and changes, still encounters several challenges. With our paper, we seek to examine shipping digitalization logics and factors affecting the digitalization processes. Which drivers push the adoption of digital technologies in shipping and which digitalization management practices enable them? We follow a qualitative research approach to gain in-depth insights from experts' interviews, with a multi-case study. For shipping companies, shipping digitalization is primarily driven by business efficiency and process improvements and demands communicated by customers and paved by competitors. Other shipping industry actors, like classification societies, marine insurance companies or digital technology companies perceive digitalization as an opportunity to further redefine their role and create new value propositions in the digital environment. A multitude of technologies, for autonomous ship and smart shipping, also trade and maritime logistics blockchains is effectual in this digital transformation process with heterogeneous expectations, enabling capabilities, approaches and outcomes.

1. Introduction

A considerable research effort has been concentrated on technical and operational implications of digitalization in shipping. However, research works and available results that address the shipping digitalization phenomenon with a

combined technical and management approach are still lacking. New research questions are needed in order to frame the digitalization technologies adoption or development and identify management approaches to leverage appropriately. With our study we seek to understand and consistently conceptualize the reasons why shipping organizations decide to digitalize their service, operations and cyber-physical assets, also revisit their value creation and appropriation approaches and strategy, their digital-era innovation capabilities and innovation processes. In the following sections, we illustrate the primary technologies that shape the digital transformation in shipping, exemplifying the areas affected; we further present the theoretical basis regarding drivers and digital technology adoption logics and enablers. We have reviewed and synthesized prevailing research streams dealing with digital innovations, digital strategy and Industry 4.0 and blockchain technologies in order to frame the current research gap in maritime management studies and contribute in developing a deeper understanding of the digitalization technologies and their business implications. We conducted a multi-case study to analyze how incumbent organizations in the shipping sector manage digitalization, related with an array of technologies, namely IoT, data analytics, artificial intelligence and blockchain. Given the scarcity of research on the shipping digitalization technology and management, our goal was to build a foundational, overarching model, using grounded theory techniques in case study research (Saldana, 2009).

Firstly, we elaborate a technology-centered model of shipping digitalization that embeds three intertwined pillars: digital technologies (IoT, big data analytics, AI, blockchain), digital solutions (smart shipping systems and services), and digital business concepts, models and practices (digitalization drivers, capabilities and innovation process and modes). Secondly, we devise a reconceptualization of the above constructs and perspectives so as to embody the idiosyncrasies of shipping digitalization and digital transformation, in the current transformation phase of incumbent shipping organizations, based on the findings, the extent of validation and the insights we gained with our field study. The multi-case research we present took place within five of the largest and most advanced shipping institutions, worldwide; including two shipping companies, one classification society and one autonomous ship and one maritime blockchain consortium, henceforth making the research setting suitable for investigating the phenomenon of interest, namely shipping digitalization - constituent technologies and management.

2. Conceptualization of Shipping Digitalization

2.1. The research process

Digital transformation in shipping already affects shipping companies' departments, maritime business networks and supply chains, as well as seafarers and professionals onboard and ashore. Digitalization, in particular value generation enabled by digital infrastructures and services is characterized by heightened integration of shippers and maritime transport and logistics enterprises, beyond synchronized technical architectures and business process and henceforth creating the possibility for new business logics and economic and social value (Andal-Ancion et al, 2012; Colbert et al, 2016; Chesbrough, 2010; Fitzgerald et al, 2014; Osterwalder, et al, 2005). Respectively, a number of related action fields needs to be addressed and structured to assist both academics and professional engaged in digital transformation in shipping.

In order to devise our conceptual, research framework, we explored the main research streams of digital transformation, digitalization and digital innovation in Information Systems, Management Science and Innovation Management studies, today. We considered this approach as appropriate in order to gain a deeper, general understanding of the fields of interest, associated with digital transformation, across industries, and subsequently contextualize the research issues of relevance in the shipping environment (Legner et al, 2017).

For our literature review, we used the Association of Information Systems (AIS) "basket" of journals and conferences which are identified as the leading sources in IS research. We have also based our theoretical framework development on searches in Academy of Management (AOM) journals and conferences, primary sources in Management Science and Innovation Management, henceforth having acquired a representative overview of the research streams, themes and issues in both these communities.

Our research is complemented with a continuous, longitudinally performed scanning of related, evolving literatures in Information Systems and Software Technology, also Maritime Studies; furthermore publications in non-academic press related with digital market, ship and port technologies, have been considered. We reviewed various studies from consulting companies (e.g., Boston Consulting Group, EY, Accenture) and IT vendors (e.g., IBM, Kongsberg), which have enabled us to critically assess, contextualize, filter and synthesize the prevailing research perspectives for the purpose of our study.

Hence, we complemented theoretical insights from first tier academic literature with practical insights from sector specific analyses. Although the results of the later studies were generic or vendor specific, they offered a valuable complementary perspective of shipping business and market trends and orientations.

Six main research streams for shipping digitalization management were considered most pertinent, namely digital strategy, digital innovation, Industry 4.0, and adjacently the themes of business models, analytics and blockchain; all themes are being intensely researched today in the IS and Management Science communities. Under the umbrella of these broad, prevailing six research streams, we have identified a number of finer grained research perspectives of interest, which can articulate the idiosyncrasies of shipping digitalization management logics and factors of implementation and management.

Our framework development is based on grounded theory methodology, which dictates constant theoretical development. Henceforth, throughout the field research and the interviews process, we compared new insights gained from the interviews against the perspectives we initially developed in our framework and study design and revised the framework as necessary. In that sense, the final theoretical framework we present has emerged during the field research process.

2.2. The model

Based on the conceptual analysis proposed by Wiesböck (2018), digital innovation in shipping can be articulated along three basic pillars: (1) innovative digital technologies (IoT, analytics, AI, blockchain) (2) innovative digital solutions (smart shipping systems and services, maritime blockchains), and (3) digital business concepts, models and management practices (digital mindset and skillset, technology partnerships). Based on generic digital technologies, shipping companies and maritime organizations develop industry and company specific innovative digital solutions and integrate them in their existing (inter) organizational and technical systems. This process includes the sourcing, adaptation, or development as well as the management of digital infrastructures and technology applications. Accordingly, the transition from a generic digital technology, like IoT or big data analytics platform to a particular shipping digital solution, like a predictive maintenance solution, characterizes an organization's digitalization. Innovative digital solutions, in turn, shape and are being shaped by the emergence of innovative digital business concepts and practices that are intertwined with digital solutions. This transformation process embedded in digital solutions and enacted with digital business models and practices is defined as digital transformation and captures the organizational changes and business model innovations induced by digital technologies (Atzori et al. 2010; Beck et al. 2017; Bharadwaj et al. 2013; Bordeleau et al. 2018; Demirkan et al. 2015; Kane et al. 2015).
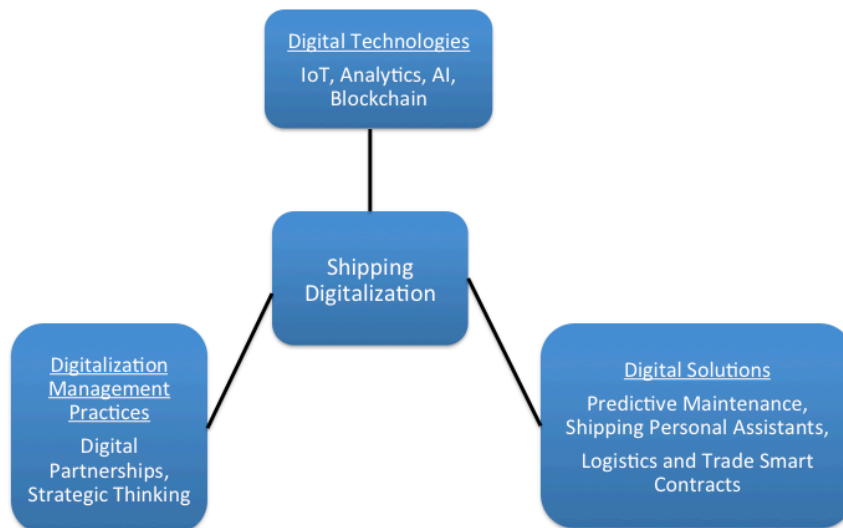
Fig. 1. A Tripartite Model of Shipping Digitalization

The adoption, adaptation, development, and management of innovative digital technologies, which represents the foundation for digital innovation (Nambisan et al. 2017) is based on digital infrastructures (Henfridsson and Bygstad 2013), henceforth the capability to (re)source and manage digital infrastructures (i.e. order newbuildings with IoT hardware, networks) is foundational to shipping digitalization.

To create and operate digital business models and practices firms need the develop and enact a digitalization capability; an ability to think strategically about digital technologies, approaching digitalization as a source for value creation (Barrett et al., 2015), to leverage technology-based business relationships and create digital innovation networks (Lyytinen et al. 2016), to leverage also the explorative mode of digital innovation, besides focusing on short sighted improvements of existing business and enterprise or ship operations software and processes through the use of innovative digital technologies (Nambisan et al. 2017; Yoo et al. 2012).

Incumbent, leading shipping companies, today, primarily develop innovative digital solutions (i.e. blockchain based smart contracts) by aligning shipping strategic, operational and tactical needs and objectives with digital technologies affordances. To this end, typically incumbent shipping companies and maritime organization form digital technology partnerships, consortia, and joint ventures.

Shipping companies and maritime organizations realize the necessary conditions in the form of appropriate structures (i.e. creating new digital units or smart shipping departments), resources (advanced cyber-physical infrastructures, data assets and employees with digital skills), culture (data and digital savvy organizations), as well as governance mechanisms (cross departmental collaboration), which enable them to leverage digital technologies. Apparently, shipping companies with digitization engagements complement digital solutions with innovative digital business concepts, models and practices (Svahn et al, 2017).

In the following, we elaborate further the particular elements of our tripartite model of shipping digitalization.

3. Shipping Digitalization: Technologies and Solutions

In this section, we outline the technological foundations of the shipping digitalization, which form a pluralist creation of use cases (i.e. AI systems for process automation, insight and action, and customers' engagement). A multitude of digitalization outcomes (application areas) is emergent. They are summarized in Table 1.

3.1. IoT: Internet of Ships and Sea Services

Sensors, actuators, or processors are embedded in vessels' technical systems, like engines, communications and data fusion systems, propellers or cargo systems (Levander, 2017) Embedded software platforms integrate and manage the increasingly autonomous functions of ships and the interconnected shipping business processes as well as the connected maritime ecosystem service systems.

Furthermore, in order the above described technical and business design approach to be broadly materialized, a number of support platforms are explored today; open data platforms collecting, curating, processing and offering APIs of ship machinery and devices' technical operation datasets. Digital solutions providers are expected to create new services based on data monetization business models, currently denoted as sea services.

Shipping digitalization research needs to address both the technical networking and data analytics aspects effectual to ship cyber-physical systems and ship IoT platforms (i.e. new ontologies, database, electronics and communications standards), as well as the business model related aspects for fostering IoT enabled ship and shipping services (Lycett, 2013; Shmueli et al, 2011; Thomas et al, 2014).

3.2. Artificial Intelligence: Autonomous Vessels and Smart Shipping

Artificial Intelligence (AI) is gaining a new momentum in shipping applications and ship technology. Two distinct fronts are identified:

Firstly, the autonomous vessels technology, as vastly materialized by applying various techniques and technologies ascribed in general as artificial intelligence. Machine learning techniques for improved situation awareness support a number of ship operations and functions, including anomaly detection for navigation, maneuvering or collision avoidance. Condition based monitoring of ship mechanical systems is another major application area.

Self-management and autonomous systems design principles and capabilities, i.e. monitoring, control, optimization and autonomy at various levels (0-5 or 6) and functional areas of ship operations (navigation, cargo handling) are relevant.

Various initiatives have been undertaken on the development of smart ship operations technologies for improving safety and efficiency in navigation, primarily. In recent years, autonomous vessels research and development efforts are of paramount importance, whereas almost all advanced maritime nations currently work on autonomous vessels initiatives, with different stages of maturity and progress. Recently launched works by IMO related committee is also an accelerating factor in autonomous vessel technology development.

In general, an autonomous ship is operated by a land-based surveillance and control center connected by a collection of digital technologies such as IoT, data analysis technology, various sensors, and broadband communication. Highly automated (autonomous) or remote controlled or remote control of certain tasks of shipboard operations like vessel operations, cargo management / cargo handling, are distinguished and tested in various autonomous vessels research projects globally today, including the national initiatives and projects of Japan, China or industry led projects in North Europe (Jokioinen, 2017).

Secondly, smart shipping is related with commercial and technical operations improved reliability, optimization and control. AI is supporting a number of application areas at the tactical level of shipping management, including asset optimization, fleet planning, service planning and chartering, also at the operational level, with incremental improvements of ship equipment and conditions based monitoring software (i.e. predictive maintenance), being a most popular development area today. Energy consumption monitoring and environmental regulations compliance smart application are also emerging.

Strategic level smart applications are also in the advent, like shipping markets monitoring software and personal digital assistants.

Shipping digitalization research needs to address both the whole spectrum of AI use cases in ship and shipping operations (i.e. planning, commercial operations and support business operations), in diverse shipping sub –sectors, and their business implications as well (Loebbecke et al. 2015; Lycett, 2013; McAfee and Brynjolfsson, 2012).

3.3. Blockchains for Maritime Logistics and Trade

Extant blockchain research, both generic and maritime blockchain works, is mostly addressing technological perspectives; it is use case specific and details the constituent parts of blockchain technology, like consensus mechanisms or alternative development platforms, architectures and design aspects. Only very recently, a number of academic research papers address factors affecting blockchain technology diffusion and management.

Maritime blockchain technology is already tested by major maritime industry partnerships, with remarkable attention attracted (i.e. Maersk-IBM TradeLens Platform, PSA-IBM platform and Port of Antwerp-T-mining pilot), also, pilot consortia (i.e. Japanese Trade Blockchain platform) and a remarkably increasing number of start-ups. The works under the UN/CEFACT auspices is also an accelerating factor in blockchain technology development.

The blockchain technology has matured enough beyond crypto currencies or public, permissionless platforms to include more focussed, hybrid architectures and smart contracts for suitable maritime use cases like marine insurance or maritime logistics and trade transactions.

Shipping digitalization research needs to address both a broad spectrum of maritime blockchain use cases, beyond bill of landing or letter of credit transactions to more realistic and radically designed use cases, architectures and alternative development environments, materializing the potential of blockchain for a new paradigm of disintermediation/remediation and transparency. Furthermore, management perspectives need to be addressed; the determinant factors of diffusion, platform economics, standardization economics and market acceptance viewpoints can be further examined (Pilkington, 2016; Sternberg and Baruffaldi, 2018; Underwood, 2016).

Table 1. Shipping Digital Solutions

Digitalization Areas	Digital Technologies-Solutions
Ship Operations-Autonomous Functions	IoT, analytics, AI, also 5G
	Various levels of Autonomy for Ship Operations: Navigation, Berthing, Collision Avoidance.
Shipping Commercial and Business Management Operations	Analytics, AI, IoT
	Asset optimization, fleet planning, service planning, Predictive maintenance, conditions monitoring, situation awareness.
Trade and Logistics Functions	IoT, analytics, blockchain
	Cargo monitoring, Paperless Trade, Smart Contracts
Digital Platforms	Analytics, AI
Internet of Ships Platforms &	Smart Cargo Booking
Internet of Sea Services Platform	Open Data Center for shipping companies, shipbuilders, equipment manufacturers, IT companies, weather information companies, and digital solution providers.

4. Digitalization Management: Concepts, Models and Practices

4.1. Digital strategy and business models

Digital business strategy has longitudinally and consistently been articulated along the merely "tactical and operational" objectives of cost-reductions, quality improvements, process improvements or operational excellence, as well as the objectives of supplier and customer engagement, insight and decision support aims. The research streams of business models and digital innovation have enriched the discussion with new angles for new digital product/service development, new value creation and digital value propositions, data monetization and the role of business networks and digital platforms (Kane et al, 2015; Nylén and Holmstrom, 2015; Liere-Netheler, et al, 2018; Teece, 2010; Zott et al, 2011).

Our research framework considered the *expectations/drivers* associated with the digitalization processes in shipping; the identification of drivers is primarily relevant to the digitalization awareness phase, preceding the actual development or adoption of technology. Drivers are understood as the perceived or expected business advantages that result from embedding digital technology in shipping services, smart shipping systems or new business models, like blockchain-enabled smart contracts and open, Internet of Ships platforms for data sharing and shipping services (Liere-Netheler, et al, 2018).

Furthermore, we have included in our initial theoretical framework and respectively related interview questions that addressed the *value creation* and *digital business models* aspects; in specific how the notion of value creation resonates and is operationalized in the context of digital strategy in shipping, how it is understood by professionals and to what extend it is a utilitarian, practice oriented construct that enables the actualization of digitalization initiatives. Remarkably, in our field study, shipping organizations interviewees consistently avoided to respond to related questions and prompts, contrary to the questions and prompts addressing the drivers and strategies for digitalization that were regularly, eagerly discussed. Therefore, in our second iteration of the theoretical base refinement, the academically, formally prescribed value creation and business model angle was omitted, from further development and synthesis with the rest of the research lenses, as not relevant or rather overlapping with adjacent concepts and management tools in practice-oriented shipping digitalization management.

In the sequence, in Table 2, we elaborate the main digitalization drivers that were validated or emerged through our case studies, as pertinent constructs of shipping digital strategy and business models.

Table 2. Drivers of Shipping Digitalization

Digitalization Drivers	Business Innovation Logic
Process improvements	Smart shipping systems automate via self-management properties the planning, and actual operation of technical, commercial and support functions of shipping. Main perceived advantages are further improvement in cost efficiency, as well as improvements related with safety and shippers and business partners' satisfaction. Major innovations are: condition-based ship systems monitoring and predictive maintenance, real time cargo monitoring and self-adjustment of ship operations.
Cost Reduction	Digitalization improves cost–efficiency in terms of a number of application areas: more accurate energy consumption monitoring, emissions monitoring, digital twin platforms for integrated ship design and operation, predictive maintenance, cargo monitoring ,also safer ship operations with various levels of autonomy.
Customer and Business Partners Expectations	The traceability of freight throughout the shipping and maritime transport process, aligned with the whole supply chain and production processes is essential for the quality levels demanded by end customers. Shipping business is gradually aligned with this

business model enabled by digitalization.

Workplace Improvement	Autonomous ship technologies and functions, like autonomous navigation, collision avoidance and berthing functions will improve safety and business performance. Complex or risk entailing activities can be performed by autonomous vessels and automated ports infrastructures. Condition-based ship systems monitoring and predictive maintenance, autonomous and self-managed ship. operations directly contribute to these driver.
Vertical and Horizontal Integration	Datafication at the tactical and operational level by analytics and sensor technology can be integrated to enable top management level cognitive applications and also feed back actions at the ship and shipping management levels. Also, integration of the various digital solutions used in the different stages of planning and ship and shipping operations.
Data Monetization Models	New business models arise form datification. Shipping industry organizations have accumulated large and rich datasets of their business, markets, customers, business partners and market environment. Based on these data assets and advances in database, cloud and visualization technology but foremost computational techniques, shipping industry organizations may develop open data platforms and data analytics based services and solutions to satisfy old and new strategic objectives and business models.
Radical Innovations	(i) Autonomous ships and (ii) blockchains are two radical innovations for the shipping industry. New knowledge, new market structures but also new sources of value can be designed, tested and appropriated by competent actors. Incumbent, leading companies are involved in "edge exploration" in both these radical innovation fronts to secure an early mover position and control/leverage in related markets.
Market pressure	Competitors already use digital shipping technologies. It is imperative to secure a competitive advantage with digital technology and not lag behind the market standards.
Innovation Push	Innovative digital shipping service and smart systems, result in a dominant technology push force, and market competition, both enabling digitalization. Shipping companies and maritime organizations determine the particular models and practices to generate value.
Institutions	Industry associations, regulation and standards organizations and industry institutions play a role in setting norms, business and technical standards of digitalization, acting as exogenous factors.

4.2. Digitalization approaches and management practices

Success factors or the notions of *enabling factors* and *determinants* of shipping digitalization represent those managerial areas that can be influenced in order to enact and steer digitalization management.

Our research framework considers those factors, as well. In particular, we examined the *digital innovation capabilities* (i.e. leadership, data culture, resources), which may constitute managerial action items and ensure positive digitalization outcomes (Ethiraj et al, 2005).

Based on the seminal works of Bharadwaj (2000), we initially view digital innovation capabilities as a construct with six dimensions: digital infrastructure, digital business partnerships, digital business strategic thinking, digital business process integration, structures and network orientation/connectivity.

In addition, we addressed the adoption of state of the art methodologies of innovation management, alongside the mainstream shipping management operations; hence we examine the course of the various digitalization activities and management practices along *the different phases of the innovation process*, namely digital opportunity identification/ideation, digital initiative exploration and testing, and lastly, actual launching/operation of the digital technology systems/services (Salerno et al, 2015).

Also remarkably, in our field study, interviewees mostly did not directly discuss these questions, however, they did refer to management concepts and practices related with what the literature essentially denotes as digital innovation capabilities, namely digital culture or digital leadership, partnerships and collaboration orientation, also learning/market intelligence capability. This may be partly be ascribed to the fact that interviews were shipping business middle managers, not highly exposed to business school or academic management and business nomenclature, also the digitalization projects they are involved and we studied are mostly at the testing phase, not at the actual commercial or operational phase; hence, the success of the initiatives can not be effectively assessed, at this point, to a much lesser extent be correlated to particular management concepts and practices. Interviewees were mostly keen to discuss aspects related with the approach taken as regards the innovation process of digitalization systems development; therefore innovation process factors are also validated and maintained in the digitalization management theoretical framework as relevant. Last, we include the generic notions of opportunities and barriers of digitalization as appropriate prompts to address possibly missing aspects as regards the technologies and digitalization management affordances and practices.

In the sequence, we elaborate the main digitalization management factors, entailing innovation process concepts, digital capabilities notions and adjacent models and management practices overall, as were validated or emerged through our case studies.

Re-conceptualizing capabilities for shipping digitalization

Extant literature on the digital innovation capabilities construct reveals that despite the numerous analyses that address the new digital and data economy idiosyncrasies and heterogeneity of digital business environments and business models, the innovation capabilities construct remains not drastically adapted to the digitalization context.

Strategic thinking is the common denominator in incumbent shipping companies' cautious, incremental digitalization projects and in radical innovation initiatives led either by cross-industry or governmental auspices and leadership. The realization of the paradigm shift at the C-suite level, also the middle management level is critical. A digital mindset is emergent, complementing established strategic-orientations and supported by a market intelligence capability. Smart shipping systems and services, like ship equipment and cargo systems enhanced with sensors, actuators, computing power, and connectivity (Porter and Heppelmann, 2014), also maritime ecosystem services, integrate physical assets and resources into wider cyber-physical infrastructures and service systems. Apparently shipping industry organizations which are engaged in digitalization, actively explore and basic premise that the "basis of competition shifts from services to product and service systems and to systems of systems" (Porter and Heppelmann, 2014). Although this shift attracts competitors from outside the industry, shipping companies and other maritime organizations primarily still face competition threats from digitalization leaders, among the industry competitors.

Partnerships, Consortia and Joint Ventures are all becoming dominant business networks forms and technology management strategies, appropriate to address the risks, uncertainties and knowledge dispersion regarding digital technologies and solutions, like autonomous systems and smart shipping systems development and operation.

Heighted competition among shipping companies, liner alliances, national and regional clusters necessitate certain post industrial era strategies for research and development, in particular as regards radical innovations, such as autonomous vessels technology or blockchain platforms that require large industry support (i.e. in standards development) and market acceptance, to materialize their benefits.

Appropriate structures are necessary and are implemented in the form of new departments (digital or smart shipping ones), formalized cross departmental teams for digitalization projects development, also open innovation forms with external partners of complementary knowledge and business expertise. Internal also external collaboration is mostly the norm in digitalization processes.

Resourcing in terms of new data science, AI and programming skills, rather than pecuniary resources, is a determinant factor of digitalization acknowledged in academic, empirical also practice-oriented endeavors. Shipping is not an exception. Shipping industry organizations have accumulated large and rich datasets of their business transactions, markets trends, freight rates, tariffs etc., also customers' and business partners' business behavior.

Based on these data assets and advances in database, cloud and visualization technology but foremost computational techniques, shipping industry organizations may develop stronger data analytics capabilities to satisfy their digital strategy objectives. Building this data (analytics) capability comes with the awareness, realization and active exploration of business benefits stemming from datafication and data monetization models.

Last but not least, a resourcing capability, in terms of high cost vessels/fleets with autonomous functions embedded in IoT enabled cyber physical systems is a relevant construct as well.

Innovation process

Digitalization is a continuous, non-linear process, although with relatively distinct phases, including the awareness and realization of potential benefits of the digital technologies and models, exploration of emerging services, systems, applications and business affordances, and eventually the actual implementation phase and appropriation of digital technologies and business model. Digitalization as an innovation process entails the continuous scanning of the shipping markets and competitors, but foremost today different markets for relevant business models and practices to adapt (i.e. autonomous vehicles) or new needs (shortage of seafarers) and opportunities even problems to solve and exploit. The ideation phase and project/system refinement in terms of iterative filtering, design, testing and validation up to commercialization and launching entail appropriate project management, design thinking and human resource management techniques and methodologies. Henceforth, an innovation process is a demanding organizational routine, supported by a mix of related methodologies, which may assist the uncertainty management of digitalization. Digitalization is different from previous technological innovation trajectories, necessitating internal and external collaboration, networks and platforms as dominant governance mechanisms. Therefore, shipping digitalization as a transformational process entails new management tools to organize as a process. Best practices from other industries are already considered, adapted and it is observed to be actively leveraged by leading shipping organizations.

Exploration vs. Exploitation

The innovative potential of shipping digital solutions, business models, and strategies is approached in view of the potential to decrease transaction costs, better coordinate knowledge and further resources and generate economic and social value by redefining the nature of valuable, rare, tangible and digital resources of shipping organizations. The digital strategy imperative of shipping companies and maritime organizations is ultimately an endeavour of balanced, portfolio strategy. The scope of digital transformation, the options for business model reinvention and "edge exploration" along with the prioritization logic of short-term improvements vs. paradigmatic digital technology projects and their strategy execution possibilities (partnerships, greenfield) entail different business logics and management practices.

In the following Table 2, we elaborate the main digitalization management concepts, models and practices that were validated or emerged through our field research.

Table 3. Shipping Digitalization Management

Concepts, Models, Practices	IS and Innovation Management Constructs
Digital Innovation Capabilities	Strategic Thinking (Paradigm Shift and Digital Mindset), Partnerships, Data Culture, Structures, Resourcing (Digital Skillset, Autonomous Fleets, Smart Systems)
Innovation Process Practices	State of the Art Methodologies, Market Intelligence, Agile Development, Brainstorming- Delphi, Scenario Analysis
Explorative vs. Exploitative Innovation Mode	Balancing Digitalization Portfolios
Collaborative-Open Innovation Model	Network and Platform orientation vs. Industrial era Technology Strategies
	External and Internal Collaboration
	Data Sharing vis a vis Data Ownership

5. Methodology and cases

In order to examine how digitalization transforms the shipping service, smart ships and smart shipping systems, also the shipping companies' management logics and practices, we studied five cases addressing different perspectives of the shipping industry. For each case, we performed in-depth interviews with key interviewees who were responsible for managing and implementing shipping and ship smart systems that involve IoT, big data and analytics, AI or blockchain technologies. An interview script with three sections, namely shipping digitalization strategy, and drivers, actual digitalization technologies and systems in development or use, and effectual digitalization management approaches, guided the interviews. We typically started with a brief introduction of the study rationale and the request that the interviewees generally portray the shipping digitalization technologies that they consider important and how these are used and possibly shape new shipping strategies and business models, also how the digitalization is affecting shipping markets structure, shipping companies' and other stakeholders' management practices. In the following, the interviewees were asked to describe in detail how the particular key technologies of shipping digitalization enlisted are applied, used or offered by the interviewees' company; furthermore, to explain whether (and which) new functions, services are enabled by the digitalization projects or platforms they are involved, to explain to which extent current processes embed or leverage the functions, and to describe implications of the emergence of smart ship and smart shipping or blockchain technology with regards to their organizations' business processes and business models. In addition, the research protocol included the an analysis of the innovation process and pertinent digital innovation capabilities enabled (or lack thereof) hindered their organization's digital transformation. Last, interviewees' were asked to comment and assess the overall potential, opportunities and challenges of shipping digitalization.

Due to the novelty of the shipping digitalization phenomenon, the companies/organization/consortia we investigated were selected for two reasons: they are large, incumbent companies/organizations in the shipping industry, well renown for business and technological excellence and strategic orientation for quality and innovation. Henceforth, we ensured that the interviewees were engaged in shipping digitalization to an extent that merits an investigation. The resulting set of interviewees was expected to provide us with a comprehensive and representative

view of shipping digitalization logics, factors and approaches, as they are known experts in shipping management business, information technology, or marine engineering, and their responsibilities include managerial as well as a technical tasks. All interviews proceeded with cross-functional groups that involved experts from an array of information technology, operations, smart shipping, marketing groups/departments/units or team members. We henceforth ensured that the interviewees' complementary perspectives would allow us to investigate how shipping digitalization is shaped and is shaping the industry and individual companies' and organization's management practices and strategies, as well as identify the technological trajectory of smart shipping services and autonomous ship systems. Before conducting the interviews, we sent a two-page summary of the main interview questions (both in English and Japanese) to each organization or contact person, whereas each interview lasted for about an hour. All interviews were conducted face-to-face, at the studied organizations' premises and were transcribed. One interviews was conducted throughout in English, and the others were conducted mainly in Japanese and translated simultaneously in English. Our research team consisted of two academics, and two postgraduate researchers, one of them being a high level, civil servant, and expert in maritime transport matters.

We followed the principle of "emergence" from grounded theory. Henceforth, our research process encompassed the research gap identification, the problem formulation, the case study design, and data collection, the framework validation and furthermore iterative theory elaboration, as emerged from and anchored in our field research data. In that sense, our study design was determined by our academic and professional experiences, predispositions and perceptions about shipping digitalization, but also allowed for the emergence of new theoretical insights (Saldana, 2009).

Interviews were conducted in an open-ended and semi-structured manner, based on the script provided in Appendix A. In addition, for triangulation purposes, secondary data was collected and analyzed, such as presentation slides, companies' presentation material, such as brochures and leaflets and additional material provided by interviewees after the meetings. This information helped us to frame the digital technologies and solutions' features and affordances discussed, also digitalization management logics and practices investigated.

In the following the findings of our research are summarized in Table 4. Shipping Companies A and B present a mostly converging portfolio of digitalization projects and initiatives, including smart applications for business and technical operations, and participation in autonomous ship and blockchain platform research project and partnership.

The classification society organization is engaged in broad range of digitalization projects like software for ship inspections and shipping companies business consulting, also a radical innovation digitalization project, developing a dominant open, data sharing platform for the shipping sector.

Table 4. Study Findings

Case Digitalization Technology and Solutions	Digital Strategy Drivers	Digitalization Management Models and Practices	Challenges
Shipping Company A	Process Improvements Cost Reduction Technology Push	Strategic Thinking Partnerships Structures (spin off technology company) Explorative vs. Exploitative Innovation Mode	N/A
Shipping Company B	Competition Process improvements	Strategic Thinking Partnerships Structures (Smart shipping	Technology Maturity Cost Efficiency Standards

	Cost Reduction	department)	
	Customers' Expectations	Internal and External Collaboration	
		State of the Art Methodologies	
		Explorative vs. Exploitative Innovation Mode	
Classification Society	Data Monetization	Strategic Thinking -Paradigm Shift and Digital Mindset	Market Acceptance
	Radical Innovation		Standards
		Open Data-Data Sharing Model	
		Network and Platform orientation	
		Internal and External Collaboration	
Autonomous Vessel Consortium	Radical Innovation	Strategic Thinking -Paradigm Shift and Digital Mindset	Cost-efficiency
	Institutions		Technology Maturity
	Technology Push	Internal and External Collaboration	Standards
Maritime Blockchain Consortium	Radical Innovation	Strategic Thinking -Paradigm Shift and Digital Mindset	Standardization
	Institutions		Market Acceptance
	Technology Push	Internal and External Collaboration	Technology Maturity

6. Discussion and Conclusions

The main corps of shipping digitalization research, so far, primarily entails engineering analyses; thus, suitable theoretical standings about the development and use of emergent digital technologies in shipping, as well as organizational ramifications resultant from digital innovations are still lacking.

In our study, incumbent, leading shipping organizations, with proven digitalization activities and experiences, were investigated. We have developed a tripartite model of shipping digitalization that examines three intertwined pillars: digital technologies (IoT, big data analytics, AI, blockchain), digital solutions (smart shipping systems and services), and digital business concepts, models and practices (digitalization drivers, capabilities and innovation process and modes). We devised our theoretical model, it's constructs and perspectives, based on principal IS and Management literatures and contextualized and synthesized them so as to address and conceptualize the idiosyncrasies of shipping digitalization and digital transformation, in the current digitalization trajectory phase. Based on the field research findings, the extent of validation and the insights we gained with experts' interviews, we have developed a reference framework of shipping digitization areas, interlinked with digital strategic drivers and

associated management models and practices. Our work contributes with an overarching model of digitalization, which presents pertinent technological and managerial aspects to be further developed, enhanced and validated by maritime studies' scholars.

Our research has certain limitations, mostly inherent in qualitative research; our multi-case study findings are not statistically representative; qualitative insights and digitalization management research directions, also the outline of selected, pertinent and nuanced aspects of smart shipping systems and their transformative potential management are examined. The research is based on the interviewees' descriptions, representing their subjective experiences, and to a lesser extent to a hermeneutical phenomenology, which builds on the researcher's interpretations and critical assessment of the experts' experiences and standpoints. Furthermore, the research findings depend heavily on the interaction between the researchers and managers/experts interviewed; hence a different research setting might lead in different responses, data and pertinent observations and conclusions for the same organizations.

The different nuances and heterogeneity of the strategies, drivers, managements practices and challenges, in shipping companies, maritime organizations like classification societies, or marine insurance companies, and radical innovation development consortia, needs further elaboration. Cultural aspects are not addressed/assessed either, as influencing factors. Digitalization barriers or shortcomings at the strategic, tactical and operational level as correlated with the size of the shipping/maritime organizations were not detected (i.e. lack of investment hesitation, technical or knowledge shortcomings).

Appendix A. Interviews Questionnaires

Interviews questionnaires were devised, and versioned according to the specific activities of the companies/organizations investigated. In the following, we presented the questionnaire (Q1) for shipping companies.

A.1. Q1

凡例
赤字：なるべく原文に沿ったもの、青字：船社様向けに日本側で解釈したもの
- Introduction: Research Objectives, Team, Interview Protocol
  はじめに：研究目的、調査手順など

In a semi-Structured Interview, the following blocks of questions will be discussed (with either the same person or different persons in related departments, emphasizing the respective, detailed questions in blocks A-C):
以下の A から C の質問についてヒアリングさせて頂ければ幸いです。
- A. Digital strategies, business drivers and expected results.

  A.情報革命方針、ビジネス上の動機、期待される成果
- Which are the primary technologies you envisage as important for shipping digitalization (smart shipping)?
  - communications, IoT, big data analytics, AI, blockchain, any other/all of them

  海運の情報化（スマートシッピング）について、どの技術が最も重要だと思われますか？（例えば、通信、IoT、ビッグデータ分析、AI、ブロックチェーン）
  貴社の情報化について、（今後）どの技術が最も重要になってくると思われますか？（例えば、通信、IoT、ビッグデータ分析、AI、ブロックチェーン）
  Could you tell us a bit more about?
- How would you define digitalization (or smart shipping) in the maritime sector, today? What is it about primarily, as regards policy and strategic objectives?
  海運業界において、情報化（スマートシッピング）をどう位置づけられますか？ 主に政策や戦略目標に関して教えてください。
  （赤字と同じ）
- Are there any *new* strategies pursued (other than cost-efficiency, sustainability etc) with smart shipping?
  スマートシッピングにより、どのような新しい戦略（費用効率、持続可能性などを除く）を追求されていますか？
  （赤字と同じ）
- How would you delineate the value created with shipping digitalization?
  - economic value, social value

- o improving competitiveness, business efficiency, innovation, transparency, safety, regulatory compliance, economic development

海運情報化により想定される利益についてどのようにお考えでしょうか?
・経済的価値、社会的価値について
・競争力強化、業務効率化、技術革命、透明性確保、安全確保、コンプライアンス、経済成長など
情報化により想定される経済的価値および社会的価値についてどのようにお考えでしょうか? （貴社において具体的に計測されているシステム導入効果がありましたら教えてください．）
Could you tell us a bit more about?

- How would you expect digitalization to affect shipping markets in terms of consolidation of players, new dominant players, new markets creation etc?

業界統合、新たな支配層、新たなマーケット創出などに関して、情報化が海運市場に及ぼす影響についてどのように期待されますか?
情報化により、業界統合や新たなキープレーヤーの登場、新たなマーケット創出などが発生すると思われますか? （例えば船社やアライアンスの再編、情報共有プラットフォームなどがあげられるかと思います。）

- How would you expect digitalization to affect shipping companies' (your company also) business behavior, in terms of
  - o new shipping services/business models
  - o new management practices

情報化が海運企業（貴社も同様）の企業行動に及ぼす影響について、下記の観点からどのように期待されますか?
・新しい輸送サービス/ビジネスモデル
・新しい経営慣行
情報化によって生じたメリットやデメリットについて教えてください。

- Do you consider as a desirable/probable digitalization outcome the development of
  - o Closed, few/dominant maritime digital platforms
  - o Open and common/interoperable digital platform(s)

望ましい/可能性の高い情報化の成果として、下記の技術の開発を検討していますか?
・閉鎖された少数/支配的な海運情報化プラットフォーム
・オープンで共通/相互運用可能な情報化プラットフォーム（複数）
情報プラットフォームの望ましい姿（閉鎖型、開放型、その業界の範囲）について教えてください。

- Do you currently *explore* and/or already *operate (pilot/at scale)*, smart shipping technology and operations, as regards
  - o Ship operations and Technical Management
    - Navigation, Situation awareness
    - Ship Equipment and Conditions Monitoring, Predictive Maintenance
    - Energy Consumption Monitoring
    - Environmental Regulations Compliance
  - o Commercial Operations
    - Asset Optimization
    - Fleet Planning
    - Service Planning
    - Chartering
  - o Crew Work and Training
  - o Autonomous Ship Project

現在、下記の項目に関して、スマートシッピング技術と運用について現在検討中、あるいはすでに運用（実証実験/大規模運用）していますか?
・船舶運航と技術管理
　航海、状況認識
　船舶の設備と状態の監視、予測的なメンテナンス
　エネルギー消費のモニタリング
　環境規制遵守
・商業活動
　資産の最適化
　船隊計画
　サービス計画
　傭船
・船員の仕事と訓練
・自律船プロジェクト
（赤字と同じ）

Could you tell us a bit more about your flagship projects, related with the above?
上記に関連して、貴社の主力プロジェクトについてもう少しお聞かせください。
自動運航船、船舶向け IoT プラットフォーム、SIMS(Ship Information Management System)などのプロジェクトについてお聞かせください．

- Which are the digital strategies or digital business model your company plans or currently supports with the above technologies/projects?
  上記の技術/プロジェクトの中で、貴社が計画している、または現在支援している情報戦略または情報ビジネスモデルはどれですか?
  上記の項目の中で、長期的に貴社が検討されていたり、興味を持っている項目について教えてください。

- Is digital innovation part of your company's overall strategy; Are related issues discussed at the highest level in the company?
  情報的革新は、貴社の全体戦略の一部ですか? 関連する問題は、会社の最高レベルで議論されていますか?
  情報化に関する技術開発について、CTO や CIO の経営層の関与など貴社内での位置付けについて教えてください。

B.	Shipping 4.0, Autonomous Ship, Smart Shipping Technology

B. Shipping4.0、自律船、スマートシッピング技術
- Related with the above, could you please briefly describe the main technical features of the flagship digitalization projects you are currently developing or planning?
  - o	For each one, could you give us a description of the
    - main functional architecture
    - technical architecture
    - platforms and tools used for development
    - main computational techniques/algorithms used? i.e.type of analytics / machine learning techniques per smart shipping application implemented
  上記に関連して、現在開発中または計画中である主力情報化プロジェクトの主な技術的特徴を簡単にご説明下さい。
  ・主な機能的構成
  ・技術的構成
  ・開発に使用されるプラットフォームおよびツール
  ・主な計算技術/アルゴリズム、すなわちスマートシッピングのアプリケーションごとのアナリティクス/機械学習技術のタイプ
  （赤字と同じ）
- Would you consider the above digital technologies/projects distinctly differentiated from other organizations' initiatives? i.e. Maersk, Kongsberg, Rolls Royce and other related smart shipping joint ventures
  - o	Do you primarily differentiate in terms of
    - technology and technical capabilities
    - operational results
    - market positioning/scale
    - other
  上記の情報技術/プロジェクトは、他の組織的なイニシアティブ、すなわち Maersk・Kongsberg・Rolls Royce などによるスマートシッピングに関する合弁事業とは明確に異なると考えていますか?
  貴社は主に以下の点について差別化を図っていますか?
  ・技術と技術力
  ・運営実績
  ・市場ポジショニング/規模
  ・その他
  （赤字と同じ）
  Could you tell us a bit more about?
- Which are the cyber security main concerns and solutions you consider?
  サイバーセキュリティーに関する懸案事項とその対策についてどのようにお考えでしょうか?
  （赤字と同じ）

C.	Digitalization Management: approaches, practices

C. 情報化の管理：方法と実践
- How would you assess the maturity/business impact of the following technologies:
  - o	Shipbuilding and system integration

- o Autonomous ship research and development
- o Ship and Technical Management operations
- o Commercial and Business Operations
- o Other/All

次の項目について、技術の成熟度/ビジネスへの影響をどのように評価しますか？
・造船とシステム統合
・自律船の研究開発
・船舶および技術的管理業務
・商業および事業運営
・その他/すべて
（赤字と同じ）

Could you tell us a bit more about?
- How do you choose/prioritize your particular digitalization (smart shipping) projects? Did you follow a formal process to determine and launch them i.e. brainstorming, Delphi etc

  特定の情報化プロジェクト（スマートシッピング）をどのように選択/優先付けしますか？ ブレーンストーミングやデルファイ法など、正式な手順に従って決定し、立ち上げましたか？
  （赤字と同じ）

- What is your company's innovation process approach and milestones, as regards the:
  - o Ideation (smart shipping opportunity discovery)
  - o Experimentation (projects/operational areas' design, testing),
  - o Acceleration (launching strategy)

  下記の項目に関して、貴社の革新過程の方法とマイルストーンは何ですか？
  ・観念化（スマートシッピングの機会の発見）
  ・実験（プロジェクト/運用領域の設計、テスト）
  ・加速化（立上げ戦略）
  下記の項目に関して、革新過程において用いられた方法とその時の目標（対象範囲の拡大）やそのステップごとの期間はどのようなものでしたか？
  ・観念化（スマートシッピングの機会の発見）
  ・実験（プロジェクト/運用領域の設計、テスト）
  ・加速化（立上げ戦略）

- What is your approach to smart shipping project/portfolio management, i.e. in terms of
  - o Balancing breakthrough and mature digital technology projects (i.e. autonomous ship and vessel monitoring projects)
  - o Financing
  - o Risk Management
  - o Change Management

  下記の項目について、貴社のスマートシッピングに関するプロジェクト/ポートフォリオ管理についてどのようなアプローチを採っていますか？
  ・画期的新技術と成熟した情報技術プロジェクトとのバランス（自律船プロジェクトと船舶監視に関する一連のプロジェクト）
  ・財政
  ・危機管理
  ・変革管理
  （赤字と同じ）

- What is your management approach for implementing them, in terms of:
  - o Responsible business unit
  - o new structures
  - o roles assigned, and
  - o technology or business alliances, networks you form respectively

  下記の点から、それらを実施するための管理手法は何ですか？
  ・責任ある事業組織
  ・新しい構造
  ・割り当てられた役割
  ・技術的またはビジネス上のアライアンス、ネットワーク
  上記のプロジェクト管理において用いられた方法について、工夫された点をお知らせください。

- Do you primarily conduct in house or collaborative, open innovation for the smart shipping projects?

  スマートシッピングに関するプロジェクトのために、社内や他社共同で主にオープンイノベーションを行っています

か？
（赤字と同じ）

- Do you measure/benchmark the performance/results of the smart shipping projects implemented?
  実装されたスマートシッピングに関するプロジェクトに関して、性能/結果の測定/比較評価を実施されていますか？
  スマートシッピングに関するプロジェクトにおいて、効果測定を実施されていますか？
- Do you primarily see the above as necessitating new business capabilities or exploitation of existing, incrementally improved capabilities?
  上記について、新しい業務能力の必要性、あるいは漸進的に改善された既存能力の活用、主にどちらを考えていますか？
  （赤字と同じ）

- What are the most critical digital innovation capabilities for shipping companies (in your company, also in general), as regards i.e.
  - Leadership, commitment to innovating with technology
  - Quality or Market orientation
  - Resourcing
  - Network and Collaboration orientation
  - Culture
  - Other
  以下の中で、海運企業（貴社、一般的に）における情報化に対する最も重要な革新的能力は何でしょうか？
  ・技術革新に関するリーダーシップ、合意
  ・品質や市場指向
  ・資源提供
  ・ネットワークと協同体制指向
  ・文化
  ・その他
  （赤字と同じ）

- How would you see the procurement of digital technology in shipping companies to change in the future (make it or buy it or any other options)
  将来的に、海運会社における情報技術の調達がどのように変化すると考えますか？（自社開発、購入、その他）
  （赤字と同じ）
  Could you tell us a bit more about (your company's pathway/in general)
  下記の項目について、貴社や一般論として、もう少し詳しく教えてください
- The maritime software ecosystem is constantly expanding and improving. How do you see this development to affect your company's digitalization management (shipping companies in general also)?
  海運業界のソフトウェアの生態系は絶えず拡大し、改善しています。 このような発展は、貴社の情報化管理に影響すると考えますか？（海運会社全般でも同様に？）
  （赤字と同じ）

- What are the major opportunities and benefits with digital technology (smart shipping) exploration/exploitation today?
  情報技術（スマートシッピング）の探索や開拓に関する主なチャンスとメリットは何ですか？
  （赤字と同じ）
- What are the major obstacles of digital technology (smart shipping) adoption today
  情報技術（スマートシッピング）の採択に関する主な障害は何ですか？
  （赤字と同じ）
- What are the main standardization issues you consider
  貴社が考える主な標準化に関する問題は何ですか？
  （赤字と同じ）
- What are the main legal, regulatory issues you consider
  貴社が考える主な法規制に関する問題は何ですか？
  （赤字と同じ）

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