The disruptive impact of future advanced ICTs on maritime transport: a systematic review

Carmen Bălan
Faculty of Marketing, The Bucharest University of Economic Studies, Bucharest, Romania

Abstract

Purpose – This systematic literature review focuses on the following future advanced information and communication technologies (ICTs) applied in the maritime transport of cargo: Internet of Things (IoT), big data, cloud computing and autonomous ships/vessels (including unmanned ships/vessels). The review question is: "RQ: In what context and by means of what mechanism does the implementation of future advanced ICTs have disruptive impact on maritime transport?".

Design/methodology/approach – The paper complies with the methodological requirements of systematic reviews. The information analysis and synthesis are based on the CIMO logic, referring to the context (C), intervention (I), mechanism (M) and outcome (O) of the implementation of future advanced ICTs in maritime transport.

Findings – The review identifies the contextual factors and components of the mechanism that lead to the disruptive impact of different types of future advanced ICT interventions on maritime transport.

Research limitations/implications – The review approaches only the most important future advanced ICTs that will disrupt maritime transport.

Practical implications – The maritime transport organizations should consider: intended outcome as intervention trigger; increased efficiency and responsiveness; benchmarking.

Originality/value – For the first time, the CIMO logic is applied in a systematic review focused on future advanced ICTs in maritime transport. The CIMO-DMT model is elaborated as a basis for further research. Ten directions of study are recommended in a future research agenda.

Keywords CIMO approach, Future advanced information and communication technologies (ICTs), Internet of Things (IoT), Big data, Cloud computing, Autonomous ships/vessels, Unmanned ships/vessels, Maritime transport, Supply chain, Disruptive technologies, Cargo

Paper type Literature review

Introduction

The maritime transport plays a substantial role in the supply chains worldwide. It has a share of 80 per cent of the volume and 70 per cent of the value of goods traded globally (UNCTAD, 2017, p. X). In 2016, the total volume of seaborne trade reached 10 287 million tons (UNCTAD, 2017, p. 5). Future will bring new growth opportunities, among which the progressive adoption of future advanced information and communication technologies (ICTs).

Experts underlined that transport and logistics adopted the data-driven technologies faster than other sectors (Deloitte, 2015). Such technologies were applied in diverse areas from maritime and air transport to warehousing. On the horizon 2030, the ICT maritime opportunities are related to connectivity and automation (Waterborne, 2016). Many companies have already embraced new ICTs. A relevant example is Maersk Line, the largest shipping company worldwide. Maersk Line appointed Ericsson – leading provider of technology and services – to develop the Remote Container Management (RCM) by means of end-to-end systems integration and deployment of mobile and satellite communication to its fleet of container vessels (Ericsson, 2012).

The future advanced ICTs have a potential disruptive impact on maritime transport and supply chains. The internet of Things (IoT), big data, cloud computing and autonomous vehicles/systems range among the technologies that are considered disruptive (Schuelke-Leech, 2018). A survey made by Forrester Consulting on behalf of KPMG (2016) among 580 senior executives (business and IT decision makers) of technology companies in 16 countries revealed that more than 70 per cent of respondents consider that data and analytics, cloud services delivered over the internet and IoT have a moderate or significant impact on how operations are run. The disruptive impact of these technologies is expected under the form of productivity increase, overall cost reduction and quality improvement.

This article is a systematic review of the published literature on future advanced ICTs in maritime transport. The approach is in

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line with the literature relative to systematic reviews (Tranfield *et al.*, 2003; Petticrew and Roberts, 2006; Rousseau *et al.*, 2008; Denyer and Tranfield, 2009; Briner and Denyer, 2012).

In the field of supply chain management, experts highlighted the need for more transparent and systematic procedures (Seuring and Gold, 2012), for systematic literature reviews (Wilding and Wagner, 2012; Wilding and Wagner, 2014), as well as for new paradigms (Durach *et al.*, 2017). The article contributes to the fulfilment of the need for such reviews.

In essence, a systematic review is "an efficient technique for hypothesis testing, for summarising the results of existing studies, and for assessing consistency among previous studies" (Petticrew, 2001, p. 99). Unlike traditional narrative reviews, the systematic reviews rely on a replicable, scientific and transparent process (Tranfield *et al.*, 2003, p. 209).

Denyer and Tranfield (2009) underlined that systematic reviews in management and organizational studies comply with four key principles: transparency, inclusivity, explanatory nature and heuristic nature. The synthesis based on explanation aims to identify causal mechanisms and to critically approach them, to produce a transferable theory in the form of "what works for whom in what circumstances" (Pawson, 2006).

Out of the diverse range of advanced ICTs, this review focuses on IoT, big data, cloud computing, as well as on autonomous ships/vessels (including unmanned ships/vessels). The review question is:

RQ: In what context and by means of what mechanism does the implementation of future advanced ICTs have disruptive impact on maritime transport?

It is the first time such review question is raised.

This review brings a two-fold contribution to the present body of knowledge. The former consists in the elaboration of the CIMO-DMT model relative to the disruptive impact of future advanced ICTs on maritime transport. The latter is the agenda of potential research directions. In addition, the implications for the maritime transport organizations and for society are underlined.

Systematic review methodology

The need for this article was identified by means of a literature survey aiming to spot the existence of systematic reviews on the impact of future advanced ICTs on maritime transport. Following this literature survey, two articles were identified. The former is a systematic literature review on managing supply chain resources with big data analytics (Barbosa *et al.*, 2018). The latter is a comprehensive review referring to the integration of cloud computing in the supply chain processes (Jede and Teuteberg, 2015). No systematic review was identified on the impact that implementation of future advanced ICTs has on maritime transport.

The systematic review process consisted in five distinct stages, following the recommendations of Denyer and Tranfield (2009). These stages were the following: review question formulation, locating studies, study selection and evaluation, analysis and synthesis, reporting and using the results.

Step 1: Formulating the review question

The major question of the review does not refer to the entire and diverse portfolio of future advanced ICTs. Several major technologies were selected, respectively IoT, big data, cloud computing and autonomous ships/vessels (including unmanned ships/vessels).

The review question is:

RQ. In what context and by means of what mechanism does the implementation of future advanced ICTs have disruptive impact on maritime transport?

The CIMO logic (Denyer *et al.*, 2008) was applied in the formulation of the review question. This logic involves the context (C), the type of intervention (I), the generative mechanism (M) and the outcome (O).

Step 2: Locating studies

The method used to identify studies was the database search. Four prominent databases were considered: Emerald Insight, ScienceDirect, Scopus and Web of Science Core Collection. They were selected because of the access provided to high quality research literature in relevant domains, respectively, to a very large number of publications and peer-reviewed articles.

Before starting the search process, a list of key search terms was developed based on the review question. The search terms and the strings of search terms are presented in the Table I.

Each database was searched separately. The search was carried out during the period July 6-8, 2018. In the case of the advanced ICT "Internet of Things", the search was also done on the basis of the acronym "IoT". The output of this search step was a comprehensive list of documents for each database that could help to answer the review question.

Step 3: Study selection and evaluation

A set of explicit criteria was defined and applied to ensure the transparent selection of the documents identified in the second step of the systematic review process. The selection criteria applied for the inclusion and exclusion of documents are presented in the Table II.

After the application of the selection criteria and the elimination of duplications, 20 articles remained from the initial documents identified in the four databases.

The "References" section of each of the 20 selected articles was used to identify additional articles on topics related to the future advanced ICTs in maritime transport, within the four databases. This action was triggered by the hypothesis that articles may exist in databases without being identified during the search with strings of terms. Within "References", several published documents were found. They were searched in the four databases. After the inclusions and exclusions based on the selection criteria, only four additional articles remained. Thus, the cumulated number of articles reached 24.

A synoptic view of the total number of identified and selected documents is provided in the Table III.

The 24 selected articles differ in terms of awareness of the relevant literature, theoretical background, rigor of the

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Table I Search terms and strings of search terms used in the systematic literature review

First search term	Second search term	Third search term
Search terms		
Internet of Things	Transport	Maritime
IoT		Sea
Big data		Ocean
Cloud computing		Ship
Autonomous ship		Vessel
Autonomous vessel		Cargo
Unmanned ship		Container
Unmanned vessel		
Search strings		
("Internet of Things") AND (transport) AND (maritime OR sea OR ocean OR ship OR vessel OR cargo OR container)		
("IoT") AND (transport) AND (maritime OR sea OR ocean OR ship OR vessel OR cargo OR container)		
("big data") AND (transport) AND (maritime OR sea OR ocean OR ship OR vessel OR cargo OR container)		
("cloud computing") AND (transport) AND (maritime OR sea OR ocean OR ship OR vessel OR cargo OR container)		
("autonomous ship" OR "autonomous vessel") AND (transport) AND (maritime OR sea OR ocean OR cargo OR container)		
("unmanned ship" OR "unmanned vessel") AND (transport) AND (maritime OR sea OR ocean OR cargo OR container)		

Table II Criteria for inclusion and exclusion, which were applied in the systematic literature review

Criterion	Reason for criterion use	Inclusion	Exclusion
Type of published document	To focus on quality published documents	Article published in scientific peer-reviewed journal	Article published in non-scientific non-peer-reviewed journal, review article, conference paper, book etc.
Period	To consider documents that actually refer to future advanced ICTs, not to "mature" technologies that became common practice	2010 – 2018	Before 2010
Document format	To make possible the appropriate analysis and synthesis of the information presented in the published document	Full text	Abstract only
Language of the document	To access documents published in the international language that is most widely used by researchers	English	Any other language than English
Relevance in terms of research field	To create a pool of published documents relevant from the perspective of maritime transport	Published document that refers to future advanced ICTs in maritime transport	Published document that refers to future advanced ICTs in inland waterway transport or in other research fields such as medicine (e.g. "blood vessels"), oceanography, geography etc.
Relevance in terms of future advanced ICTs that were considered	To concentrate on the following future advanced ICTs: Internet of Things (IoT), big data, cloud computing, autonomous ships/vessels and unmanned ships/vessels	Published document that refers to one or more of the future advanced ICTs considered	Published document that refers to any future advanced ICT other than those considered
Relevance in terms of the object of maritime transport	To refer to the flow of goods in maritime transport	Published document that refers to cargo in maritime transport	Published document that refers to passenger transport

methodology design, generalizability of results, contribution to the development of theory and/or practice, etc. Representing a very limited pool of documents, the articles did not make the object of further evaluations for the exclusion of those that do not meet specific quality criteria.

Step 4: Analysis and synthesis

Data extraction forms were used to prepare the information for analysis and to develop a comprehensive summary representation of the 24 selected articles. The forms were created in electronic format, using Microsoft Excel. The information extracted from each article was organized in

Table III Number of identified and selected articles by string of search terms and by database

Indicators by search string	Databases: Emerald Insight	Science Direct	Scopus	World of Science
a) Search string ("Internet of Things") AND (transport) AND (maritime OR sea OR ocean OR ship OR vessel OR cargo OR container)				
Total number of published documents identified in each database	2411	787	625	26
out of which: a.1. Number of published documents excluded based on the selection criteria: type of published document, period, document format, language of the document	1912	317	377	23
a.2. Number of published documents included based on the selection criteria: type of published document, period, document format, language of the document	499	470	248	3
out of which: a.2.1. Number of articles excluded due to the lack of relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	498	467	247	3
a.2.2. Number of articles included due to their relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	1	3	1	0
Total number of selected articles after exclusion of duplicates (resulted from this search string)	4			
b) Search string ("IoT") AND (transport) AND (maritime OR sea OR ocean OR ship OR vessel OR cargo OR container)				
Total number of published documents identified in each database	103	1309	399	16
out of which: b.1. Number of published documents excluded based on the selection criteria: type of published document, period, document format, language of the document	42	933	241	13
b.2. Number of published documents included based on the selection criteria: type of published document, period, document format, language of the document	61	376	158	3
out of which: b.2.1. Number of articles excluded due to the lack of relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	60	374	157	3
b.2.2. Number of articles included due to their relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	1	2	1	0
Total number of selected articles after exclusion of duplicates (resulted from this search string)	3*			
c) Search string ("big data") AND (transport) AND (maritime OR sea OR ocean OR ship OR vessel OR cargo OR container)				
Total number of published documents identified in each database	238	1160	823	16
out of which: c.1. Number of published documents excluded based on the selection criteria: type of published document, period, document format, language of the document	98	512	413	13
c.2. Number of published documents included based on the selection criteria: type of published document, period, document format, language of the document	140	648	410	3
out of which: c.2.1. Number of articles excluded due to the lack of relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	139	645	408	3
c.2.2. Number of articles included due to their relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	1	3	2	0
Total number of selected articles after exclusion of duplicates (resulted from this search string)	6			
d) Search string ("cloud computing") AND (transport) AND (maritime OR sea OR ocean OR ship OR vessel OR cargo OR container)				
Total number of published documents identified in each database	159	826	561	15
out of which: d.1. Number of published documents excluded based on the selection criteria: type of published document, period, document format, language of the document	75	349	329	15
d.2. Number of published documents included based on the selection criteria: type of published document, period, document format, language of the document	84	477	232	0
out of which: d.2.1. Number of articles excluded due to the lack of relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	84	475	229	0
d.2.2. Number of articles included due to their relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	0	2	3	0
Total number of selected articles after exclusion of duplicates (resulted from this search string)	4			
e) Search string ("autonomous ship" OR "autonomous vessel") AND (transport) AND (maritime OR sea OR ocean OR cargo OR container)				
Total number of published documents identified in each database	228	30	76	2
out of which: e.1. Number of published documents excluded based on the selection criteria: type of published document, period, document format, language of the document	192	10	45	2
e.2. Number of published documents included based on the selection criteria: type of published document, period, document format, language of the document	36	20	31	0

(***continued***)

Table III

Indicators by search string	Emerald Insight	Science Direct	Scopus	World of Science
	Databases			
out of which: e.2.1. Number of articles excluded due to the lack of relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	36	16	27	0
e.2.2. Number of articles included due to their relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	0	4	4	0
Total number of selected articles after exclusion of duplicates (resulted from this search string)	5**			
f) Search string ("unmanned ship" OR "unmanned vessel") AND (transport) AND (maritime OR sea OR ocean OR cargo OR container)				
Total number of published documents identified in each database	54	28	33	1
out of which: f.1. Number of published documents excluded based on the selection criteria: type of published document, period, document format, language of the document	51	10	17	1
f.2. Number of published documents included based on the selection criteria: type of published document, period, document format, language of the document	3	18	16	0
out of which: f.2.1. Number of articles excluded due to the lack of relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	3	12	12	0
f.2.2. Number of articles included due to their relevance in terms of: research field, future advanced ICTs considered and object of the maritime transport	0	6	4	0
Total number of selected articles after exclusion of duplicates (resulted from this search string)	6**			
Overview				
Total number of articles selected from the databases before the addition of articles from "References"	20			
Number of articles added after the search within the "References" section of the articles initially selected	4***			
Total number of articles selected for review	24			

Notes: *The three selected articles that correspond to the search string (b) are duplicates of articles identified with the search string (a) one of the articles approaches several advanced ICTs, including the Internet of Things (IoT) and cloud computing; **Four of the selected articles that correspond to the search string (e) are duplicates of articles identified with the search string (f); and ***The articles added from "References" focus on autonomous ships/vessels (including unmanned ships/vessels)

Table IV Categories used for data extraction and analysis in the systematic review

Perspective	Category	Information relative to the category
Descriptive	Future advanced ICT focus	Future advanced ICT that represents the subject of the article
	Year	Year of official publication of the article
	Article category	Category that best describes the content and main features of the document, respectively: research paper, technical paper, conceptual paper, viewpoint etc. (according to the classification suggested by the ScholarOne platform)
	Journal	Journal that published the article
Thematic	Context	Context within which the intervention takes place, described by contextual factors
	Intervention	Specific implementation of the considered future advanced ICT in maritime transport
	Mechanism	Instruments, processes, systems, infrastructures and other sub-categories that contribute to the intervention related to the future advanced ICT
	Outcomes	Impact of the implementation of a specific future advanced ICT on different levels such as: maritime transport, human factor/personnel, implementing organisation, other levels of the supply chain
	Other	Any other information from the articles that is relevant for the systematic review

worksheets according to the descriptive and thematic categories presented in the Table IV.

An explanatory method of synthesis was applied. Rousseau *et al.* (2008) identified four major forms of research synthesis: aggregation, integration, interpretation and explanation. According to Denyer and Tranfield (2009, p. 686), in management and organization studies, reviews should be interpretive or explanatory, rather than aggregative.

The explanatory approach focuses on causal mechanism that generates specific outcomes in a certain context. The strengths are the following: identification of contextual factors; discerning the relation between a specific intervention and its outcomes; use of data resulted from various research methodologies; and pragmatic approach aiming to provide information for decision-making (Rousseau *et al.*, 2008).

The synthesis was based on the CIMO logic. From this perspective, the review suggests that the intervention (I) related to an advanced ICT (such as IoT, big data, cloud computing, autonomous ships/vessels, including unmanned ships/vessels) may produce different outcomes (O), based on different mechanisms (M), depending on the specific maritime transport context (C).

Step 5: Reporting and using the results

The results of the review process are presented in a distinct section of this article. Following the analysis and synthesis of the evidence, a research agenda is formulated. New study directions and questions are brought to the attention of researchers.

Diminishing bias

Bias mitigation was given special attention in the design and implementation of the systematic review process. The reason is that review quality is influenced by the extent to which methods for diminishing bias were applied.

Firstly, the systematic nature of this literature review differentiates it from the narrative reviews which have been criticized since late 1990s for the implicit bias of researcher in selecting the reviewed contributions (Fink, 1998; Hart, 1998). Compared to the traditional review approach, the systematic review process diminishes bias by being replicable, scientific and transparent (Tranfield *et al.*, 2003). Second, methods that limit bias were applied. Examples of such methods are the "comprehensive search of relevant articles" and the application of "explicit, reproducible criteria" for article selection (Cook *et al.*, 1997, p. 377). Another method consists in "providing an audit trail of the reviewer's decisions, procedures and conclusions" (Tranfield *et al.*, 2003, p. 209), which is "linking the claims made by the authors of the review with the existing evidence" (Denyer and Tranfield, 2009, p. 679).

To diminish bias, the comprehensive search method consisted in the exploration of four internationally recognized databases that abstract and index a large number of publications. Thus, the search was not focused on a specific set of journals. The method relative to the "audit trail" encompassed multiple facets of the review process. First, the principles of the systematic reviews for management and organizational studies were applied (Denyer and Tranfield, 2009, pp. 678-681), respectively: transparency, inclusivity, explanatory and heuristic nature. Second, the five steps (Denyer and Tranfield, 2009, pp. 681-686) of the systematic review process, from question formulation to reporting and using the results were accomplished. Thus, bias was diminished by applying the same strings of search terms to each database. Clearly stated criteria for inclusion and exclusion of articles from the total number of documents identified in the databases also contributed to bias mitigation. The Excel worksheets used to extract information from the selected articles provided an auditable connection between the aspects reported in the review and the underlying evidence existing in those articles. The methodology section of the systematic review ensures the necessary transparency and provides an insight into the procedures that can be replicated.

Findings: Descriptive perspective of the reviewed articles

A descriptive analysis is made to ensure the background for the thematic analysis of the articles. The descriptive approach focuses on the following aspects: future advanced ICT focus, year of publication, article category and journal.

The number of selected articles that approach a specific advanced ICT is shown in the Table V. The autonomous ships/vessels (including unmanned ships/vessels) are the subject of a larger number of articles.

One of the selection criteria refers to the year of publication. The review encompasses the articles published in the period 2010-2018, because peer-reviewed journals started to include articles on future advanced ICTs approximately by 2010.

The articles selected (based on specific criteria) after the search carried out in the four databases reveals that only recently, the future advanced ICTs in maritime transport were addressed in peer-reviewed journals (Table VI). During the period 2010-2012, it seems to be no significant signs of published research results on the application of future advanced ICTs in maritime transport, as regards the IoT, big data, cloud computing, autonomous ships/vessels (including unmanned ships/vessels).

The year 2016 stands out compared to the previous years, because of a higher number of articles. Similarly, the year 2018

Table V The selected articles by future advanced ICT

Advanced ICT	Articles	No. of articles	Share of the total number of reviewed articles (%)
Internet of Things (IoT)	Ferretti and Schiavone (2016), Gnimpieba *et al.* (2015), Harris *et al.* (2015)*, Verdouw *et al.* (2016), Zhang *et al.* (2018)	5	20.83
Big data	Kang *et al.* (2018), Lee *et al.* (2018), Mirović *et al.* (2018), Wu *et al.* (2017), Xu *et al.* (2016), Zaman *et al.* (2017)	6	25
Cloud computing	Costa *et al.* (2016), Cristea *et al.* (2017), Harris *et al.* (2015)*, Tsertou *et al.* (2016)	4	16.67
Autonomous ships/vessels (including unmanned ships/vessels)	Ahvenjärvi (2016), Burmeister *et al.* (2014), Kretschmann *et al.* (2017), Man *et al.* (2015), Porathe (2016), Wahlström *et al.* (2015), Wróbel *et al.* (2016), Wróbel *et al.* (2017), Wróbel *et al.* (2018a), Wróbel *et al.* (2018b)	10	41.67

Note: *The article of Harris *et al.* (2015) refers to several ICTs and it is cited for IoT and cloud computing in this table

Table VI Number of articles published by future advanced ICT and by year

Future advanced ICT	2014	2015	2016	2017	2018
Internet of Things		2	2		1
Cloud computing		1	2	1	
Big data			1	2	3
Autonomous ship/ vessel including unmanned ship/vessel	1	2	3	2	2
Total	1	5	8	5	6

will very likely be a significant one in terms of number of published articles on the future advanced ICTs in maritime transport. The topic of autonomous ships/vessels is not new, but it received more attention in the past five years. Besides this topic, big data is also a subject of interest to researchers.

Each selected article was analyzed to identify the specific category to which it belongs. In this respect, the categories were those suggested by the ScholarOne platform: research paper, viewpoint, technical paper, conceptual paper, case study, literature review and general review (Emerald Publishing, 2018). However, considering the selection criteria used for this systematic review, only some of these categories were relevant, respectively: research paper (that reports any type of research); viewpoint (which presents the opinion and interpretation of the author); technical paper (that describes and assesses technical products, processes or services); and conceptual paper (which formulates hypotheses, discusses and compares others' studies and theoretical viewpoints).

The classification of each article considered the category that best describes the content and main features of the document. In the case that an article shares the characteristics of two categories, the classification considered the category that corresponds to the predominant nature of that article.

The distribution of the pool of selected articles by category is presented in the Table VII.

The most numerous articles are the research papers (50 per cent of the 24 articles), followed by technical papers (29.17 per cent). The rest are viewpoints (12.5 per cent) and conceptual papers (8.33 per cent). The share of 80 per cent held by the research and technical papers could indicate the focus on the in-depth study of future advanced ICTs in maritime transport, beyond a stage of conceptual clarifications.

The journals in which the articles were published are presented in the Table VIII.

The domains of the journals are diverse and include: maritime navigation, transport, engineering, computer science, business, manufacturing and logistics. The variety of domains may be an advantage for the development of the research on the topic of future advanced ICTs in maritime transport, as new and multi-faceted perspectives will evolve in the future.

Findings: Thematic perspective of the reviewed articles

The CIMO logic is the basis of the following thematic perspective and underlines the major components of this approach: context (C), intervention (I), mechanism (M) and outcome (O). The analysis and synthesis of the information provide a comprehensive perspective of all the future advanced ICTs considered (IoT, big data, cloud computing, autonomous ships/vessels, including unmanned ships/vessels).

Context

The first component of the CIMO approach is the context. The thematic analysis and synthesis of the information existing in the reviewed articles revealed various contextual factors in which the interventions related to the future advanced ICTs take place.

Several categories of factors were identified. They refer to the implementing organization; human element; autonomous or unmanned ship/vessel; maritime transport and external environment.

The contextual factors related to the *implementing organization* are diverse: type of organization; magnitude and complexity of the activities; vision; objectives; strategic orientation; source of competitive advantage; management practices; importance attached to innovation and IT; competences/capabilities of the organization; product range; types of decisions made; diversity of logistics partners.

The *types of organizations* discussed in the reviewed articles are indicated by the following examples: German seaport of Hamburg (Ferretti and Schiavone, 2016), Singapore Strait (Kang *et al.*, 2018); Piraeus Container Terminal (Tsertou *et al.*, 2016); Puerto de La Luz seaport in the Canary Islands (Mirović *et al.*, 2018); liner shipping company (Lee *et al.*, 2018); manufacturing company (Wu *et al.*, 2017); ship owners and port authorities (Zaman *et al.*, 2017).

Table VII The selected articles by category

Category	Articles	No. of articles	Share of the total number of reviewed articles (%)
Research paper	Ferretti and Schiavone (2016), Kang *et al.* (2018), Kretschmann *et al.* (2017), Lee *et al.* (2018), Man *et al.* (2015), Verdouw *et al.* (2016), Wróbel *et al.* (2016), Wróbel *et al.* (2017), Wróbel *et al.* (2018a), Wróbel *et al.* (2018b), Wu *et al.* (2017), Zhang *et al.* (2018)	12	50.00
Technical paper	Burmeister *et al.* (2014), Costa *et al.* (2016), Cristea *et al.* (2017), Gnimpieba *et al.* (2015), Porathe (2016), Tsertou *et al.* (2016), Xu *et al.* (2016)	7	29.17
Viewpoint	Ahvenjärvi (2016), Wahlström *et al.* (2015), Zaman *et al.* (2017)	3	12.50
Conceptual paper	Harris *et al.* (2015), Mirović *et al.* (2018)	2	8.33
Total		24	100.00

Table VIII Journals in which the reviewed articles were published

Journal title	Number of articles	Share of the total number of articles (%)
Business Process Management Journal	1	4.17
Computers & Operations Research	1	4.17
IFAC-PapersOnLine	1	4.17
International Journal of Database Theory and Application	1	4.17
International Journal of e-Navigation and Maritime Economy	1	4.17
International Journal of Physical Distribution & Logistics Management	1	4.17
International Journal of Production Economics	1	4.17
Journal of Business Economics and Management	1	4.17
Journal of Food Engineering	1	4.17
Nase More	1	4.17
Ocean Engineering	2	8.33
Procedia Computer Science	2	8.33
Procedia Engineering	1	4.17
Procedia Manufacturing	2	8.33
Reliability Engineering & System Safety	2	8.33
Research in Transportation Business & Management	1	4.17
TRANSNAV-International Journal on Marine Navigation and Safety of Sea Transportation	2	8.33
Transportation Research Procedia	2	8.33

The *magnitude and complexity of the activities* are contextual factors related to the implementing organization. The reviewed articles focused on organizations that carry out activities of considerable magnitude and high complexity. Such examples are the port of Hamburg – the most important German port and Europe's third largest container port (Ferretti and Schiavone, 2016); the Singapore Strait – one of the most important shipping waterways in the world, which plays a vital role in the international transport of containers, bulk cargo and crude oil (Kang *et al.*, 2018); Piraeus Container Terminal – in the fastest growing port of Europe (Tsertou *et al.*, 2016) – a manufacturer of branded products, which is a global market player (Wu *et al.*, 2017).

Other contextual factors of the implementing organization, which influence the interventions related to the future advanced ICTs are: *vision; objectives; strategic orientation; source of competitive advantage; management practices; importance attached to innovation and IT; and competences/capabilities of the organization*. Such factors are found in the article of Ferretti and Schiavone (2016). The objectives, strategic orientation and importance attached to the future advanced ICTs are considered by Tsertou *et al.* (2016).

A contextual factor consisting in the *product range* is provided by the article of Wu *et al.* (2017) that presents the example of a manufacturer of branded consumer electronics.

The *types of decisions made* are mentioned in the article of Lee *et al.* (2018) that refers to the operations team of a liner shipping company which make decisions on vessel speeds, scheduling of vessels and planning of cargo loading.

The factors related to the *diversity of logistics partners* are presented by Wu *et al.* (2017) and evolve from a competitive global logistics network involving air freight forwarders, sea freight forwarders, truck companies and global express operators.

A distinct category of contextual factors is related to the *human element* in the case of ships/vessels which are autonomous or unmanned. Major factors related to the human element are: human-made design of the autonomous ship/vessel (including the hardware and software); personnel of the remote-control center (located onshore or on another ship/vessel) which monitors and coordinates the autonomous ships/vessels; crew of the manned ships/vessels that navigate in the same traffic area as the autonomous or unmanned ships (Ahvenjärvi, 2016). There are also factors like the challenges for autonomous ship/vessel handlers in maintaining situational awareness, as well as the harmony between ship/vessel, personnel and environment (Man *et al.*, 2015). To these may be added the factor of skill loss ("de-skilling") by the ship/vessel handlers/crew members, which may follow the implementation of the "unmanned" technology (Porathe, 2016).

The context is also described by a category of factors related to the *autonomous or unmanned ships/vessels*. Such factors are the types of *costs* and *cost changes* in the case of autonomous ships/vessels compared to the conventional ships/vessels. The types of costs are operating costs, voyage costs (fuel price, fuel costs for the main engine and fuel costs for the auxiliary engines), port call costs and capital costs. The cost changes specific to an unmanned autonomous bulker in comparison to a conventional bulker are the following: cost savings in terms of crew wages and crew related costs (medical, cabin and safety equipment) because of the absence of crew on board; cost increase related to personnel costs and operating costs of the shore control center and to the cost of maintenance crews that conduct the necessary repairs while the ship is in port; reduced costs because of the higher efficiency of fuel consumption; cost savings because of the decrease in electric power consumption; cost increase because of the personnel that provides assistance for approaching and berthing during port calls and for unforeseen events during the journey; mixed effects on capital costs because some of the systems which are compulsory on conventional ships are no longer necessary on unmanned autonomous ships/vessels and because other systems will be necessary to ensure at least the same safety level as for conventional bulkers (Kretschmann *et al.*, 2017).

A distinct category of contextual factors refers to the *maritime transport*. This category includes a diversity of factors. The globalization effects on freight transport, the integration of different transport modes, the unexpected events during transport (e.g. changes in weather conditions, strikes, accidents, etc.), the congestion, capacity problems and delays in Europe's freight transport system and the increasing dynamic and structural complexity of logistics systems are mentioned by Costa *et al.* (2016). Other factors are the increased competition in the shipping business environment and the decreasing profit margins (Cristea *et al.*, 2017). Numerous other factors are enumerated by Harris *et al.* (2015), respectively: slow adoption of future advanced ICTs in multimodal freight transport in Europe; lack of effective and efficient information connectivity among and between various modes (water, air, road and rail) in multimodal transport; containerization as an enabler of multimodal transport; challenges for the multimodal transport because of the deployment of different ICTs by the various players (such as freight forwarders, third-party logistics service providers, couriers, carriers of different modes of transport, multimodal transport operators, rail, sea carriers, port and intermodal terminal operators); user-related, technology-related and policy-related barriers to the adoption of future advanced ICTs. Additional factors are the reduced visibility and information exchanges between related stakeholders on real-time location and the status of a container and its contents (Tsertou *et al.*, 2016).

Several factors related to *maritime transport as an industry* originate in the domain of human capital and ecological impact of autonomous ships/vessels (including unmanned ships/vessels).

Examples of factors related to the *human capital* are the following: estimated long-run shortage of qualified masters, officers, engineers (Burmeister *et al.*, 2014; Porathe, 2016); trend towards reduction in the number of crew members of merchant ships (Wróbel *et al.*, 2018a); challenge to maintain relatively low operational expenses for an efficient international trade (Burmeister *et al.*, 2014); threat for the shipping industry to be unable to attract human resources from the millennial generation (born between 1980 and 2000) (Porathe, 2016); challenge to redirect crew towards more demanding and interesting work, to attract and retain professional human resources (Burmeister *et al.*, 2014); specification of operational requirements from international conventions in terms of functions to be performed and not in terms of on-board crew members to perform those functions (Wróbel *et al.*, 2018a).

Among the factors referring to the *ecological impact* of the maritime transport range: the estimated trend towards improved design of the ships/vessels with direct influence on fuel consumption and greenhouse gas (GHG) emissions (Kretschmann *et al.*, 2017); the anticipated overall design of unmanned ships that will be significantly different in terms of hull design and propulsion arrangement (Wróbel *et al.*, 2018a).

The context is also described by the category of factors related to the *external environment*. Such factors are: members of the supply chain (Gnimpieba *et al.*, 2015); stakeholders (Ferretti and Schiavone, 2016); characteristics of demand and supply (Verdouw *et al.*, 2016; Zhang *et al.*, 2018); implementation of the same advanced ICT by other stakeholders (Ferretti and Schiavone, 2016); technology-related factors that inhibit ICT adoption (Gnimpieba *et al.*, 2015; Harris *et al.*, 2015; Zhang *et al.*, 2018); organizational-user-related factors and policy-related factors that inhibit ICT adoption (Harris *et al.*, 2015). Other factors are: cargo damage and cargo theft (Wu *et al.*, 2017); weaknesses of the existing technology applications (Xu *et al.*, 2016); European Union MRV (Monitoring, Reporting and Verification) regulation that establishes responsibilities for the quantification of the CO_2 emissions for ships above 5000 gross tonnage (Zaman *et al.*, 2017); international legislation for the reduction in the ecological impact of ships (Burmeister *et al.*, 2014); commitment of the European Commission to reduce GHG emissions by 80 per cent below 1990 levels by 2050 (Porathe, 2016). Other factors related to the external environment cover: the development of autonomous and remote operation in various fields such as aviation, forestry, cars, subway systems, space operations, military, cranes (Wahlström *et al.*, 2015); increased likelihood of unwelcome events (such as those related to the human operator's mental model of automation), as a result of the trend towards systems' automation (Wróbel *et al.*, 2018a).

The reviewed articles differ in terms of range of contextual factors considered and depth of analysis.

Intervention

The second component of the CIMO approach refers to the intervention related to the future advanced ICTs in maritime transport. Two major themes were found in the reviewed articles – the type of intervention and its drivers.

The first theme consists in the *type of intervention*. The analysis of the articles led to the identification of the following types: study/investigation, analysis and assessment; development/design; adoption, implementation and use.

The type of intervention centered on *study/investigation* takes the form of: exploration of the paradigm shift from cloud computing to fog computing, in relation to Smart Cargo (Costa *et al.*, 2016); identification of the human factor issues in remote monitoring and controlling of autonomous unmanned vessels through scenario-based trials (Man *et al.*, 2015); investigation of the feasibility of unmanned, autonomous merchant vessels (Porathe, 2016); providing insight for the design of the shore control centers (Wahlström *et al.*, 2015); and study of the effect of unmanned ships on the safety of maritime transport (Wróbel *et al.*, 2017).

The type of intervention consisting in *analysis and assessment* incurred by the future advanced ICTs is illustrated by: detection of anomalies in marine operations from data gathered on vessel movement (Mirović *et al.*, 2018); investigation of cargo loss in logistics systems by means of data-driven analytics (Wu *et al.*, 2017); identification of the ways in which cloud computing may become an enabler of dynamic and synchromodal container consolidation at the Piraeus Container Terminal (Tsertou *et al.*, 2016); analysis of the economic benefit of unmanned autonomous bulkers in comparison with conventional bulkers (Kretschmann *et al.*, 2017); hazard analysis associated with the design and operation of unmanned ships/vessels (Wróbel *et al.*, 2016); and assessment of the safety of a remotely controlled generic merchant vessel (Wróbel *et al.*, 2018a; Wróbel *et al.*, 2018b).

Examples of intervention that underline the *development/design* related to the future advanced ICTs in maritime transport are: elaboration of the ship traffic fundamental diagram that represents the speed-density relationship (Kang *et al.*, 2018); development of an improved MAC (media access control) protocol design in the data exchange system for the Internet of Vessels (Zhang *et al.*, 2018); development of the concept of an autonomous unmanned dry bulk carrier that is at least as safe as a manned vessel (Burmeister *et al.*, 2014); creation of a decision support system for making decisions on vessel speed in maritime logistics (Lee *et al.*, 2018); development of navigation strategies based on monitoring of fuel consumption, various emissions, use of lighting, heating (Mirović *et al.*, 2018); development of a big data acquisition and analysis platform for intermodal transport (Xu *et al.*, 2016); development of a conceptual architecture for a cloud-based platform design that implements continuously data storage and analysis services for large maritime ships (Cristea *et al.*, 2017); and development of a solution to assess and communicate the uncertainties of the safety control (Wróbel *et al.*, 2018b).

The type of intervention consisting in the *adoption, implementation and use* of the future advanced ICTs is reflected by the following: adoption of the innovative IoT infrastructure by the Hamburg seaport (Ferretti and Schiavone, 2016); IoT adoption in multimodal transport (Harris *et al.*, 2015); cloud computing adoption in multimodal transport, under the form of cloud-based Electronic Logistics Marketplace (Harris *et al.*, 2015); implementation of the autonomous (including unmanned) ship/vessel technology (Ahvenjärvi, 2016); use of IoT technologies to track pallets and containers in a collaborative supply chain (Gnimpieba *et al.*, 2015); use of IoT in the virtualization of the fish supply chain (Verdouw *et al.*, 2016); and use of big data in the shipping industry (Zaman *et al.*, 2017).

The second major theme referring to the intervention consists in its *drivers*. In fact, the drivers are the aims of or reasons for the intervention related to the future advanced ICTs. Two major categories of drivers were identified. The former refers to process improvement and the latter to performance enhancement.

The category focused on *process improvement* targets aspects such as: information, measurement, control and dealing with challenges.

The drivers relative to information are: information sharing on logistic flows for traceability, collaboration and interoperability between different actors within the supply chain (Gnimpieba *et al.*, 2015); need to address the issue of reduced visibility and limited information exchange (on real-time location and status of a container and its contents) between all stakeholders in the process of container consolidation within a port terminal (Tsertou *et al.*, 2016); identification of the causes of cargo loss severity (Wu *et al.*, 2017); need for clear and well tested examples on how modern technologies in storage and computations can be applied in real case scenarios (Cristea *et al.*, 2017); and diminishing the information gap consisting in the absence of an objective study on the effect of unmanned ships on safety of maritime transport (Wróbel *et al.*, 2017).

Examples of intervention drivers related to measurement are: development of a useful tool for measuring the effect of various hazard factors on the safety of unmanned ships (Wróbel *et al.*, 2016); meeting the need for a new method of safety assessment based on the theoretic approach that accidents are caused by the inadequate interactions between the system components (Wróbel *et al.*, 2018a; Wróbel *et al.*, 2018b).

The control-oriented drivers include: achieving a decentralized and autonomous control of logistics processes (Costa *et al.*, 2016); creation of shore control centers able to ensure agile command and control of the autonomous ships/vessels (Wahlström *et al.*, 2015).

Finally, the drivers that refer to dealing with challenges are: enhancing the capabilities to deal with challenges consisting in perishable products, unpredictable supply variations, stringent food safety and sustainability requirements (Verdouw *et al.*, 2016); and diminishing the slot reservation collision/conflict rate in the data exchange systems for the Internet of Vessels (Zhang *et al.*, 2018).

The category focused on *performance enhancement* includes drivers relative to aspects such as: organizational performance, maritime transport performance and costs.

The drivers centered on the organizational performance are: improvement in the quality of port services (Ferretti and Schiavone, 2016); improvement in ship energy efficiency and safety at sea (Mirović *et al.*, 2018); estimation of the real fuel consumption function for speed optimization problems (Lee *et al.*, 2018); prediction of vessel performance (Zaman *et al.*, 2017); and optimization of various means used in multimodal transport (Xu *et al.*, 2016).

The drivers related to the improvement in maritime transport performance are: achievement of a more sustainable maritime industry and of an improved competitiveness (Ahvenjärvi, 2016); contribution to all main dimensions of sustainability, respectively economic, ecological and social (Kretschmann *et al.*, 2017); safer navigation and more sustainable maritime transport (Burmeister *et al.*, 2014; Porathe, 2016); and better onshore working environment, increased safety for seafarers and reduced environmental impact (Man *et al.*, 2015).

Several drivers are centered on costs, respectively: cost reduction (Ferretti and Schiavone, 2016; Porathe, 2016) and need to find an alternative to the ongoing high-cost of investment in IT resources and management (Harris *et al.*, 2015).

The thematic analysis revealed a large array of intervention types and of drivers that trigger them.

Mechanism

The next component of the CIMO approach refers to the mechanism of the intervention related to the future advanced ICTs in maritime transport.

The thematic analysis facilitated the identification of two major themes of the mechanism. The former refers to the interrelated components of the intervention mechanism and the latter to the conditions for the intervention success.

The synthesis of the information led to the following *components of the mechanism*: participants involved and the relationships between them; data used and their sources; infrastructures; systems; instruments; methods and techniques applied; processes; operational modes; and practices.

The *types of participants involved* are part of the intervention mechanism related to the future advanced ICTs in maritime transport. The participants may be various organizations or persons. Examples of participating organizations are: port and its stakeholders such as industrial and logistic companies, professional partners, public institutions (Ferretti and Schiavone, 2016); supplier of goods, 4PL operator, shipping company, terrestrial carrier operator and final customer (Gnimpieba *et al.*, 2015); shippers, carriers and customers that use open or closed Electronic Logistics Marketplaces and achieve spot trading or long-term collaborations (Harris *et al.*, 2015); and all the stakeholders in container consolidation within a port terminal, such as shippers, carriers, warehouse management systems, forwarders and container terminal operators (Tsertou *et al.*, 2016). In addition, individual participants should also be considered part of the intervention mechanism, respectively: operator (master experimented in navigating ships in simulated environments), supervisor, engineer and captain (Man *et al.*, 2015).

Few reviewed articles addressed the *relationships between participants*. In the case of organizational participants, the aspects presented are the partnerships and collaborations between them (Ferretti and Schiavone, 2016). As regards the individual participants, the relationships refer to the assignment of roles, duties and responsibilities and to the organizational hierarchy of the shore control center for the autonomous ships.

The *data used and their sources* are a component of the intervention mechanism. The reviewed articles refer to several categories of data on: ship/vessel and its performance; on-shore operators of the autonomous ships/vessels; and external environment.

Examples of data on the *ship/vessel and its performance* and of data sources are: dynamic location, sailing speed and other messages of a ship provided by the Automatic Identification System (Kang *et al.*, 2018); service history data from the liner shipping company (Lee *et al.*, 2018); fuel consumption, various emissions, the use of lighting, heating and similar processes, data from sensors and the Automatic Identification System (Mirović *et al.*, 2018); cargo loss data collected from the insurance reimbursement claim database of the case company's insurance company (Wu *et al.*, 2017); information on the longitude and latitude coordinates, moving directions, velocities, working power, gas emissions, destination, details of the loaded cargos and system malfunctions from the OBD bus (for the vehicle status information), Automatic Identification System (AIS), Beidou System as satellite positioning module and sensors (Xu *et al.*, 2016); data on traffic, cargo and machinery from sensors (Zaman *et al.*, 2017); tracking data relative to ship movements and ship data (speed through water, speed over ground, propulsion power, propulsion torque, true wind speed, specific fuel oil consumption) – data obtained from the Automatic Identification System (AIS), consisting in a constellation of satellites and ship sensors (Cristea *et al.*, 2017); and number and type of pallets used per order, in the process of planning and consolidating container shipments at a port terminal – data obtained from the cloud-based information portal (Tsertou *et al.*, 2016).

Data relative to the *on-shore operators of the autonomous ships/vessels* refer to the levels of situational awareness (SA) of the operators working within the shore control center (SCC) (Man *et al.*, 2015). These data are compared to the actual situation of the ship/vessel. The data relative to operators was collected during interviews after the simulation, while the data relative to ship/vessel was provided to operators by the dashboards used in the SCC.

The reviewed articles refer to the following data on the *external environment* and to their sources: weather archive big data on temperature, salinity, drift velocity, current and wind speed from the Copernicus Maritime Environment Monitoring Service (Lee *et al.*, 2018); data on weather from sensors (Zaman *et al.*, 2017); and maritime accidents that occurred during those parts of voyage that are most likely to become unmanned in the future – data obtained from publicly available investigation reports (Wróbel *et al.*, 2017).

The mechanism component consisting in *infrastructures* encompasses examples such as: intelligent infrastructures based on technologies such as bluetooth, hotspots or WLAN, cloud, mobile devices, IoT and big data (Ferretti and Schiavone, 2016); wireless network or self-organized network and multimodal monitoring platform to collect all data (Xu *et al.*, 2016); remote sensor networks (Zaman *et al.*, 2017); shore control centre (SCC) with monitoring and controlling workstations (Burmeister *et al.*, 2014; Man *et al.*, 2015); advanced and integrated sensor systems for automated lookout (Burmeister *et al.*, 2014); on-board computerized system which periodically sends information to the SCC (Man *et al.*, 2015); large shared displays (to help maintain shared awareness in SCCs), cameras with live video feed for remote operation, voice loops which are real-time auditory channels connecting physically distributed people, multiple control centers (Wahlström *et al.*, 2015); and redundant propulsion systems, secure communication links and additional environmental sensors to provide unmanned ships/vessels with sufficient level of operational safety (Wróbel *et al.*, 2016).

Another component of the intervention mechanism is represented by *systems*. The reviewed articles refer to systems like: new traffic management system that is connected by sensors to the existing 140 bridges and that interacts with the "Port Road Management Centre" (Ferretti and Schiavone, 2016); Geographic Information System (GIS) (Xu *et al.*, 2016); predictive maintenance system and automatic mode detection system (Zaman *et al.*, 2017); autonomous navigation system (complying with collision regulations and ensuring safe operation in difficult weather); and autonomous engine and monitoring control system (that facilitates failure prediction and optimal efficiency) (Burmeister *et al.*, 2014).

As mechanism component, *instruments* take the form of: various sub-projects and initiatives to accomplish the "Smartport Logistics" project (Ferretti and Schiavone, 2016); classic traffic flow (speed-density) models (Kang *et al.*, 2018); weather impact miner to identify important factors that can affect the fuel consumption of vessels (Lee *et al.*, 2018); big data analytics platform, 3D map showing the incoming and outgoing vessels (Mirović *et al.*, 2018); MySQL database for static data and NoSQL Cassandra distributed database for dynamic packets (Xu *et al.*, 2016); MAXQDA 10 (computer analysis assistance tool used for qualitative text analysis, as well as frameworks, memos and diagrams) (Man *et al.*, 2015); operational context relationship diagram for unmanned ships and model of relationships between the safety levels of unmanned merchant vessels (Wróbel *et al.*, 2016); framework for safety analysis of unmanned ships presenting accident causes and consequences (Wróbel *et al.*, 2017); and list of hazards and related safety constraints (Wróbel *et al.*, 2018a; Wróbel *et al.*, 2018b).

The *methods and techniques applied* are integrated in the intervention mechanism. Examples from the reviewed articles are: a novel weighted least square approach applied to develop the ship traffic speed-density formulations accurately (Kang *et al.*, 2018); particle swarm optimization (PSO) metaheuristic algorithm applied to many real-world applications (Lee *et al.*, 2018); Auto Associative Kernel Regression and Sequential Probability Ratio Test technique used to detect anomalies and trigger alarms (Mirović *et al.*, 2018); predictive analytics and prescriptive analytics (Wu *et al.*, 2017); comparative analysis of cloud computing and fog computing (Costa *et al.*, 2016); and actual ship performance analysis and testing the conceptual architecture for a cloud-based platform in normal operation conditions (Cristea *et al.*, 2017). To these may be added methods and techniques applied in the case of autonomous ships/vessels (including unmanned ships/vessels): expected present value (EPV) of cost of owning and operating a conventional and an autonomous bulker over their operational lifetime, as well as the comparison of the required freight rate of the two types of bulkers (Kretschmann *et al.*, 2017); experimental design based on five scenarios developed by subject-matter experts as well as interviews with operators after the simulation (Man *et al.*, 2015); distribution of the remote monitoring operations of the autonomous ships/vessels between multiple shore control centers and the use of semi-automatic reports and reminders to facilitate communication (Wahlström *et al.*, 2015); communication of information by means of tools like ambient displays (sound and lighting etc.), use of remotely movable cameras, multimodal presentation of information (including sounds and haptic feedback based on motion), use of flexible physical spaces (dynamic lighting and movable walls and furniture), use of audio analysis of the spoken communication and of the enhanced audio from the ship, from the engines room (Wahlström *et al.*, 2015); use of Bayesian Networks to develop model structure related to the safety of unmanned merchant vessels (Wróbel *et al.*, 2016); validation of the model structure by applying it to a real maritime accident of fire on board of a fully manned merchant vessel (Wróbel *et al.*, 2016); subjective two-step what-if analysis supported by Human Factors Analysis and Classification System for Marine Accidents (HFACS-MA) method (Wróbel *et al.*, 2017); System-Theoretic Process Analysis (STPA), a methods applied to innovative technical systems, according to which safety is seen as a control problem, rather than an object of quantification (Wróbel *et al.*, 2018a; Wróbel *et al.*, 2018b); and mitigation potential analysis to assess the effectiveness of suggested measures to diminish hazards (Wróbel *et al.*, 2018a; Wróbel *et al.*, 2018b).

The intervention mechanism also comprises the *process* component. Examples of processes are the following: mining more than 43 million pieces of AIS data (Kang *et al.*, 2018); big data acquisition based on the IoT (Xu *et al.*, 2016); use of a closed Electronic Logistics Marketplac (ELM) to manage the order-fulfilment process and facilitate communication within the supply chain (Harris *et al.*, 2015); research process consisting in data collection, processing, analysis and interpretation (Man *et al.*, 2015); and handover of the autonomous ships/vessels between multiple control centers, to avoid monitoring discontinuities generated by shift changes (Wahlström *et al.*, 2015).

In the case of autonomous ships/vessels, the mechanism includes the *operational modes*. Researchers refer to operational modes such as: manned operation, autonomous execution, autonomous problem-solving, remote operation and fail-to-safe (Burmeister *et al.*, 2014; Man *et al.*, 2015). Another approach of these operational modes identifies six levels of ship autonomy, according to the ShipRight procedure of Lloyd's Register (Wróbel *et al.*, 2018a; Wróbel *et al.*, 2018b).

The mechanism also relies on the component *practices*. Examples of practices related to the future advanced ICTs in maritime transport are: task automation (in the new system of traffic management and in the trade flow management) (Ferretti and Schiavone, 2016) and use of software as a service (SaaS) that became a common way of accessing cloud computing on-demand and paying only for the actual use of computing resources (Harris *et al.*, 2015).

The second major theme related to the mechanism is represented by the *conditions for the intervention success*. The reviewed articles refer to the following conditions: establishment of successful partnerships and inter-organizational collaborations (Ferretti and Schiavone, 2016); simultaneous adoption by the Hamburg seaport of the different types of IoT-based technologies, to enhance their favorable impact on the business processes (Ferretti and Schiavone, 2016); creation of many heterogeneous networks of players to perform technology-based projects (Ferretti and Schiavone, 2016); harmonization of the IoT adoption project of the seaport with the smart-city project of the Municipality of Hamburg (Ferretti and Schiavone, 2016); implementation of a hybrid approach based on the combination of fog computing (focused on decentralized computing) and cloud computing, (centered on centralized computing) in the multimodal transport of freight (Costa *et al.*, 2016). Other conditions focus on the autonomous ships: the design of the SCC system should not imitate the actual bridge of the ships/vessels and the design of the alarm system of the SCC should facilitate the proactive involvement of the operators (Man *et al.*, 2015); future autonomous technology should make an unmanned system at least as safe as a manned ship and should provide the operators of the SCCs with adequate situational awareness (Porathe, 2016); unmanned ships/vessels should be connected to global support networks and provide information like video and sensor data (Wahlström *et al.*, 2015); and SCCs should communicate with manned vessels and the authorities (Wahlström *et al.*, 2015).

The systematic review identified numerous components of the intervention mechanism. The conditions for the intervention success are integral part of the mechanism.

Outcome

The thematic analysis and the synthesis of the information facilitated the identification of intervention outcome of the effect/impact of the intervention related to the future advanced ICTs on maritime transport.

Three major themes were identified, specifically outcome reach, impact area and estimated impact.

As regards the *outcome reach*, the following levels were identified in the reviewed articles: maritime organization that makes the intervention related to the future advanced ICTs; personnel of the SCCs (in the case of autonomous ships/vessels, including unmanned ships/vessels); maritime transport; and supply chain members. The estimated impact may be expressed in qualitative or quantitative terms. Hereinafter, the impact areas and the estimated impact are presented for each level.

In the case of the *maritime organization* that makes the ICT intervention, the outcome may be envisaged in *impact areas* such as: performance of the business processes of the seaport for the implementing organization and for the partners (Ferretti and Schiavone, 2016); information sharing with the supply chain members (Gnimpieba *et al.*, 2015); container tracking in supply chains (Harris *et al.*, 2015); quality of transport planning for both ship operators and cargo owners (Verdouw *et al.*, 2016); slot reservation conflict in VHF Data Exchange System (VDES) for the Internet of Vessels (Zhang *et al.*, 2018); costs and profitability (Kretschmann *et al.*, 2017); own performance and competitiveness (Cristea *et al.*, 2017; Harris *et al.*, 2015; Tsertou *et al.*, 2016); economic and environmental impact of speed optimization (Lee *et al.*, 2018); energy efficiency, emission control, cost reduction (Mirović *et al.*, 2018); cargo loss prevention (Wu *et al.*, 2017); improving multimodal transport management (Xu *et al.*, 2016); vessel optimization, asset utilization and performance (Zaman *et al.*, 2017); security area which includes effects consisting in the risks associated with the on-demand services provided by a third party (Harris *et al.*, 2015; Tsertou *et al.*, 2016); and effectiveness of information management by the personnel of the shore control center (Man *et al.*, 2015).

For the maritime organizations, the *estimated impact* expressed in *qualitative* terms could be one or more of the following: improvement in the effectiveness and efficiency of a wide range of business processes is seaport, better integration with customers, reduction in direct contacts and formal information exchanges with them and, finally, easier and shorter decision-making processes, faster transport of containers to the destinations (Ferretti and Schiavone, 2016); traceability, collaboration and interoperability between different actors in the supply chain (Gnimpieba *et al.*, 2015); higher capacity utilization and service level in container shipping (Verdouw *et al.*, 2016); reduction in the fuel cost and in Green House Gas (GHG) emissions (Lee *et al.*, 2018; Mirović *et al.*, 2018); transparent multimodal transport throughout the whole procedure and no information barriers among the multimodal transport means (Xu *et al.*, 2016); enhanced effectiveness of operational scheduling, improvement in cargo handling performance and increased vessel safety and security (Zaman *et al.*, 2017); cost reduction, improvement in customer service, increase in the efficiency and profitability of company operations, enhancement of the competitive advantage (Cristea *et al.*, 2017); capability to focus on own core business strategies because of the use of cloud as a service (Harris *et al.*, 2015); and ability to add and remove computing capacity on demand for the dynamic container consolidation, according to the traffic intensity (Tsertou *et al.*, 2016).

Within the impact area referring to the effectiveness of information management by the personnel of the shore control center (SCC), the estimated impact is a better knowledge of the human factor issues in the SCC (in a shore-based environment) and of the principles of design of the remote monitoring and controlling of the autonomous unmanned ships/vessels, to allow shore-based operators to increase situational awareness, as well as to create and maintain harmony in ship/vessel handling (Man *et al.*, 2015).

The autonomous ships/vessels have as estimated effects the decline in operational expenses, the reduction in the environmental impact and the attraction of seagoing professionals (Ahvenjärvi, 2016).

In *quantitative* terms, examples of the *estimated impact* of the intervention are the following: potential reduction of 30 per cent in the time allocated by the planning team to handle the bookings, changes and cancellations for the voyage of a representative vessel with a capacity of 350 containers (Verdouw *et al.*, 2016); decline in the average slot reservation conflict rate by 3-4.5 per cent within a simulation related to SOTDMA (Self-Organizing Time Division Multiple Access) protocol, key technology of the AIS (Automatic Identification System) (Zhang *et al.*, 2018). Within the impact area related to cost and profitability, important estimated effects consist in cost reduction. Expected present value of the cost of owning and operating an autonomous bulker over a 25-year period is US$4.3mn lower than for a conventionally manned ship. Thus, assuming identical cargo carrying capacity, the required freight rate of the autonomous bulker (which produces a zero net present value) is 3.4 per cent lower than the required freight rate of the conventional vessel (Kretschmann *et al.*, 2017). Such outcomes could be possible in the scenario of a combination of crew reduction and fuel efficiency increase because of the improvements in the design of ships/vessels which are expected in the future. The estimated cost savings reach over a million euros annually, in the case of a fully autonomous, unmanned, battery powered and electrically driven concept ship (such as ReVolt) compared to an ordinary diesel-run ship (Ahvenjärvi, 2016).

When the outcome reaches the level of *SCC personnel*, potential challenges may appear in the *impact area* of information and communication. Examples of such potential negative effects are: ineffective level of situational awareness as a result of the reduced sense of the ship; information overload because of the monitoring and control of multiple ships and because of the diversity of available information; communication challenges in the relations with the other members of the SCC personnel, with the crews of the manned ships/vessels and authorities (Wahlström *et al.*, 2015).

In the case of *maritime transport* as outcome reach, two *impact areas* were identified – effectiveness of planning and control of transport processes (Costa *et al.*, 2016), the safety impact area (Ahvenjärvi, 2016; Burmeister *et al.*, 2014; Wróbel *et al.*, 2016). In the former impact area, from a qualitative perspective, the *estimated outcome* for the maritime transport consist in the ability to develop interoperable and interconnected solutions for multimodal transport management and information systems (Costa *et al.*, 2016). In the latter impact area, the effects incorporate the influence of the human factor (Ahvenjärvi, 2016). Both positive and negative effects are identified. The positive effect is the elimination of the errors made by human operators. However, a negative outcome may exist: inappropriate functioning because of the errors made by humans in the software development for the autonomous ship/vessel; potential unwanted habits developed by the crew of the manned ship/vessel because of the predictable operation of the autonomous ship/vessel; inefficient control because of errors made by the personnel that remotely operates the ship/vessel. The positive effects in the impact area of safety are also because of the improved reliability of navigation information (Burmeister *et al.*, 2014). Unmanned vessels would perform better in reducing the likelihood of accidents than in mitigating its consequences (Wróbel *et al.*, 2017). The hazard analysis of the unmanned ships/vessels may have as positive outcome the assistance provided to the designers of such vessels to identify the relationships between safety features (Wróbel *et al.*, 2016). Similarly, the assessment of the safety of a remotely controlled generic merchant vessel would help future designers because it identified that software development and validation is the part of the system that is affected by most significant uncertainties related to safety performance (Wróbel *et al.*, 2018a; Wróbel *et al.*, 2018b).

When the outcome reach is represented by the *other supply chain members*, an impact area could be the control over the container consolidation process (Tsertou *et al.*, 2016). The *estimated impact* (in qualitative terms) consists in the following effects: greater control of the consolidation process; improved capacity to proactively respond to exceptional events; better visibility of container situation, financial aspects and feedback/performance reviews (Tsertou *et al.*, 2016).

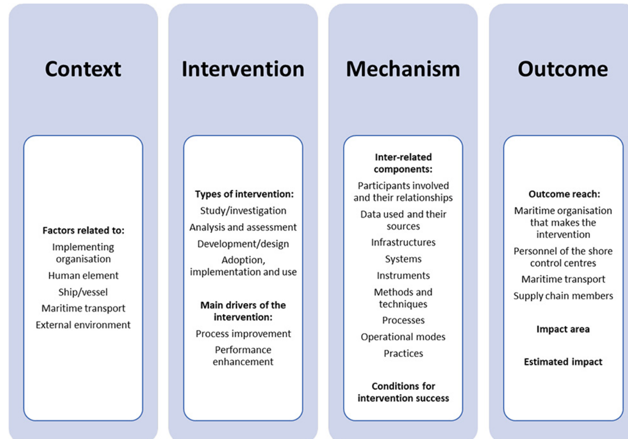
An aspect that calls for further research studies is the fact that actual impact of the intervention is rarely presented in the reviewed articles. One of the reasons could be the ongoing character of the ICT projects.

Discussion

Based on the CIMO "lens" used in the systematic review, this article suggests the CIMO-DMT model relative to the disruptive impact of future advanced ICTs on maritime transport. The model is based on the themes identified in the articles relative to the IoT, big data, cloud computing and autonomous ships/vessels (including unmanned ships/vessels). The main components of the model are displayed in the Figure 1. Further research can explore these components and the relationships between them.

The term *disruption* is "an event in which an agent must redesign its strategy to survive a change in the environment" (Kilkki *et al.*, 2018). The concept of *disruptive technology* was developed in the second half of the 1990s (Bower and Christensen, 1995; Christensen, 1997). In 2003, the concept of *disruptive innovation* was suggested to expand the scope and include non-technological disruption besides the technological one (Christensen and Raynor, 2003). The technological innovation is just one of the types of disruption (Markides, 2006). After two decades, the concepts of disruptive technology and disruptive innovation are not fully understood (Christensen *et al.*, 2015).

Figure 1 The CIMO-DMT model relative to the disruptive impact of future advanced ICTs on maritime transport



Technology disruption occurs when "the new technology crosses the performance of the dominant technology on the primary dimension of performance" (Sood and Tellis, 2011, p. 342). A disruptive innovation is "an innovation with radical functionality, discontinuous technical standards, and/or new forms of ownership that redefine marketplace expectations" (Nagy *et al.*, 2016, p. 125).

These views on disruption must be considered when interpreting the findings of the systematic review. The application of the CIMO logic underlines that implementation of the future advanced ICTs in maritime transport leads to significant performance enhancement and consequently has disruptive impact.

However, the reviewed articles do not provide sufficient information on the extent to which such technologies surpass the performance of the existing dominant technologies on the primary dimension of performance. Several potential causes of this situation may exist. The comparison between the future advanced ICTs and the existing technologies is limited (from the perspective of the primary dimension of performance). The available information often refers to the expected and not to the actual impact of the future advanced ICTs on maritime transport. The outcome assessment usually mentions the impact area (e.g. safety, visibility, etc.), rather than the performance indicators. Relatively few quantitative data on the impact of future advanced ICTs on maritime transport are available in the published articles. Information on the actual outcome is not available in the case of real-life projects that were not finalized.

The disruptive technologies are classified in two categories, first order and second order technologies (Schuelke-Leech, 2018). The first-order disruptive technologies generate a change that is localized within a market or industry. In contrast, the second-order disruptive technologies influence many industries and generate shifts in the societal norms, interactions and relationships, institutions and organizational structures, public policies and even in the physical environment.

The CIMO approach shows that research on the future advanced ICTs applied in maritime transport revealed mostly the first-order disruptive influence and to a less extent the second-order influence.

Conclusions

This systematic review answered the following question:

RQ. In what context and by means of what mechanism does the implementation of future advanced ICTs have disruptive impact on maritime transport?

Review findings provide an overview of the four components of the CIMO approach related to the disruptive impact of future advanced ICTs on maritime transport. The CIMO-DMT model is suggested as starting point for further research.

This systematic review has some limitations. Only the most important future advanced ICTs were considered, specifically IoT, big data, cloud computing, autonomous ships/vessels (including unmanned ships/vessels). Four databases were selected (Emerald Insight, ScienceDirect, Scopus and Web of Science Core Collection). These databases were chosen because of their leading positions in terms of number of high-quality and peer-reviewed publications they index, abstract or to which they provide access. The profile of these databases is relevant to the domain approached by the review.

The following recommendations for further research are based on the findings of the systematic review. The future **research agenda** could focus on the following **directions** of study: components of the CIMO-DMT model and relationships between them; comparative analysis of future advanced ICTs and existing dominant ICTs; impact on existing business models; emerging business models; new relationship patterns; and supply chain integration. To these directions may be added those relative to the impact on: human capital; IT ecosystems and cybersecurity; costs/investments and return on investment (ROI); supply chain performance; and environment. Each direction is approached hereinafter.

Components of the CIMO-DMT model and relationships between them

Research should go beyond the technical description of the future advanced ICTs implemented in maritime transport. There is a clear need for analyzing the relationships between the components of the CIMO-DMT model. Research could aim to identify the right combination of contextual factors and mechanism components required to generate the desired outcome levels. Another research aspect is the determination of the causes that explain the gaps between desired/estimated and actual outcomes, as well as of the specific conditions/prerequisites that should be accomplished to achieve the success of specific interventions related to the future advanced ICTs.

Comparative analysis of the future advanced ICTs and existing dominant ICTs

The proof that a new technological disruption becomes a fact is the superior performance of the new technology in comparison to the existing dominant technology, in terms of the primary dimension of performance (Sood and Tellis, 2011). Further research should make a comparative analysis and identify the factors that lead to superior outcomes of ICTs in the maritime transport of cargo.

Impact on the existing business models

The dynamic capabilities of the organization influence how fast business models are designed, tested, refined, implemented and revised (Teece, 2018). At the same time, business models adapt to the opportunities and threats from the external environment (Saebi *et al.*, 2017). The implementation of future advanced ICTs in maritime transport may challenge the viability of the traditional business models within the supply chains. Research could approach the following: disruptive changes driven by the future advanced ICTs in the existing business models of the maritime transport operators; types of factors that influence and moderate the disruptive impact; and business models that will progressively disappear from supply chains.

Emerging business models

New business models are necessary to leverage new technologies (Johnson *et al.*, 2008). Further development of the research on business models will focus on innovation, change and evolution, as well as on design (Wirtz *et al.*, 2016). Innovative business models based on future advanced ICTs may have a disruptive impact on maritime transport and supply chains. Researchers should address the new business models and new types of players that will emerge under the impact of the future advanced ICTs that will be implemented in maritime transport.

New relationship patterns and supply chain integration

The functioning of the supply chain as a unified system requires coordination among members (Arshinder and Deshmukh, 2008). The relationships between the "traditional" and the new types of supply chain players will evolve under the impact of the future advanced ICT implementation in the maritime transport. Research should identify the strategies and tools based on future advanced ICTs that may improve coordination between the supply chain members. Structural embeddedness is related to a supply network perspective. From the dyadic relationships studied in the past, researchers refocus on extended supply networks (Choi and Kim, 2008) that stimulate the adaptive collaborative behavior (Nair *et al.*, 2018). Various factors could negatively influence the integration between the supply chain stages, in the context of advanced ICT implementation in maritime transport. Consequently, researchers should investigate the impact that future advanced ICTs implemented in maritime transport will have on information visibility and information sharing across the stages of the supply chain, as well as the potential challenges to the integration.

Impact on the human capital

Research shows that ICTs have a positive and significant impact on productivity (Cardona *et al.*, 2013). The ascending evolution of ICTs may influence the range of digital and non-digital skills of the human capital (Van Laar *et al.*, 2017). Research should explore the qualitative and quantitative effects that future advanced ICTs will have on human capital in maritime transport (new skills required, jobs displaced, new jobs, etc.).

Impact on the IT ecosystems and cybersecurity

Companies will look to the future advanced ICTs through new lens. From managing ICTs as a set of internal technologies, they will shift to managing "a broad network of ecosystem technologies" (Desmet *et al.*, 2017). Cybersecurity is considered a critical issue for companies and an important component of the cyber-physical system of systems (Lamnabhi-Lagarrigue *et al.*, 2017). The objective to effectively and efficiently manage future advanced ICTs in the IT ecosystems will require researchers to study the impact that adoption of a specific ICT by a maritime transport operator will have on the partner companies and on the cybersecurity responsibilities of the supply chain members.

Impact on the costs/investments and return on investment (ROI)

The balance between the benefits and the costs entailed by the ICTs seems to be "poorly understood", both over time and across countries (Hughes *et al.*, 2017). Researchers must analyze how the design, implementation and monitoring of the future advanced ICTs will impact the value of costs/investments of the maritime transport players and will potentially influence the costs/investments of the other supply chain members. The research questions may refer to the way in which the supply chain members can jointly develop and manage future advanced ICT projects towards increased ROI.

Impact on the supply chain performance

The measurement of supply chain performance is a fruitful research area (Balfaqih *et al.*, 2016). However, most of the literature on supply chain performance measurement is confined within firm boundaries (Maestrini *et al.*, 2017). Both positive and negative implications may be anticipated for the entire network in delivering the valuable solution expected by the ultimate buyers. As regards the implementation of future advanced ICTs in the maritime transport, researchers should insist upon aspects such as: impact evaluation methods; potential impact on other supply chain members (besides those from the maritime transport); and strategies and tactics to be applied for an enhanced positive impact.

Impact on the environment

The research on the sustainable and green supply chain management is in a growing and maturing stage (Fahimnia *et al.*, 2015). In the future, the research on the environmental impact of supply chains should integrate the triple bottom line (TBL) perspective (Rajeev *et al.*, 2017). The implementation of future advanced ICTs in maritime transport will have effects that go beyond the profitability and market competitiveness, into the fulfilment of objectives related to the future sustainable development of the society. Further research of the future advanced ICTs should identify: methods to diminish significantly the product losses that are caused by cargo depreciation during the maritime transport; impact on the carbon footprint of each supply chain level and of the entire production and distribution network, in the case of specific products; and correlation of the environmental impact with the economic and social aspects from a TBL perspective.

The findings of this systematic literature review have direct implications for practice. The maritime transport organizations can benefit from the implementation of the CIMO-DMT model relative to the disruptive impact of future advanced ICTs. The main implications for these organizations refer to the following aspects: intended outcome as intervention trigger; increased efficiency and responsiveness; and benchmarking.

Intended outcome as intervention trigger

The implementation of future advanced ICTs by maritime transport organizations is not an end in itself. Each intervention related to such technologies is justified whether it can lead to the desired outcome. Thus, the intended outcome becomes a reference for the choice of the right type of intervention and of the mechanism components within a particular context. Setting, measuring and monitoring quantitative key performance indicators related to the future advanced ICTs could help maritime transport organizations to achieve the intended outcome with the expected return on investment. The intervention and mechanism may be adjusted to attain the expected outcome.

Increased efficiency and responsiveness

Companies are in a continuous search for new solutions to improve their performance. Information technology revolutionized traditional logistics and supply chain and provided benefits such as increased efficiency and responsiveness (Gunasekaran *et al.*, 2017). Future advanced ICTs have the potential to enhance these benefits. Decision-makers can obtain the intended outcome from the implementation of the future advanced ICTs if strategies and actions are based on appropriate relationships between the components of the CIMO-DMT model. In this respect, management must understand the contextual factors, as well as identify the most appropriate intervention and mechanism to create the expected outcome. As regards the context, management will consider the factors related to implementing organization/organizations, human element, autonomous or unmanned ship/vessel, maritime transport and external environment. For each type of intervention related to the future advanced ICTs (study/investigation, analysis and assessment; development/design; adoption, implementation and use), maritime transport organizations must clarify the drivers related to process improvement or performance enhancement. The design of the mechanism for the implementation of the intervention has to address the following components: participants involved and the relationships between them; data used and their sources; infrastructures; systems; instruments; methods and techniques applied; processes; operational modes; and practices. The successful functioning of the intervention mechanism depends on meeting several conditions/requirements. The expected outcome should be defined in terms of reach, impact area and estimated impact.

Benchmarking

This managerial tool is a cornerstone for companies to be at the forefront of excellence (Wong and Wong, 2008). To achieve sustainable competitive advantage, companies should not limit benchmarking to the operational level, but address a wider range of levels relative to value chain, strategies, operational aspects and projects (Hong *et al.*, 2012). The practice and scientific literature provide diverse benchmarking models (Anand and Kodali, 2008). To improve performance based on future advanced ICTs, the maritime transport organizations may apply benchmarking methods and models, considering best practices in the maritime sector or in other industries. The inter-organizational benchmarking within supply chain may improve performance related to the future advanced ICTs.

The disruptions generated by future advanced ICTs in the maritime transport could have social implications. These technologies and especially the autonomous ships/vessels will redefine the jobs of employees working in the maritime transport. A pessimistic perspective of the impact of future advanced ICTs would underline the displacement of some specific jobs (e.g. in the case of unmanned ships/vessels). In contrast, a realistic perspective will focus on the need to develop the new skills of the future workforce in maritime transport. Higher-level thinking skills, transdisciplinary approach and collaboration skills in the virtual environment will be in higher demand than basic cognitive skills such as basic data input and processing.

The CIMO-DMT model and future agenda provide relevant premise for the development of explanatory research on the disruptive impact of future advanced ICTs on maritime transport. These technologies have implications for practice and society. The hype surrounding the new advanced ICTs increases tremendously the expectations of decision-makers. Researchers have an opportunity window to explore how such technologies can make valuable contributions to business and supply chain performance.

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About the author

Carmen Bălan is Professor PhD at the Bucharest University of Economic Studies, in the Department of Marketing of the Faculty of Marketing. The research interests encompass marketing, supply chain and pricing. Her book on logistics was the first of a Romanian author and provided value to both the academic and business environments in Romania. She is one of the co-authors of four edited book titles published by Taylor and Francis/Routledge and of one edited book title published by Springer. Carmen Bălan can be contacted at: carmen.balan@mk.ase.ro