A serving innovation typology : mapping port-related innovations

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A serving Innovation Typology: Mapping Port related innovations

Abstract
The port sector is often perceived to be lagging behind in terms of innovative initiatives. It is unclear whether this is the result of a more limited engagement of the scientific community, or poor external marketing from port operators or whether the limited number of port-related scientific studies is not representative of the real volume of innovation in the sector.

In order to offer deeper insight into the connections between the academic (port) innovation literature and actual innovation practices in the port sector, firstly, the literature is reviewed over the 2011-2018 period. Secondly, the paper proposes a typology, which supports the management of the innovation process and upon which future research could be based. Last, the analysis of 75 port-related innovation initiatives provides an application of the proposed typology.

The findings from the study of innovation in the port-related sectors show that multi-dimensional innovation encompassing technological, managerial, organisational and cultural aspects is prevailing in this industry. So far only a handful of innovation cases are the result of co-operation, generally with other firms upstream or downstream in the maritime supply chain. Ultimately, it emerges, however, that collaborative innovation or co-innovation is the way forward for future maritime- and port-related innovation.

Keywords: maritime transport, port, innovation typology; port-related innovation; maritime supply chain,

1. Introduction

The transportation industry has made considerable progress during the past decades in various areas such as policy-making, technologies and environmental initiatives (Banister and Stead, 2004; Bontekoning and Priemus, 2004; Vivanco et al., 2015). Innovation has played an important part in supporting and advancing the development of the transportation industry. On the one hand, transportation is capital-intensive, which contributes to the need for technological advancement in facilities and equipment (Van Geenhuizen et al., 2003; Ambrosino et al., 2018). On the other hand, innovations in policy-making and in the organisational aspects of transportation (software) go hand in hand with technology and infrastructure (hardware) in order to achieve improved results in terms of efficiency (Weber et al., 2014).

In general, innovation is seen as essential for maintaining and enhancing the competitiveness of an industry and of organisations (Flint et al., 2005). Innovation contributes, hence, to the competitive advantage of the transportation sector. In a similar vein, innovation can be strategic in keeping national shipping and port industries competitive (Jenssen, 2003). Although the industry offers multiple opportunities to innovate, a comparative study of the International Transport Forum (2010) shows that the maritime and port sector in particular appears less pro-active in comparison with other sectors (e.g. banking, pharmaceutical)[1]. As the complexity of contemporary production processes increases, and greater reliance is made on efficient transport in global supply chains, it is necessary to assess whether the maritime sector is sufficiently prepared for the new economic, environmental and social requirements. This study investigates, thus, innovation in the maritime and port industry.

This research was motivated by three limitations in the current scientific maritime and port innovation literature. Firstly, innovation is often confused with invention. According to Schumpeter (1939), innovation is the market introduction of a technical or organisational novelty, not just its invention. In order to distinguish between innovation and invention in the sector of interest, it is necessary to draft a uniform definition of what innovation entails in this context (section 3). The second limitation is that there are no contributions on innovation typology with regard to the port-related industry, or even the transportation sector more in general. General innovation typologies were developed in the literature (Booz, et al., 1982), but a classification of the types of innovation in the wider port context is missing. This fact limits understanding and comparative research. Hence, a conceptual typology is developed in the paper (Section 4). Thirdly, only few studies focused on port- or maritime-related innovation projects. Exceptions are Acciaro et al., 2014; Arduino et al., 2013; De Martino et al., 2013; Jenssen, 2003; Keceli, 2011. As is shown in this paper, in the post-economic crisis era of 2009, the port and maritime industries have taken steps to develop new initiatives in terms of innovation. Progress on academic research related to maritime supply chain innovation and sharing the knowledge in industry meetings could help the industry to implement these innovative initiatives with success, and thus, catch up with other sectors that have innovation in their DNA. It is not clear at this stage whether innovation research is lacking because of a lack of actual innovation cases in operational practice, or as a result of a a lack of supportive research.

The present study contributes to addressing these knowledge gaps. The rest of the paper is organised as follows. Section 2 describes the research process. In section 3, the paper provides a clear definition of what is to be conceived as an innovation. In section 4, it advances a conceptual typology applicable to innovations in the port-related industry. It is important to note that the research in this paper is delimited to cargo transport through ports, and does not deal with passenger transport. Section 5 reviews existing practice cases of maritime- and port-related innovation and applies the typology framework developed in section 4 to them. In section 6, conclusions are drawn and suggestions for future research directions are given.

2. Research process

The research process used to build this paper can be structured in three phases. The first phase consisted of collecting and reviewing previous research contributions. Peer-reviewed articles over the 2011-2018 period were screened and selected using well-recognised academic database search engines (Scopus, Science Direct and Web of Science). The following key words were used

[1] The classical way to measure innovation performance is through the volume of R&D investment. Typical R&D figures are significantly lower for the transport and logistics sector than for other industrial sectors. The question is raised whether R&D fully reflects the level of innovation activity.

as search strings: ‘maritime innovation’ and ‘port innovation’ in conjunction with ‘technology’, ‘regulation’, ‘environment’ and ‘organisation’. Contents, relevance and quality were the three criteria for screening the papers. A full-text reading focusing on the objective, the methodology and the conclusion resulted in retaining 43 relevant studies (see Table 1 and Annex 1). The second phase in the research process focused on developing an innovation typology. The typology is not only valuable from a research perspective, but it also provides the basis for operators and policy makers to take suitable measures to increase the chances of success of an innovation initiative. The typology can also be generalised beyond the port context, so that it can also be used for non-port innovation. Finally, case studies have been built to provide empirical support to the typology definition, which allowed investigating the applicability of the proposed typology. For this empirical analysis, 75 innovation cases were selected for which information was gathered through the review of literature and industry documents and by means of interviews with relevant stakeholders. With the collected information, the cases could be tested on their fit in the developed typology.

3. Definition of innovation

The concept of innovation appeared more than 75 years ago in the academic literature with Schumpeter (1939) being one of the first to introduce innovation as “‘*doing things differently in the realm of economic life*”, where *“new combinations”* of resources bring about five different types of innovation: 1) new products or a new quality of a product, 2) new methods of production, 3) new markets, 4) new sources of supply of raw materials and intermediate goods, and 5) new methods of organizing the economic process. Most of these types of innovation are still identified in the latest (3rd) edition of the Guidelines for Collecting and Interpreting Innovation Data (Oslo Manual, OECD and EC 2005, 46f): *“An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organisation or external relations. Four types of innovation are distinguished: product innovations, process innovations, marketing innovations and organisational innovations.”*

Drucker (1985) put forward a more operational definition: *“Innovation is change that creates a new dimension of performance and to innovate is to turn change into opportunity. Systematic innovation therefore consists in the purposeful and organized search for changes, and in the systematic analysis of the opportunities such changes might offer for economic or social innovation.”* In the same study, he therefore introduces the notions of purpose, efficiency gains and calculated risk taking.

Based on the above, Arduino et al. (2013) developed a more specific definition: *“A technological or organisational (including cultural as a separate sub-set) change to the product (or service) or production process that either lowers the cost of product (or service) or production process or increases the quality of the product (or service) to the consumer.”*

Although different definitions of innovation were proposed in the literature, the following similarities can be identified. First, innovation drives change. Second, there are different kinds of innovation.

Whether the involvement is on a product or more on the process, however, does not fundamentally matter. In other words, the definitions do not specify a particular form of inputs or outcomes.

In the remainder of this paper, it is opted to apply the definition of Arduino et al. (2013) as it is more concrete, it allows measuring the impacts, and it can be fully applied to a port and maritime supply chain. Moreover, it allows testing innovation projects that were not analysed before in the same context.

Starting from the selected definition, the following section will carry out a literature review and develop a typology framework for innovation initiatives.

4. From literature review to a conceptual typology of maritime- and port-related innovation

It is important to recognise that a number of typologies or classification systems are possible to cover the innovation initiatives (Booz, et al., 1982). The varied and eclectic nature of innovation present in the port context implies that a number of descriptors may be used, alone or in combination with others, to classify innovation. Based on the insights of the literature, five dimensions of innovation are proposed in this section to develop the typology: 1) the background of the innovation, 2) the openness of the innovation, 3) the actors involved, 4) the magnitude of impact, and 5) the source of innovation. For each dimension, firstly, the relevant general literature is reviewed, and subsequently a summary with respect to the typology is given. The section closes with a summary.

4.1 Innovation background

The first dimension is linked with the background of the innovation, which refers to the targeted goal of the innovation. Given that the innovation may differ with regards to the nature of change, the motivation to innovate determines the background. So far, the literature has not come to a consensus on a commonly adopted approach of classifying innovation according to their background.

By using a very broad approach, Hollanders et al. (2012) state that innovation projects may be grouped as: Technological (product and/or process) or Non-technological (marketing, organisational and/or cultural). In particular, technologies, and especially emerging technologies, either improve or have the potential to improve GDP (Freeman, 1982). Today's emerging technologies include computational sciences, micro-electro-mechanical systems (MEMS), nanotechnology, mobile technologies, bio-fuels, and others (Cordero, Walsh & Kirchhoff, 2005; Garg et al., 2015; Kautt, Walsh & Bittner, 2007; Lantada et al., 2015). Some of them are also found in the port and maritime industries. Furthermore, emerging technologies are often used to develop radically new products with exceptional benefits to society (Groen & Walsch, 2013; Allarakhia & Walsh, 2011; Barras, 1986).

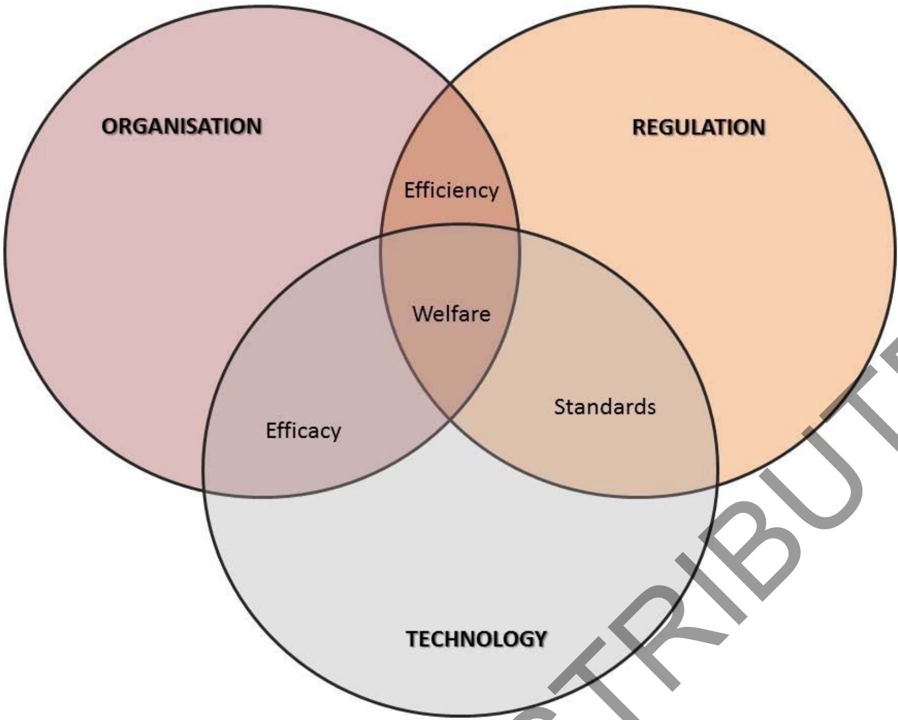
Due to its multi-faceted nature, Roumboutsos et al. (2011) state that an innovation initiative may be regarded as a hybrid, requiring or encompassing simultaneously technology and organisational change or organisational and cultural change. A predominant component of innovation may be identified in a project, although the predominant component may well vary depending on the temporal phase reached in the innovation process.

In line with the multi-facet nature, Arduino et al. (2013) come to the below classification which occurs in the wider transportation practice:

- Purely technology innovation
- Managerial, organisational & cultural innovation
- Technology, managerial, organisational, cultural innovation
- Public policy innovation

Combining Hollanders et al. (2012), Roumboutsos et al. (2011) and Arduino et al. (2013) with reference to the criteria ‘Innovation background’, existing research focusing on port-related innovation can be divided into three major types: Regulatory, that includes institutional, policy or similar innovation types.Organisational, that includes management, system or similar innovation types and.Technological that includes product or process innovation.(Figure 1) These innovation types are not mutually exclusive and interaction among innovation types also needs to be considered. For example, technological innovation will most probably trigger or require innovation in processes (management, operational, cultural etc.) (Bergek et al., 2008; Carlsson et al., 2002) suggesting a system change. A technology innovation may cut across national, regional and sectoral boundaries (Hekkert et al., 2007; Markard and Truffer, 2008) and this characteristic reflects on both the deployment of the technology and the interdependency of actors and their interrelations.

Figure 1. Interrelation of the major types of maritime innovation



As mentioned in section 1, there were only a few scholarly articles specifically researching innovation *per se* in the port-related industry. However, upon a broader literature analysis, it emerged that there is a good number of publications, which involve enhancement of regulation, organisation, technology or a combination of these aspects of innovation, without explicitly referring to 'innovation'. To widen the scope of the literature review, these innovation-related scientific articles were included, to derive the pattern of innovation types according to the 'background' dimension as they feature in the port context.

Table 1 summarises the innovation-related articles encountered in recent (2011-2018) port-related academic literature. Annex 1 presents the detailed findings of the reviewed literature, per source. A fairly good balance between the three major innovation types is found. This reveals that accounting for multiple aspects when developing innovation is essential in this highly dynamic and competitive industry. Accordingly, scholars try to provide solutions or improvements to tackle higher expectations from stakeholders such as customers, shareholders, regulators or society by and large.

Table 1: Port-related academic literature classified according to innovation background

Topic			Sub-topic	Example
Regulation & Institutional	Organisational	Technology		
x			Regulation development	Defilippi (2012)
x	x		Concessions	Chen and Liu (2015), De Langen et al. (2013)
x	x		Hinterland co-ordination	Ambrosino et al. (2018), Hintjens (2018), Iannone (2012), Lam and Gu (2013), Van der Horst and Van der Lugt (2011), Colombo et al. (2011)
	x		Port-centric logistics, dry ports and offshore logistics hubs	Wei et al. (2018), Wang et al. (2018), Kramberger et al. (2018), Do et al. (2013), Monios and Wilmsmeier (2013), Olivo et al. (2013), Veenstra et al. (2012)
	x		Maritime logistics hubs	Lee et al. (2018), Yang (2013), Nam and Song (2011)
	x		Empty container logistics	Zhang et al. (2018), Vojdani et al. (2013), Dang et al. (2013), Chao and Yu (2012)
	x		Chain planning	Fancello et al. (2011)
	x	x	ICT	Min et al. (2017), Pagoropoulos (2017), Keceli (2011), Marianos et al. (2011)
	x	x	Environmental management	Aydogly and Aksoy (2015), Marenco and Cantillo (2015), Klopott (2013)
		x	Container terminal optimization	Gharehghozli et al. (2016), Kaveshgar and Huynh (2015), Zeng et al. (2015), Sharif and Huynh (2013), Ambrosino et al. (2013), Zhao and Goodchild (2013), Thai (2012), Klerides and Hadjiconstantinou (2012), Golias (2011), Golias and Haralambides (2011), Monaco and Sammarra (2011)
	x		Climate change	Osthorst and Mainz (2013)

Although none of the above references deals exclusively with the innovation process, but rather with the technical and performance aspects of the innovation initiative, the innovation cases that were studied in literature as such would be useful to submit to a process analysis, which is what this paper will undertake.

4.2 Innovation openness

Innovation openness is the second dimension for classification. The extent of sharing information, process and outcome, allows innovation to be furthermore categorised as ‘open’ or ‘closed’ (Remneland-Winhamn and Knights, 2012). The term ‘closed innovation’ refers to the tendency to keep innovation activities within the firm or cluster of firms; exchanging knowledge with the external environment is called instead ‘open innovation’. While open innovation was once the research interest of a few, it is now part of mainstream research (Chesbrough, 2003). Closed innovation (for instance, the development of a port information technology (IT) platform) increasingly evolves to open innovation (for instance, all ports within a country contribute to the development of such an IT platform). The development cost is expected to reduce through open innovation, while the efficacy of funds employed and resulting efficiency in a network industry improves. An even broader interpretation of open innovation is that it is made available as open source, with the possibility of using and contributing to the improvement for everyone (Remneland-Winhamn and Knights, 2012). Nonetheless, tensions between open source and open innovation can emerge because of unresolved patent issues or as firms attempt to gain a first mover advantage, also in the port sector. Besides, the network nature of the port and, in general, of the transportation sector should not be overlooked. Many innovations, especially those related to Information Communication Technologies, need to be open in order for their full benefits to be realised (Koski and Kretschmer, 2004).

4.3 Actors involved

Another dimension relates to the number and type of actors directly involved in the decision process. In his early work, Schumpeter (1912/1983) focused on the individual entrepreneur primarily in new firms who act as driver of 'creative destruction'. They search for unexploited business opportunities by trying out new combinations of resources. In his later work, Schumpeter (1939) acknowledged that large established firms, which can build up substantial barriers to entry for new innovators and thus play a crucial role in the innovation process dominate competition in many markets.

According to Habbay (2012), Park et al. (2012), Roumboutsos et al., (2011 and 2014), the actors involved in the innovation depend on the 'type of change' that occurs. They distinguish among '(Business) Unit Change' and 'Market Change':

- (Business) Unit Change or a change occurring at one specific location and/or for one specific operator (e.g. the indented berth, allowing (un)loading operations on both sides of the ship, at the Ceres Paragon Terminal in Amsterdam);
- Market Change or a change occurring for an entire product market (e.g. (unmanned) container handling).

Analysing the maritime and port literature, it is hard to determine whether most innovation featured a rather business or market involvement. However, it is clear that there is a significant difference in the number of actors' interests that need to be aligned in the 'market change' innovation and, consequently, in the risk associated with this type of innovation.

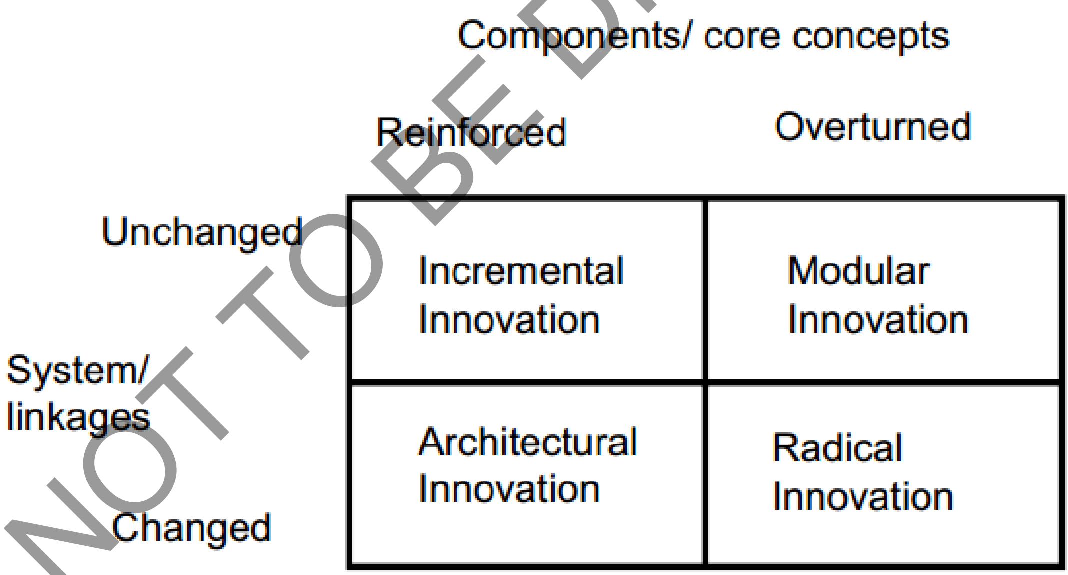
It should also be noted that the innovation process consists of several phases, typically split into 'initiation', 'development' and 'implementation', whereby the involved actors can be different across each phase. The latter will also need to be different according to the 'recipe for success' that can be devised for any innovation type and stage (Acciaro et al., 2018).

4.4 Magnitude of impact

A further classification of innovation relates to the magnitude or size of impact of innovation and it can be described as 'incremental', 'modular', or 'radical' (Hemphälä and Magnusson, 2012; Bourreau et al., 2012; Crozet, 2010). In Schumpeter's view (1983), innovation either concerns market experiments with ‘radical’ innovations (for instance, the introduction of the container) creating major disruptive changes, or ‘incremental’ innovation, which continuously advances the process of change (for instance, cranes that enhance performance, or improvements in IT developments). The impact of innovation can also be discontinuous. The result of the process of change can reflect in the short or medium run or can become apparent only long after introduction.

Henderson and Clark (1990), focusing on product innovation only, distinguish among two types of knowledge: component and system knowledge (see figure 2). Firstly, ‘component’ knowledge refers to *“the knowledge of each of the components that perform a well-defined function within a broader system that makes up the product. This knowledge forms part of the ‘core design concepts’ embedded in the components”*. Secondly, under ‘system’ knowledge, the same authors understand “*the knowledge about the way the components are integrated and linked together. This is knowledge about how the system works and how the various components are configured and work together”*. The latter is referred to aslo as *architectural knowledge*.
The consideration of the impact of innovation in realtion to the two types of knowledge discussed above and the size of the impact, leads to a two dimensional matrix with four categories, depicted in figure 2. The two extremes are ‘incremental innovation’ on the one hand (in the top-left) and ‘radical innovation’ on the other hand (in the bottom-right). Henderson and Clark (1990) indicate architectural and modular innovation as intermediate typologies.

Figure 2. Typology of innovation in terms of magnitude of impact



Source: Henderson and Clark, 1999

Arduino et al. (2013) provide a more detailed explanation for each type of innovation listed in Figure 2.

- <u>Incremental Innovation</u>: a small change to existing products/procedures (example improvements in information exchange);

- Modular Innovation: a significant change in concept within a component, but links to other components or systems remain unchanged and the impact is fairly low (example the introduction of an All-Weather Terminal, allowing to handle weather-sensitive products irrespective of meteorological conditions). System Innovation: multiple independent but integrated innovation initiaives that must work together to perform new functions or improve the overall performance of a system (example the introduction of a Port Community System or PCS).
- Radical Innovation: that is a breakthrough in the specific field that could change the entire nature of an industry. This could be seen as an entirely new way of solving specific problems. It generally results in the establishment of a new dominant design and, accordingly, a new set of core design concepts that linked together create a new kind of component or system. Existing linkages among systems and organisations may be irrelevant for the implementation of a radical innovation. Radical innovation is rare. A well-known example has been the introduction of the container.

These principles can also be applied for classifying the innovation concept. It is important that an innovation initiative is judged over a sufficiently long period of time, to avoid that its impact is underestimated, or that a not-yet-succesful initiative with a lot of potential is misjudged as unsuccesful.

4.5 Source of innovation

From the literature review, two broad categorizations of innovation according to the 'source' were observed. First, private commercial innovation, the motivations for which are either revenue generation or cost-reduction and, second, public innovation (with law/policy) initiatives, where the motivation is related to achieving an increase in socio-economic welfare. Public policy initiatives are generally targeted on complete sectoral and trans-sectoral transport markets (Arduino et al., 2013). Finally, in the case of maritime and port innovation, the source of innovation can also be public-private.

4.6. Summary typology

Referring to the literature as reviewed in the preceding sections, three main dimensions for a port innovation typology are identified: background, actors and source. The openness dimension is not included, as it is observed that the large majority of the innovation in port practice is closed. Equally, the magnitude dimension is left out, as nearly all identified innovation in ports is of the incremental type., The following typology is therefore proposed to enhance the way of analysing and classifying port-related innovation.

Table 2: Proposed summary innovation typology

	Innovation typology	Description
I.	Technology – unit change	A primarily technological change occurring at one specific location and/or for one specific operator

II.	Technology – market change	Like I, but the change occurs for an entire product market (e.g. container handling)
III.	Technological, Managerial, Organisational, Cultural – business change	Next to technological changes, the innovation also allows for changes at managerial, organizational and cultural level, all of those at the level of a specific business (e.g. handling coal transiting from Brazil to Europe)
IV.	Technological, Managerial, Organisational, Cultural – market change	Like III, but the change occurs for an entire product market
V.	Managerial, Organisational, Cultural – market change	Innovation into the organisational culture and management processes without significant technological component
VI.	Policy initiatives (Managerial, Organisation, Cultural – market change)	Policy-initiated innovation actions, which in turn may trigger further innovation. (e.g. introducing carbon tax)

The value added of this typology is that it provides a useful basis for measures to be taken by operators and policy makers to improve the chances of success of innovation initiatives; also useful in other sectors.

Section 5 applies and validates the developed innovation taxonomy to a set of existing maritime- and port-related innovation cases from practice.

5. Application and validation of the typology with cases of maritime- and port-related innovation

This section analyses the collected cases of maritime- and port-related innovation initiatives. First, the characteristics of the sample of cases is briefly described. Next, based on the proposed innovation typology (Table 2), the cases are classified according to their background of innovation activities and whether the innovation implies unit, market or business change.

5.1 Description of the studied innovation cases

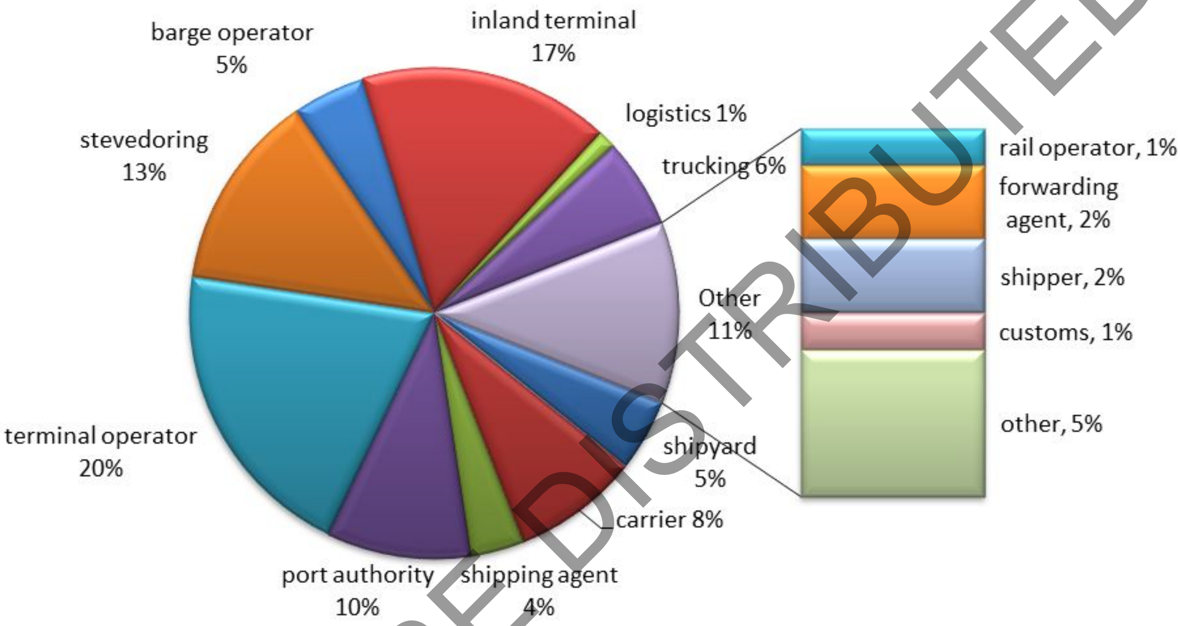
Over the 2013-2015 period, data for 75 innovation cases was collected (see Annex 2)[2]. Two innovation cases, namely the 3PL Primary Gate and Port Single Window, contain the point of view of multiple stakeholders, hence resulting in 84 case assessments in total. 28 private port operators

[2] A full description of the set of cases is available in Sys, et al. (2015).

and two port authorities contributed to the research by sharing their opinion and knowledge regarding past, present and future innovation cases developed by their company and/or in which they were involved. The participation of different actors, located in 10 different countries, ensures that the case database covers the entire supply chain.

Figure 3 shows the share of each sub-sector in the total set of cases, while details of which cases belong to which sub-sector can be found in Annex 3.

Figure 3. Distribution of the 75 innovation cases over the sub-sectors

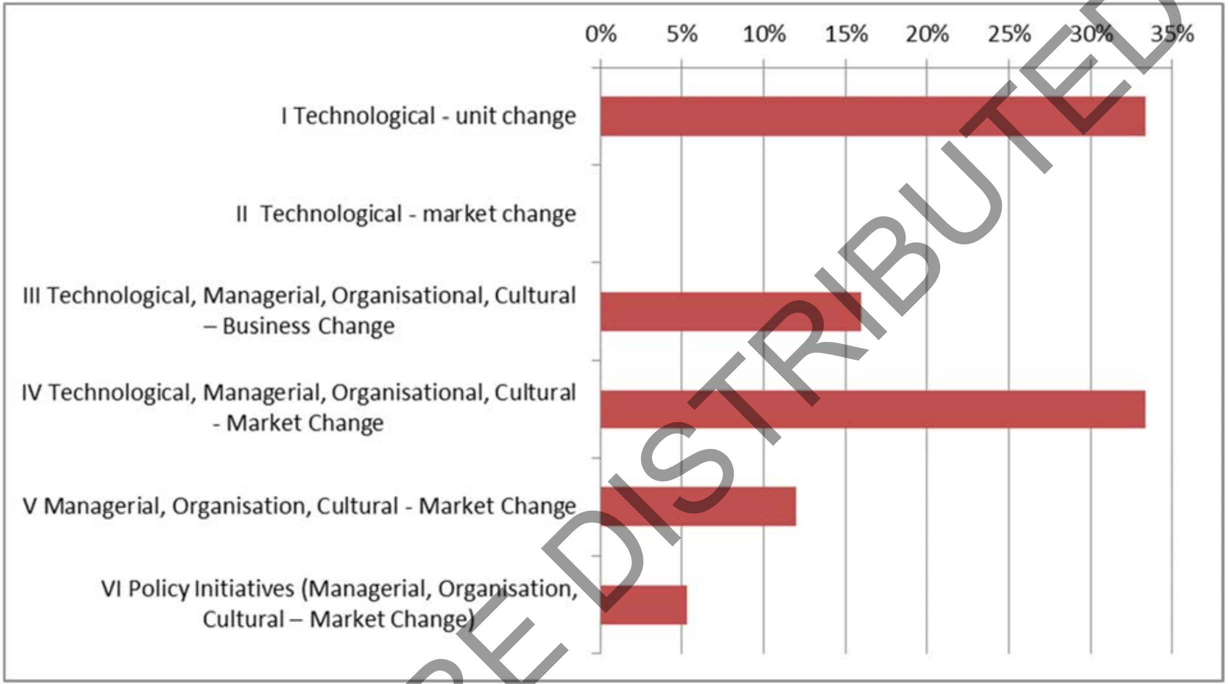


Analysing the split per country, a quite global coverage is found, especially as many of the cases originate from international players, active in various regions of the world. During the data collection, it became apparent that when a company or organization is innovative and creative, it works on different / simultaneous innovative initiatives.

5.2 Validating the conceptual typology

Figure 4 shows the results for the 84 case assessments. Type IV (Technological, Managerial, Organisational, Cultural – market change), taking up more than one-third of the cases (35%), is the most common type of innovation. Type III (Technological, Managerial, Organisational, Cultural – business change), representing almost one-third of the cases (32%) is the second common type of innovation in the sample of cases. These two types together therefore represent a predominant portion of 67%. That is, a major part of the cases features a technological or managerial/organisational/cultural change at the level of the business or the market with an impact across the entire supply chain. The third is Type V (Managerial, Organisational, Cultural – market change), which accounts for 17% of the cases. Pure technological innovations (Types I and II) take up only 10% of the cases. This reveals that purely technological innovation does not occur that often. To a lesser extent, that is also true for pure managerial, organizational and cultural innovation without a clearly visible technological component. The finding indicates that multi-background innovation is common in the port-related industry. While technological innovation is helpful for this capital-intensive industry, technology on its own appears not to be sufficient and requires managerial and organisational change to endorse and exploit it.

Figure 4: Classification of the 75 innovation cases by innovation type



Another observation is that market change is rather common, especially given that combined technological / managerial innovation clearly occurs more often than purely technological innovation. That is, the change often occurs for an entire product market and is not limited to a particular location or firm. This finding is aligned with the international and network nature of the port and maritime industry. Since the industry is international, the sphere of influence of innovation is likely to be wide.

Now, the discussion is turned to the actors involved in the collected cases. Within the sample, the innovation champions (or initiators) are the deepsea terminal operators, stevedores and inland terminals. The bulk of the companies put innovation cases that are related to the cargo flow and IT high on the agenda. In recent years, enhancing logistics and supply chain management has become crucial for trade performance. Correspondingly, optimising maritime logistics is increasingly prevalent (Nam and Song, 2013). In the digital era of SCM, information flows across various supply chain parties on top of cargo movements have also become essential (Lee et al., 2018). The advancement in IT solutions has been a key driver in the growth of service industries and continues to be the main engine for innovation in the port and maritime sector (Tseng and Liao, 2015). The sample of innovation initiatives also demonstrate such trends. These kinds of innovation are also essential for the development of new business models in the management of logistics flows as for instance the synchromodality approach (Hintjens, et al., 2015).

Furthermore, the cases can be analysed based on the magnitude of impact generated by the innovation, viz. incremental, radical, modular and system innovation. The majority of the cases are of the type ‘incremental’ innovation, which means they are not based on new initiatives / technologies, but rather further developments of existing practices. The maritime and port sector struggles with radical innovations. The findings somehow reveal the motivations of the actors initiating the innovation initiatives: cost may be the primary reason. In fact, being cost-efficient is an essential requirement of any companiy (Schiff, 2014). Minimizing cost is especially prevailing since the time of the global economic recession from 2008. The overall port and maritime industry has experienced weakening demand and has not truly recovered during the research. Hence, market players may tend to be more conservative when they have to decide on spending on new initiatives / technologies. Also, practically and technically, it requires more time, resources and expertise to create innovation with a radical impact. The risk involved in such kind of innovation projects tends to be higher. Building on existing practices and making improvements is more easily achievable and provides a more reliable outcome, and easier to sell to management and shareholders.

With regard to the source of innovation, more than 50% of the gathered initiatives are private commercial. The minority of cases is of public nature. In such initiatives, the motivation is related to achieving an increase in socio-economic welfare. In 5% of the cases, the initiatives concern public-private partnerships. This result also explains why the majority of the cases are closed. This is even more the case with IT innovation (e.g. the development of an IT platform). Nevertheless, most companies show that innovation evolves to 'open'. Development costs should decrease with an increasing interest in wider applications. This development is important for innovation and future growth. Organizations often struggle with the question of where to start. A probable path is: (phased) choices, daring to make mistakes and learning from them. From the research, it is clear that only few innovation cases are the result of co-operation, and when so, at most with the previous or following link in the maritime supply chain. This finding is in line with the claim by Lam and Van de Voorde (2011) that there is limited collaboration or integration in maritime supply chains.

The World Bank (2013) states that “*ports in all countries face continued pressure to handle higher throughput, adapt to larger and more specialized vessels, improve productivity, and adopt new technology and information systems that can meet the increasingly demanding service standards expected by shippers, logistics companies and shipping operators*”. This has an immediate impact on the capacity of the transport network and of seaports, which remain at the centre of logistics chains of modern economies. Innovation has the possibility of increasing the competitive advantage of port-related stakeholders through cluster effects. From the case analysis, it is found that stimulating innovation along the supply chain guarantees a long term balance between costs and revenues, especially when considering innovation in (inland) terminal operators, port users, competing ports, and hinterland operators. The global nature of supply chains also implies that all cases, no matter their geographical location, feature the same characteristics and issues.

Collaboration with external supply chain entities might provide even greater competitive advantage. Supply chain innovation can be important for all port-related stakeholders of all sizes. Nevertheless, innovation generating successful outcomes is usually a complex process involving the interaction of many public and private actors (De Martino et al., 2013). Therefore, collaborative innovation or co-innovation is the way forward for future maritime and port-related innovation development. Co-innovation would be a new form of innovation where the stakeholders' intention is to commonly build up new knowledge and together create opportunities for new collaboration along supply chains. Therefore, it could be claimed that the future lies within market change of Technological, Managerial, Organisational, Cultural nature, which may also support radical innovation as risks (costs and benefits) may be shared amongst co-innovating parties. Especially for small and medium-sized entreprises, which often lack the capacities, including financially, co-innovation will be the only way forward to successful adaptation to changing environments.

6. Conclusions and future research suggestions

Notwithstanding the large body of literature on innovation, few studies have investigated maritime- and port-related innovation projects specifically. This paper contributes to the literature by focusing primarily on maritime- and port-related innovation reseach. The authors reviewed the conceptual innovation typologies in the extant literature which focus on one innovation aspect at a time, neglecting the complex multisided nature of innovation in port-related sectors. This paper proposes an innovation typology for analysing and classifying maritime- and port-related innovation which is built both on the innovation background conditions and the actors involved.

Furthermore, this research is the first to collect 75 international case studies of maritime- and port-related innovation in practice and to conduct a comprehensive evaluation of port-related innovation examples. The focus of the case review on the proposed types of innovation, results in the following main findings: 1) multi-background innovation encompassing the technological, managerial, organisational, and cultural aspects is prevaling in the port-related industry; 2) market change is more common than unit change or business change; 3) the bulk of innovation cases are associated with cargo flow and IT; 4) the majority of the cases are 'incremental' initiatives, not 'radical'ones; 5) more than half of the gathered initiatives are private commercial ones, so 6) the level of sharing is understandably rather of a closed nature.

The research outcomes provide new insights for market players, policy makers, and researchers. The innovation typologies proposed serve as a guide for private and public operators that want to apply or stimulate innovation. Companies are often perceived as conservative when assessing whether to spend on new initiatives or technologies. Governments should consider providing initial funding and launching publicly-funded research and development programmes to lower the cost and risk of starting innovation projects. Also, market players will find opportunties for collaborating with maritime supply chain members in innovation inititatives. The literature and case reviews also assist researchers in understanding port-related innvoation research and practice, as well as stimulating more future studies in this evolving domain.

In this regard, the authors propose the following future research directions. There is room for expanding the geographical scope of cases. The developed typology can be used beyond the port scope from this paper s unveiled by the case review, companies may consider investment return on innovation as a key concern. It would be interesting and valuable to conduct cost/benefit analyses to estimate the value of maritime- and port-related innovation projects; as the strategy of an innovation champion is to reduce costs and obtain first-mover advantage. Comparison among different types of innovation initiatives can be performed to provide reference for actors in making their decisions. Future research can also study the relationship between companies' innovation types and financial performance such as company profit. This is also a way to quantify the value of port-related innovation projects. Moreover, empirical investigation and hypothesis testing are recommended to further analyse actors' behaviour in initiating innovation efforts. As discussed in the above section, co-innovation is the key for future maritime and port-related innovation development. Another suggestion for future research is to frame port-related innovation into supply chain collaboration or integration.

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Annex 1 Detailed findings of literature review per source, alphabetically

Published Research	Application	What is the objective of the study? \ Research question	Methodology	Keywords
Ambrosino et al. (2013)	A hypothetical case with different scenarios	the modelling and comparison of different train loading policies by varying the storage area strategies in order to evaluate them and determine the most effective policy for ensuring quickness and efficiency in the terminal.	Optimisation modelling	Rail import cycle; train load planning; stacking policies evaluation; train load policies evaluation; optimization
Ambrosino et al. (2018)	Italy	examines the effects of rail share of the different planned interventions that are aimed at increasing the rail capacity of port logistics network	Network optimization	External costs; network optimization; cost internalization
Aydogdu and Aksoy (2015)	Turkey	to develop a simulation model to capture the differences between conventional port logistics business and a conceptual model where a hypothetical PCS is in place	existing information exchange processes during the operations in Turkish ports are analysed and a simulation model of these processes is developed using the ARENA simulation program	PCS; simulation model
Chao and Yu (2012)	China	a mathematical model for repositioning containers to ports in East and North China	Mathematical programming	Liner shipping; container repositioning; multi-commodity network
Chen and Liu (2015)		to analyze optimal concession contracts offered by a landlord port authority to competing operators of container terminals	A two-stage game	Concession; container terminal
Colombo, M., Laursen, K., Magnusson, M. and Rossi-Lamastra, C. (2011)	Not Applicable	It provides a background about the relationship between networks and innovation at different levels of analysis.	A methodological review (it is an introduction to a special issue composed of 5 papers).	Networks; innovation; inter- and intra-organisational networks.
Dang et al. (2013)	Computational experiments with numerical examples, and sensitivity analysis	the problem of positioning empty containers in a port area with multiple depots	Simulation; genetic algorithm; stochastic	Empty containers positioning; control policies;
Defilippi (2012)	Port of Callao - Peru	the problem the regulator could not solve was to determine whether the market for "mineral ore stevedore services" at Callao Port was monopolistic or competitive.	(1) A descriptive case study, and (2) The use of cost functions to determine the market structure.	Port Externality; market structure; port regulation.
De Langen et al. (2013)	The Netherlands (port of Rotterdam)	Analyse the award process of the concession for a large container terminal.	(1) A descriptive case study.	Concession; competitive bidding; container terminal; modal split.
Do, N.-H., Nam, K.-C. and Ngoc Le, Q.-L. (2013)	Indochina area	Analyse the conditions for developing a dry port in Indochina area, given the advantage of location with the challenge of competition from neighbouring countries.	A qualitative descriptive study, showing the different multimodal connections and routes.	Dry ports; inland ports; transportation systems; transshipment.
Fancello et al. (2011)	Not Applicable	terminals are having to equip themselves with increasingly accurate analytical and governance tools.	Two algorithms: (1) a dynamic learning predictve based on neural networks (2) an optimisation for resource allocation	Decision support system; containership arrivals prediction; container handling optimisation; neural network; resource allocation; container hub planning
Gharehgozli et al. (2016)		Highlight the recent developments in the container terminals, which can be categorized into three areas: (1) innovative container terminal technologies, (2) new OR directions and models for existing re-search areas, and (3) emerging areas in container terminal research	Literature review	Container terminal; optimization; heuristic; simulation
Golias and Haralambides (2011)	Hypothetical cases	a new mathematical formulation for the berth scheduling problem: to simultaneously minimize the total costs from vessels' late departure and waiting time, and maximize the total premiums from vessels' early departures	Genetic algorithms; metaheuristic optimization	Berth scheduling
Golias, M. (2011)	Simulation experiments	the berth allocation problem as a bi-objective mixed-integer programming problem	Meta-heuristics	Berth allocation; optimization

Published Research	Application	What is the objective of the study? \ Research question	Methodology	Keywords
Hintjens, J. (2018)		describes a conceptual method to identify and quantify the opportunities for cooperation in the hinterland	Origin-destination	Gateway seaport; hinterland; cooperation; modal shift
Iannone, F. (2012)	Campania region - Southern Italy	Investigate the inland multimodal distribution of import/export containers handled at the seaports.	(1) An optimisation model. The objective function to minimise the sum of all container-related generalized logistic costs throughout the entire multimodal port-hinterland network.	Port-hinterland container logistics; interport; customs; extended gateway; total generalized logistic cost; mathematical programming.
Kaveshgar and Huynh (2015)		discusses the genetic algorithm developed to solve the quay crane scheduling problem with time windows (QCSPTW)		marine container terminals; quay crane scheduling; genetic algorithm
Keceli (2011)	Turkey	Effective port administration through an efficient communications for (PCSs).	Qualitative analysis - SWOT analysis & benchmarking .	Port administration; port community; information technology.
Klerides and Hadjiconstantinou (2012)	Scenarios	dual loaded automated guided vehicle (AGV) dispatching problem in container terminals	Mixed-integer programming	Multi-load AGVs; dispatching; combinatorial optimisation
Klopott (2013)	Baltic ports - Polish ports.	Evaluate the Polish ports activities on the marine environment.	An overview of the legislations, environmental performance (water port quality, air, dredging, ballast water, and noise).	Marine environment; Port externalities; environmental management; greenhouse gases.
Kramberger et al. (2018)	Adriatic ports	explores the use of dry ports as a tool of both inter-port competition and potential co-opetition	Port choice model	Port; competition; hinterland; rail; dry port; intermodal terminal; port choice
Lam, J. and Gu, Y. (2013)	Not Applicable	to categorise and analyse earlier research contributions on intermodal container flow optimisation, to identify the research trends and gaps, and to suggest future research directions	Literature review (between 1972 and 2012) of optimisation with mathematical approaches on intermodal container flow.	Intermodal transportation; intermodal network; container flow optimisation; port; hinterland; supply chain; green concern; sustainable development.
Lee et al. (2018)	Ports of Busan, Hong Kong, Shanghai, Singapore	tests the fifth generation port concept and measures port performance	CFPR, VIKOR and PROMETHEE	Asia; simulation; CFPR; VIKOR; PROMETHEE; The fifth generation ports; container ports
Marianos et al. (2011)	Greece	to provide a theoretical framework and an empirical examination of the provision of port e-services through exploratory research	Both a theoretical framework & an empirical analysis.	Port services, new port environment, electronic governance, port e-services, electronic services, online services
Marenco and Cantillo (2015)	Colombian coal terminals	to provide a framework for the evaluation of dust pollution as a result of bulk cargo terminal (BCT) operations	a simplified but comprehensive model of BCT operation	Bulk cargo; terminal; emissions
Min et al. (2017)	Incheon Inner harbor in Korea	propose an integrated terminal operating system that can reduce duplicated investments in equipment, redundant workforce, and non-value-adding processes	Analytic hierarchy process	Terminal; operating companies; global supply chains; analytic hierarchy process; maritime logistics; performance indicators
Monaco and Sammarra (2011)	Hypothetical cases	the quay crane scheduling problem	Heuristics; mathematical modelling	Quay cranes; logistics; crane scheduling; time windows; one-way constraints; spatial constraints; rail-mounted cranes; container shipping
Monios and Wilmsmeier (2013)	Scotland	site development strategies to overcome Scotland's double peripherality (i.e. both physically and institutionally) by restructuring transport chains of large shippers through new corridors	A cross-disciplinary approach combining economic & political geography.	Load centre terminal; port-centric logistics; offshore port-centric logistics
Nam and Song (2011)	Conceptual study.	heterogeneous terminology on the concept of logistics hub to define the concept applicable to the maritime industry by synthesising existing studies/perspectives and examine its possible implications.	A literature review - a synthesis of studies and implications.	Hub-and-spoke; logistics hub; distribution models.

Published Research	Application	What is the objective of the study? \ Research question	Methodology	Keywords
Olivo et al. (2013)	A hypothetical case	to describe how shipping companies perform this complex activity and its links with truck routing problems and the repositioning of empty containers on maritime networks.	A time-extended optimization model	Inland repositioning of empty containers
Osthorst and Mainz (2013)	Northwest Germany	approaching the fierce competition among European north range ports from an action- and power-oriented perspective	Literature review	Competition; port; climate change
Pagoropoulos et al. (2017)	A shipowner case study	The digitization of business processes institutionalises digital capabilities within traditional customer organisations, which in turn reveal opportunities for procurement and codevelopment of Product-Service Systems	Action research	Product-Service Systems; Digitization; Customer; Maritime industry
Sharif, O. and Huynh, N. (2013)	A hypothetical case	Assessing the performance and factors for the yard crane scheduling problem for centralised and decentralised.	A comparative study.	Multi-agent systems; optimization; yard crane scheduling
Thai, V. (2012)	Vietnam/Singapore	to draw important managerial insights about the design and implementation of human resource development policy for ports	A conceptual model of competencies constructed based on thorough literature review and in-depth interviews and validated by a survey with port personnel	Competency requirements, human resource development, port personnel, port efficiency, shipping logistics, supply chain management, flow management, competencies
Van der Horst and Van der Lugt (2011)	Port of Rotterdam	to provide insight into the patterns and conditions of the emergence of different coordination arrangements that improve hinterland accessibility	Employing the Transaction Cost Economics theory.	Hinterland accessibility; Transaction Cost Economics; coordination; port competition.
Veenstra et al. (2012)	The Netherlands (port of Rotterdam)	Supply chain and transportation network integration by extending the sea terminal gate into the hinterland explores the relationship between the extended gate concept and the better known concept of dry ports.	Qualitative business case.	Extended gate; intermodal; container terminals; ECT
Vojdani et al. (2013)	A hypothetical problem	to introduce a mathematical optimization approach, which optimizes container logistics networks and quantifies potential savings considering the establishment and operation of container pooling.	Optimization approaches	Empty container management; empty container logistics; container pooling; maritime container logistics networks collaborative container management
Wang et al. (2018)	Tianjin Port	to optimize the location of dry ports	Quantitative model	Container; dry port; location; logistics; quantitative model
Wei et al. (2015)		to studies a logistics network connecting the inland regions by dry ports	A two-stage logistical gravity model	Belt and Road Initiative; the Silk Road Economic Belt; the 21st-century Maritime Silk Road; dry ports; gravity model
Yang (2013)	East Asian region	the role of international port logistics centres (IPLCs) is becoming increasingly important. To improve customer satisfaction and service value, emphasis is increasingly placed on providing feasible solutions for IPLCs.	Fuzzy quality function deployment	Customer satisfaction; port logistics centres; service value
Zeng et al. (2018)		to model for quay crane dual-cycling scheduling	A mixed integer programming model	Container terminals; quay crane dual cycling; bi-level genetic algorithm;
Zhao and Goodchild (2013)	Various configurations	considers the effectiveness of a truck appointment system in improving yard efficiency in a container terminal.	A hybrid approach of simulation and queuing theory.	Simulation optimization
Zhang et al. (2018)		propose an empty container repositioning model in the intermodal transportation network of Belt and Road (B&R) Initiative by considering both standard and foldable containers	A mixed integer linear programming model	Belt and Road Initiative; empty container repositioning; intermodal transportation; foldable container; artificial bee colony algorithm

Annex 2: Overview of selected innovation cases per stakeholder

Innovation @ shipyard

Dynamic Operation in Dredging and Offshore
Dredge pumps
Flexible spud wagon
Wild dragon

Innovation @ deepsea terminal

Advanced Gate Automation
Administration replaced by EDI
Inland terminal
Automated Stacking Cranes
Weighbridges
Tandem lift operations
Straddle carriers from diesel to CNG
Truck Appointment System
Container terminal: bottleneck @ land side
Vado Ligure "Port gate"
Autotrakker
E-freight system "E-port"
Terminal carbon footprint tracking
Port community system PORTNET

Innovation @ carriers

E-transit
E-gate 1.0 and 2.0
Carbon footprint assessment
S-BEND on LPG carriers

Innovation @ stevedoring

Central port community system for break-bulk sector
Setting up of KVBG
Heavy cranes
Vans from diesel to CNG
All-weather terminal (NL)
All-weather terminal (BE)
All-weather terminal (ES)
All-weather terminal (FI)

Innovation cases @ port authorities

Offshore Single Point Mooring
3PL - Primary Gate of Leixões Port
Port Single Window
Carbon footprint assessment of port of Piraeus
SEAGHA
APCS

Innovation @inland terminal

Paperless Customs flow: import - extended gate up to the end consumer
Paperless Customs flow: import - paperless NCTS pilot (Port of Antwerp)
Paperless Customs flow: Export - paperless until deep-sea terminal
Expansion OCR capabilities
Portal with clients
Pre-notification deep-sea terminals ROTTERDAM
Pre-notification deep-sea terminals ANTWERPEN
Port Wide Lighter Schedule Port of Antwerp
Barge slots
Corridor management system
Digital CMR
Empty equipment
Transferium
CY Meerhout
Efficiency leadership program

Innovation @ inland operators

Urban distribution using navigation water ways (goods)
Barge heavy lift Ro-Ro hybride
Urban distribution using navigation water ways (vehicles)
Pallet shuttle barge – PSB
Small Barges and reactivation of small inland waterways

Innovation @ transport modes

ECO Combi
Transport hub
Platform EuroTransCon (import export + re-use)
Vanhool ECO Chassis
CNG Class 8 Heavy Duty Drayage Truck

Other innovations

Metrocargo
10’6” ft. container
SEA45
Modal shift (Beerse)
Modal shift (Beverdonk)
Foldable container
Bulk carrier self-loading/unloading cranes
IT data management
Emission Scrubber on APL containership

Annex 3: Industry Sectors and Stakeholders Involved

Industry sectors	
Shipyard	IHC (The Netherlands)
Carriers	MSC Belgium (Belgium), NOL (Singapore), Star bulk (Greece), Eltsons (Greece), APL (United States of America)
Port Authorities	Porto petroli di Genova (Italy) and Ports of Sines (Portugal), Lisboa and Leixões (PT), Piraeus Port Authority (Greece), Port of Antwerp (Belgium)
Terminals operators	DP World (Belgium), APMT (Italy), AET (Belgium), Terminal Bruzzone (Italy), Jurong Port (Singapore), PSA (Singapore)
Stevedoring	Wijngaardnatie (Belgium), Zuidnatie (Belgium), Waterland (The Netherlands), Gruppo Nogar (Spain), Port of Kokkola (Finland)
Barge operator	CTF (France), Blue line logistics (Belgium), UA research: small barges (Belgium)
Inland terminal	BCTN (Belgium)
Road operator	Transport Joosen (Belgium), Calcartage (United States of America)
Other	Caru container (The Netherlands), Chartwold Shipping Corporation (Greece) Software developer consultant (Portugal)
Logistics	Arcelor Mittal Logistics (Belgium)
Rail operator	Metrocargo (Italy)
Forwarding agent	ACB agency (Belgium)
Shippers	Metallo (Belgium), Nike (Belgium - validation)…
Customs	Ports of Sines (Portugal), Lisboa and Leixões (Portugal)
Container broker agency	Caru container (The Netherlands)
Research	UA (Belgium)
Software	Software developer consultant (Portugal), Software houses (Belgium)
Shipping corporation	Chartwold Shipping Corporation (Greece)

Source: Sys et al., 2015