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Digital Innovation in the Port Sector: Barriers and Facilitators

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Abstract

Digital innovation changes industry as a whole, and gradually also the port sector. The present paper examines in detail 32 ICT innovation cases collected between Autumn 2013 and Spring 2015. Leading actors along the maritime supply chain were asked to indicate the importance and to assess the degree of the success achieved in each ICT innovation initiative, to identify the driving forces behind the adoption of innovation and

to denote the associated costs and benefits. This input allows identifying the barriers of digital innovation from initiation through to implementation, as well as assessing the impact of facilitators of ICT innovation. To do this, the present research combines four quantitative instruments. The added value of this combined approach is a deeper understanding of the digital innovation process within the port sector.

The research firstly indicates that alignment exists between company strategies and success degrees in the port sector, in contrast to non-ICT initiatives. The ICT innovation initiatives also are profit-driven. Secondly, the port sector should be more open to disclose cost and benefit info, and should conduct more such analyses. Next, there are conditions that improve the degree of success. Overall, terminal alignment with the right ICT infrastructure proves key. However, too many divergent interests among the stakeholders entail that digital innovation challenges the ability to cooperate. An important finding: regulation was not identified as a barrier nor as a facilitator.

Key words: Digital innovation, Information and communication technology, barriers and facilitators, port sector, port-related actors

1. Introduction

Digital innovation changes industry as a whole, and gradually also the port sector. Under digital innovation, combinations of information, computing, communication, and connectivity technologies are considered ¹. The port sector can also expect cost savings, increased quality and further growth by implementing digital innovation. However, the speed at which digital innovation is reshaping the port sector is lower than in other industries. Given the trend towards collaborative innovation in the maritime supply chain, the question becomes what are the barriers, who has a facilitating role, and whether there is a role for regulation? That is the main research question that this paper answers for digital port-related innovation.

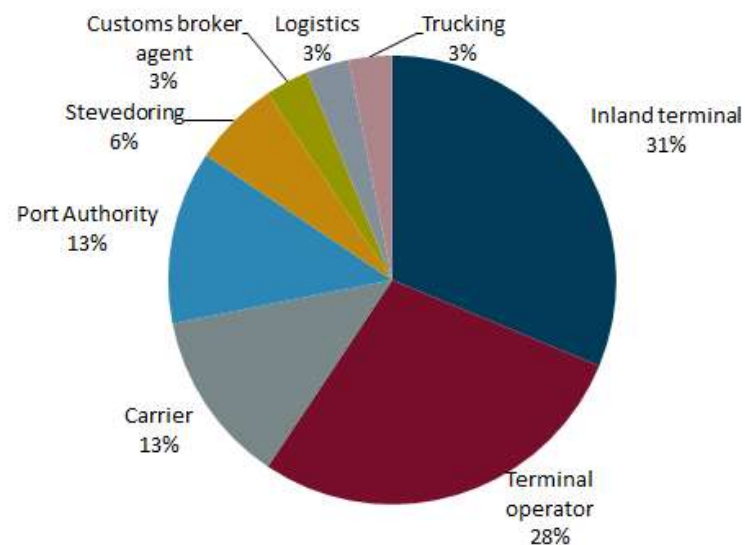
Three applications may be considered the key innovation domains in the port sector with respect to digital technology: electronic data interchange innovation, applications concerning the monitoring of vehicles and cargo, and those supporting cargo flow. While similar in scope, their responsibility and leadership lies in different entities. The majority are initiated by the port or hinterland terminal operator (Figure 1). The collected innovation initiatives have heavily relied on advancements in ICT technology, offering opportunities and improving efficiency for actors along the maritime supply chain.

The current research is based on 32 cases studies with five case studies as to IT innovation supporting the cargo flow, six initiatives concerning monitoring of vehicles and cargo, and 21 cases of electronic data interchange (information flow) collected within the context of research conducted with the financial support of the BNP Paribas Fortis

¹ A Bharadwaj and others, 'Digital Business Strategy: Toward a next Generation of Insights.' (2013) 2 Mis Quarterly 471.

Chair on Transport, Logistics and Ports at the University of Antwerp by researchers from the Universities of Antwerp, Lisbon, Genova, Aegean, Hamburg, Singapore and Los Angeles / Long Beach, collected between Autumn 2013 and Spring 2015 from 14 entities located in different countries.

Figure 1: Overview of industry actors involved



Source: own composition

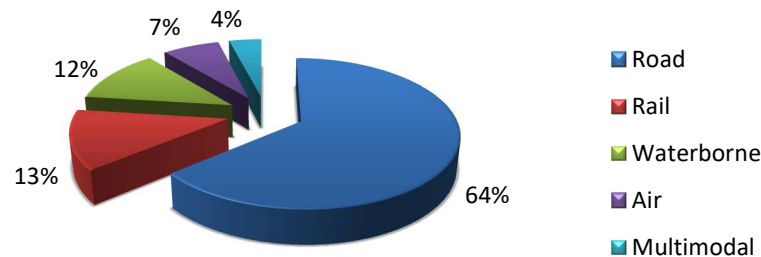
A key feature of the methodology applied is the fact that it combines four approaches to provide in combination the key factors influencing successful implementation. Each analysis is focused on the particular aspects of the decision to adopt innovation and the factors and actors influencing implementation.

The structure of the paper is as follows. Section 2 reviews the relevant literature regarding digital port innovations. Section 3 discusses the methodology applied. Section 4 briefly describes the collected data. The results of the combined approach are discussed in Section 5. Section 6 elaborates on joint lessons from the four approaches for ICT-related port innovation. Section 7 concludes on the findings.

2. Literature review focusing on digital port innovation.

Technology has evolved rapidly in the last decade and ICT developments are well established in contemporary businesses processes. ICT applications have an advantage when it comes to the variety of services they can provide. Tyrinopoulos *et al*², by listing 70 European ICT transport related applications, create a diagram of intelligent transport systems deployment by mode of transport (**Error! Reference source not found.**). Their sample focused on mature market products across Europe, and specifically excluded industry non-validated research outcomes, prototypes and non-implemented ICT solutions. They suggest that road transport has a marked advantage, but the other transport modes are currently closing the gap.

Figure 2: **ICT applications distribution by transport mode**



Source:³

The transport sector has started to develop ICT solutions over 30 years ago and is expected to continue even more after 2020⁴. A short overlook at the dedicated literature shows that the terminology used for ICT transport solutions evolved from telematics

² 'A Critical Overview of ICT Deployment in Transport in Europe' in N Thomopoulos, M Givoni and P Rietveld, *ICT for Transport: Opportunities and Threat* (Edward Elgar Publishing 2015).

³ *ibid.*

⁴ D Mohr and others, *The Road to 2020 and Beyond. What's Driving the Global Automotive Industry?* McKinsey & Company (Inc 2013).

provided for road transport to contemporary smart/intelligent solutions that make use of Cloud computing, Internet of Things or Big Data analyses ⁵. These solutions are ICT applications that address the problems that arise in all transport modes.

Literature shows that the main reasons behind the investment decision in transport ICT developments are three. Firstly, cost reduction and improvement of the service level are the most important elements in the ICT investment decision (⁶. Secondly, the transport process control and monitoring enhancement is another important element in the adoption of ICT concepts ⁷. Lastly, safety and security improvement is another reason why the transport sector also invested in digital innovation (⁸. Similarly, ⁹ enumerate a number of coordination arrangements in hinterland transport to and from the port and give communication platforms a prominent position.

⁵ Nicos Komninos, *Intelligent Cities: Innovation, Knowledge Systems, and Digital Spaces* (Taylor & Francis 2002); Emily Moir, Tim Moonen and Greg Clark, *What Are Future Cities?: Origins, Meanings and Uses* (Government Office for Science/Future Cities Catapult 2014) <http://www.demonish.com/cracker/1431189491_d2c2230ea5/14-820-what-are-future-cities.pdf> accessed 20 May 2016; Magda Pitsiava-Latinopoulou and Panagiotis Iordanopoulos, 'Intermodal Passengers Terminals: Design Standards for Better Level of Service' (2012) 48 *Procedia-Social and Behavioral Sciences* 3297.

⁶ Rajesh Piplani, Shaligram Pokharel and Albert Tan, 'Perspectives on the Use of Information Technology at Third Party Logistics Service Providers in Singapore' (2004) 16 *Asia Pacific Journal of Marketing and Logistics* 27; Shaligram Pokharel, 'Perception on Information and Communication Technology Perspectives in Logistics: A Study of Transportation and Warehouses Sectors in Singapore' (2005) 18 *Journal of Enterprise Information Management* 136; Pietro Evangelista and Edward Sweeney, 'Technology Usage in the Supply Chain: The Case of Small 3PLs' (2006) 17 *The International Journal of Logistics Management* 55.

⁷ Kenneth Button, Elly Doyle and Roger Stough, 'Intelligent Transport Systems in Commercial Fleet Management: A Study of Short Term Economic Benefits' (2001) 24 *Transportation Planning and Technology* 155.

⁸ Zhicai Juan, Jianping Wu and Mike McDonald, 'Socio-Economic Impact Assessment of Intelligent Transport Systems' (2006) 11 *Tsinghua Science & Technology* 339.

⁹ Martijn R Van Der Horst and Peter W De Langen, 'Coordination in Hinterland Transport Chains: A Major Challenge for the Seaport Community' (2008) 10 *Maritime Economics & Logistics* 108.

In addition to costs, geographical location and services ¹⁰, digital innovation will be an important parameter with respect to port competition. In the present paper, the term ‘digital innovation’ refers to new ICT developments in the port sector and more specifically to communication platforms that facilitate the exchange and management of information, IT developments that help the cargo flow and technological advancements that monitor the equipment or cargo. The enhanced sharing of information between port stakeholders regarding cargo, the preannouncement of vessel/vehicle arrival at ports/terminals or the secure electronic transfer of official documents are only a few examples of ICT innovation in this sector.

Digital innovation arises in a multidisciplinary context. Its development requires the contribution of at least two types of stakeholders, an expert in a specific field where innovation is to be implemented and an IT expert. In this context, ¹¹ map out the types of interaction between different actors, that contribute to the creation of digital solutions for smart cities. Moreover, a further step is made by ¹² who point out the necessity of a regulatory framework for the ICT market in Europe. Having these elements as critical contributors to the creation of ICT developments, it is clear that a strong cooperation between multiple stakeholders is a necessary pre-requisite to digital innovation uptake. The services provided by the port sector and maritime supply chains imply an increased

¹⁰ Hilde Meersman, E Van De Voorde and T Vanelslander, ‘Port Competition Revisited’ (2010) 55 *Review of Business and Economic Literature* 210.

¹¹ Hans Schaffers and others, ‘Smart Cities and the Future Internet: Towards Cooperation Frameworks for Open Innovation.’ (2011) 6656 *Future internet assembly* 431.

¹² Pieter Ballon and Eric Van Heesvelde, ‘ICT Platforms and Regulatory Concerns in Europe’ (2011) 35 *Telecommunications Policy* 702.

use of ICT platforms replacing traditional business models.¹³ highlight that vertical cooperation is a trend in the development of future maritime supply chains. In this regards, seaport ICT innovation enhances communication between actors involved in the same supply chain. Moreover, the most important goal of ICT platforms implemented in the seaport environment is optimizing the port's infrastructure capacity usage. While in the past, ports were confronted with excess capacity, contemporary ports are reaching their capacity limits¹⁴. Therefore, IT platforms are also implemented to assist seaports in their daily operations and to reduce congestion.

Stakeholders active in the port sector have understood that communication is very important and are establishing ICT collaboration platforms offering competitive advantage. An understanding of the costs and benefits of such platforms is required.

Carlan *et al* (2016) develop a conceptual framework for the quantification of the costs and benefits incurred by the actors involved in a port community system (PCS). Using this framework, they show that the port stakeholders adhering to this kind of collaboration might have a better competitive advantage.

In sum, ICT innovation encourages the maritime supply chain stakeholders to integrate their operational activities. As¹⁵ state that "on a long term, developers needed to focus on system integration software and process creating standards". In the maritime supply

¹³ Eddy Van de Voorde and Thierry Vanelslander, 'Trends in the Maritime Logistics Chain : Vertical Port Co-Operation : Strategies and Relationships' (University Press Antwerp 2014) <<http://anet.be/record/opacirua/c:irua:120019>>.

¹⁴ Hilde Meersman, Eddy Van De Voorde and Thierry Vanelslander, *Port Infrastructure Finance* (Routledge 2014); Yasmine Rashed, 'Container Throughput Modelling and Forecasting : An Empirical Dynamic Econometric Time Series Approach' (University of Antwerp 2016).

¹⁵ Petri Helo and Bulcsu Szekely, 'Logistics Information Systems: An Analysis of Software Solutions for Supply Chain Co-Ordination' (2005) 105 *Industrial Management & Data Systems* 5.

chain, proactive terminal gate-appointment systems are integrating the schedule of trucking companies with the terminal's infrastructure planning, and vice-versa. Opening collaboration opportunities for stakeholders that are in competition is the next challenge of seaport ICT platforms deployment. Here, the practice is to be noted of different trucking companies using the same ICT platform to exchange information regarding their transport tasks and sharing free capacity or different terminal operators active in the same port, and using the same data exchange platform for submitting customs documents. Therefore, ICT innovation in port activity, in general, is developed by a closed group of actors and is later used by a wider community.

The above literature observations are the basis for the further analyses in this paper. The next section presents the four approaches used in these analyses.

3. Methodology

A multiple analysis approach is followed in this research. Cases are first assessed on the degree to which they contribute to the achievement of particular business objectives, which, apart from strictly economic objectives, also include environmental and social objectives as imposed through regulation or the social responsibility of the company to comply with current and future institutions. To this end, thirty-four objectives are listed and scored on their importance for each case, and subsequently, the degree of compliance with the specific objective is measured. This way, an overall compliance score towards relevant objectives can be calculated per case, distinguishing among three main categories of objectives: economic, social and environmental.

Second, recommendations are made towards a cost and benefit analysis that may or may have not been conducted with respect to the application of the particular case studied.

Third, a fuzzy set Qualitative Comparative Analysis (fsQCA) is conducted, which identifies factors and actors that are important in reaching the expected results. The analysis checks for eight factors related to the system of innovation:

- Infrastructure: the physical and virtual infrastructure that actors need for functioning.
- Transition: the process through which firms adapt to new technological developments.
- Lock-in/path dependency failures: the inability of complete (social) systems to adapt to new technological paradigms.
- Hard institutions: the framework of regulation and the general legal system in support (or not) of the development of a new application.
- Soft institutions: the social institutions such as political culture and social values that support or hinder the uptake of the innovation.
- Strong networks: the support (or not) to new paradigms that evolves or is hindered if actors have close links.
- Weak networks: the support (or not) to new paradigms due to the weak linkages between actors that may allow progress or limit interactive learning and creating new ideas.
- Capabilities: firms, especially small and medium-sized firms, may lack the capabilities to learn rapidly and effectively, also including financial capability.

For each innovation initiative, the relevant actors are identified.

Finally, building further on the previously mentioned factors, linkages between actors are analysed qualitatively through the Systems of Innovation approach. Here, additional factors are also considered. These include: market demand (push or pull) and competition, between ports and also from other innovation initiatives that aim at achieving similar efficiency gains. A number of hypotheses are tested, including the importance of (i) capabilities (external knowledge and financing); (ii) the accord of all actors involved; (iii) market push and (iv) the ability of the innovation champion to influence actors and outcome.

The combination of the four approaches sheds useful light on the factors that stimulate or hinder port-related digital innovation. In particular, the need for infrastructure

standardization and regulation, and the dominance of certain players through hard-institutional (e.g. regulation) or soft-institutional (e.g. actor culture) issues or strong or weak networking are brought to light.

A detailed description of the four above-mentioned methods is available through ¹⁶. The next section provides an overview of the cases to which the four approaches will be applied.

4. The digital port innovation cases

Over the 2013-2015 period, data was collected on 75 innovation cases ¹⁷. Given that leading companies along the maritime supply chain put digital innovation high on the agenda, the thirty-two innovative concepts are singled out for further analysis. The analysis concerns the cases listed in Table 1. Notably, approximately 50% of the innovation cases in total collected concern ICT applications, implying the importance of this category of innovation for the port sector. The cases used in this paper can be grouped according to the three categories mentioned in section 1: EDI, monitoring and cargo flow support. Communication in the maritime sector has become crucial for the optimisation of operations. The category ‘Electronic data interchange’ focuses on barriers and success/failure orientated to paperless administration process. New technologies are being used, standardisation has materialized and information flows faster. Regarding IT innovation supporting cargo flow, five innovation cases are analysed. Differently from the previous category, the second cluster focuses on innovations that are enhancing the

¹⁶ Christa Sys and others, ‘Port Related Innovation: The Answer to Today’s Constraints and Challenges in Seaports Related Operations’ (2016) in review.

¹⁷ Christa Sys, Thierry Vanelslander and Valentin Carlan, ‘Innovative Concepts in the Maritime Supply Chain’ (2015) 50 p.

cargo flow. Intelligent traffic optimisation solutions, for both freight and vessels, are being compared. Moreover, mobility and delivery times are targeted as key factors that should be improved by computer-assisted planning solutions. The main goals of these initiatives are to optimize the traffic, to develop a planning algorithm and to avoid conflicts on navigational ways. The third category brings together innovations which are focused on better monitoring vehicles and cargo. Having extra information is a key asset in contemporary management systems, but collecting and delivering information without purging the goods flow must be achieved. This category contains initiatives, which have not as their initial goal to enhance cargo movement or the information flow. The current group of innovation initiatives puts forward the benefits of keeping a close look on the operations which are ongoing within the supply chain.

Table 1: Overview of innovative cases¹⁸

Electronic data interchange innovation (information flow)	IT innovation supporting the cargo flow	Monitoring innovation - vehicles & cargo
IV Administration (EDI)	III 3PL - Primary Gate of Leixões Port	IV Advanced Gate Automation
IV APCS	III Container terminal: landside	IV Autotrakker
IV APCS case: central port community system for breakbulk (initiative from the port community)	III Corridor management system	IV BCTN Portal with clients
IV Central port community system for breakbulk (initiative from the association of Traffic Flow Controllers)	IV Port Wide Lighter Schedule Port of Antwerp	IV Platform EuroTransCon (import export + re-use)
IV Digital CMR	III Vado "Port gate"	IV Truck Appointment System
IV E-freight system "E-port"		I Weighbridges
IV eTransfer		
IV eTransit (prior to the Extended GATE)		
IV Expansion OCR capabilities		
IV Extended-GATE 1.0		
IV Extended-GATE 2.0		
IV Extended-GATE 3.0		
IV IT data management		
IV Paperless Customs flow: import - extended gate up to the end consumer		
IV Paperless Customs flow: import - paperless NCTS pilot (Port of Antwerp)		
IV Paperless Customs flow: Export - paperless until deepsea terminal		
IV Port community system Portnet		
IV Port Single Window		
IV Pre-notification deepsea terminals ANTWERPEN		
IV Pre-notification deepsea terminals ROTTERDAM		
IV SEAGHA - port community system		

I = Technological - unit change, II Technological - market change, III Technological, Managerial, Organisational, Cultural – Business Change, IV Technological, Managerial, Organisational, Cultural - Market Change, V Managerial, Organisation, Cultural - Market Change, VI Policy Initiatives (Managerial, Organisation, Cultural – Market Change)

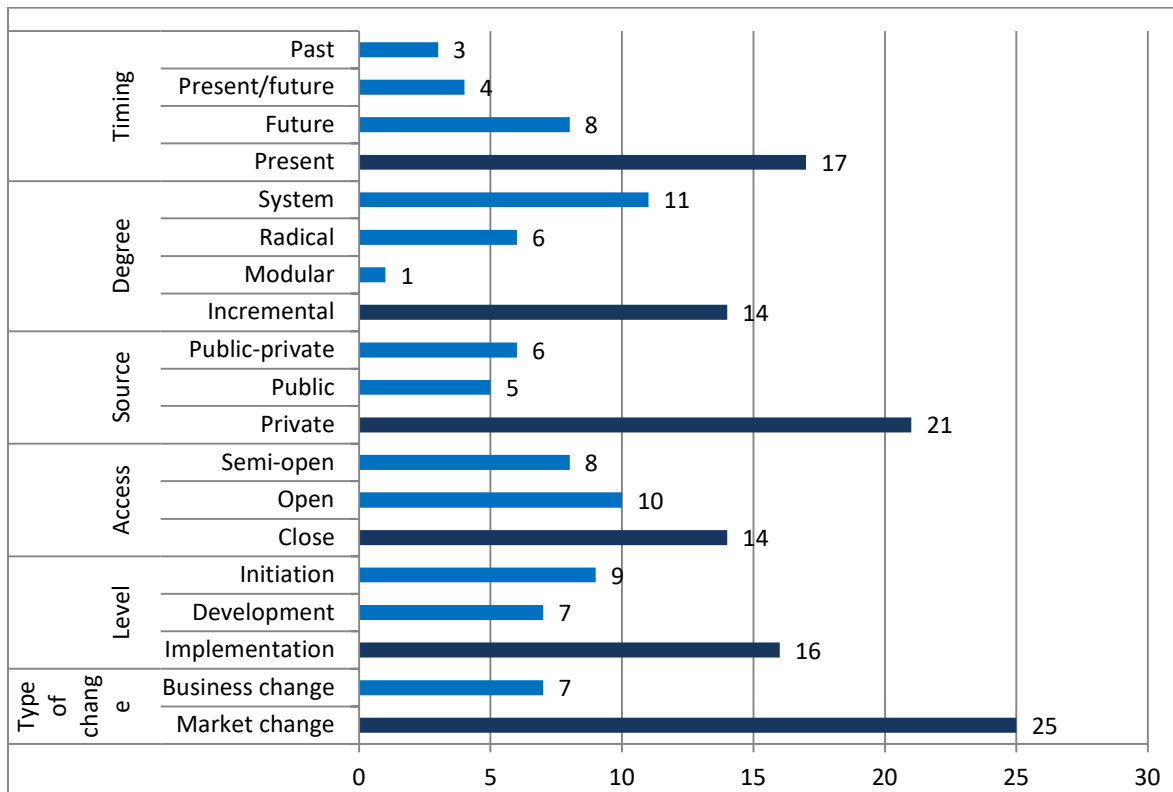
¹⁸ For an description: see Sys, Vanelslander and Carlan (n 17)

Figure 3 gives an overview of the case set statistics according to different innovation typologies. The mainstream of these cases are examples of ‘incremental’ innovation¹⁹, i.e. innovative projects that build on existing practices. Furthermore, the majority of these initiatives are instances of private commercial innovation. Of this sub-set of cases, the majority (14) were found to be closed innovations²⁰, with either a market change (25) or a business change impact (7).

Figure 3: Case Descriptive Statistics

¹⁹ The term ‘incremental’ corresponds to a small change to existing products/procedures, ‘system’ to multiple independent innovations, ‘modular’ to a significant change in concept within a component while ‘radical’ indicates a breakthrough in the specific field.

²⁰ ‘Open’ innovation refers to exchanging knowledge with the external environment; while ‘closed’ refers to the tendency to keep innovation activities within the firm or cluster of firms. Thierry Vanelslander and others, ‘Typology and Case Review for Port-Related Innovations’ (2016) Transport Review.



Source: own *composition* based on Sys *et al.* (2015)

5. Identifying the strategies, barriers and facilitators

The analyses followed are complementary and inter-linked. The results of each approach will be discussed individually, with a dedicated section for each. Section 5.1 determines whether the innovation cases align with the companies' strategies and the level of alignment. Then, in section 5.2, cases are viewed with respect to their Cost – Benefit analysis. Notably, apart from the level of alignment with company strategies, the adopted innovation should be ex-ante efficient and its feasibility validated. The analyses that follows, the fuzzy set Qualitative Comparative Analysis (fsQCA) and the Systems of Innovation (SI), consider that the innovation is economically justified. FsQCA in section 5.3 looks for the combination of actors and conditions leading to better results. Finally, the Systems of Innovation approach in section 5.4 determines whether basic concepts are valid, through pattern recognition.

5.1 Alignments between company strategies and degree of success

With respect to the first methodology, developed by Acciaro, *et al.*²¹, leading actors along the maritime supply chain evaluated the level of importance and the degree of the success achieved in each innovative ICT initiative with values from 1 to 5²². The triple bottom line approach is adopted to highlight the achievements of ICT innovation on three layers: economic, environmental and social added-value²³ (Acciaro & Sys, 2017).

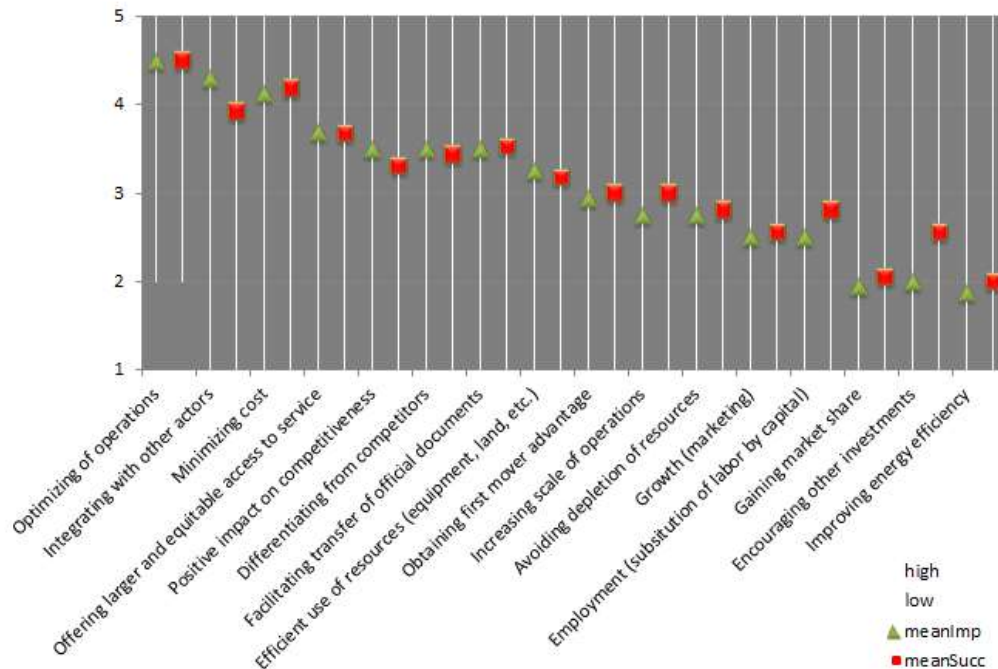
Figure 4 shows the economic objectives that have been evaluated. The main economic objectives are optimizing operations, integrating with other actors and cost minimization. With respect to the most important objective, both outputs (importance ('meanImp') and success ('meanSucc')) show lesser variation or higher consensus. In general, the results of this exercise indicate that there exists alignment between company strategies and degrees of success. Extra effort is required to improve the strategic process leading to integration with other actors; while there is clearly a win for the objective 'cost reduction'. With respect to the least important objectives, figure 4 indicates that higher success is achieved. Such incidental success is clearly observable with respect to the objective 'encourage other investments' referring to ICT innovation generating already new ideas during the development phase (e.g. consecutive versions of the case "Extended gate").

²¹ 'Environmental Sustainability in Seaports: A Framework for Successful Innovation' (2014) 41 Maritime Policy & Management 480.

²² For the level of importance, the ranking choices were 1: irrelevant, 2: slightly relevant, 3: moderate relevant, 4: relevant, 5: very relevant; while the degree of success was evaluated as follows 1: unsuccessful, 2: slightly successful, 3: moderate successful, 4: successful, 5: very successful.

²³ Acciaro M and Sys C, Innovation along the maritime Supply Chain: Aligning Strategy with Outcomes. Maritime Policy and Management (in review)

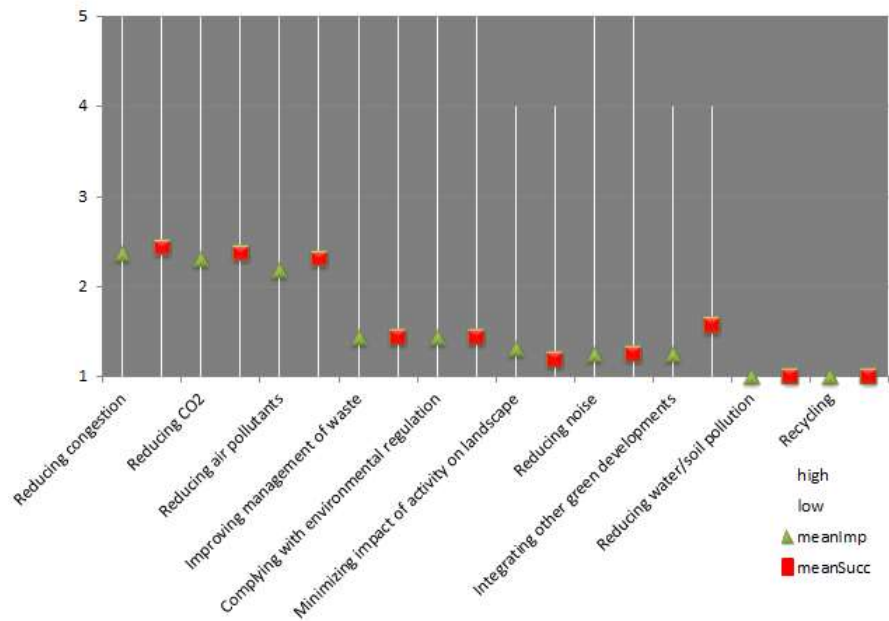
Figure 4: Economic objectives: importance versus success



Source: Own composition based on Sys *et al.* (2015)

The ranking of results regarding environmental and social value is provided by the Figures 5 and 6 respectively. A first observation concerns the lower ranking (below 3) of the environmental and social objectives in comparison with the economic objectives as found in figure 4. Notably these company objectives are mostly connected with regulations or the need to comply with future ones. Furthermore, Figure 5 shows that ICT innovation cases have been more successful in achieving objectives like reducing congestion, reducing CO₂ and air pollutants. Among the objectives listed under the category ‘social objectives’, ICT innovation concepts target the objective ‘reduction of fraud attempt’ which they are also successful in.

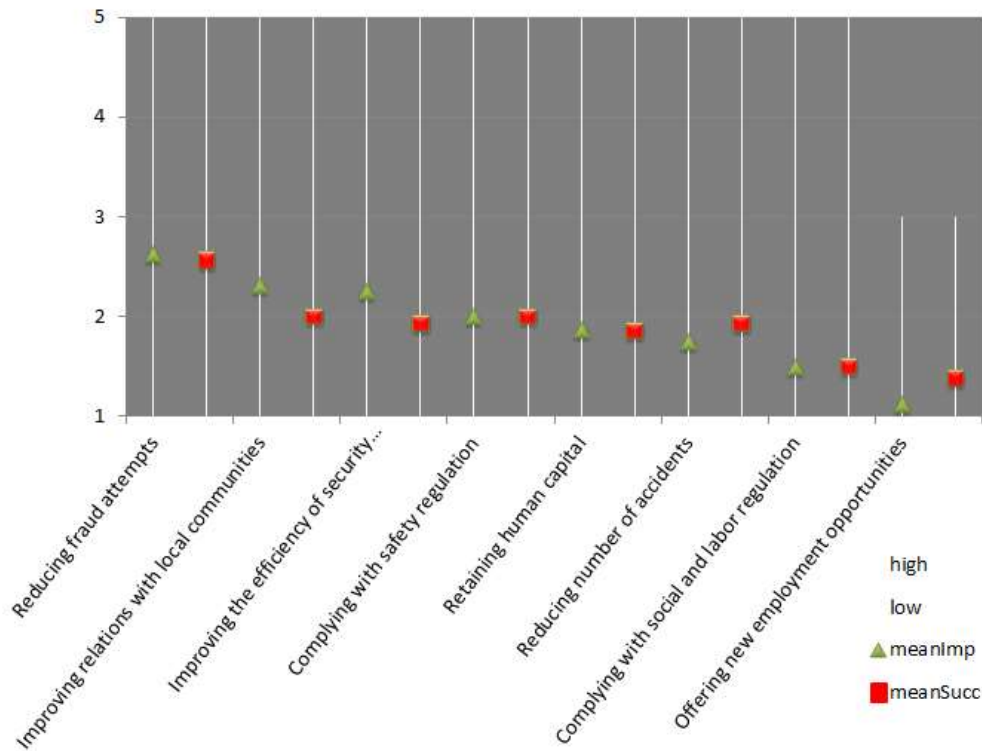
Figure 5: Environmental objectives: importance versus success



Source: Own composition based on ²⁴

Figure 6: Social objectives: importance versus success

²⁴ Sys, Vanelslander and Carlan (n 17).



Source: Own composition based on Sys *et al.* (2015)

5.2 Cost/benefit-based decisions

The second quantitative instrument is the Cost-Benefit Analysis (CBA). Examining the full data set, Giuliano *et al.*²⁵ concluded that no projects performed a comprehensive cost benefit analysis. This also applies to the ICT innovative initiatives. Because it does not involve public funding, projects mandated to reduce externalities via regulation, or major projects that include consideration of multiple alternatives, the port sector sees no need to conduct a cost-benefit analysis or cost-effectiveness assessment. Another reason cited is that it is difficult to monetize accurately the full range of benefits from such innovation

²⁵ 'Decision-Making for Maritime Innovation Investments: The Significance of Cost Benefit and Cost Effectiveness Analysis' (University of Antwerp 2016) Working paper <<https://www.uantwerpen.be/images/uantwerpen/container1244/files/TEW%20-%20Onderzoek/Working%20Papers/RPS/2016/RPS-2016-001.pdf>>.

initiatives ²⁶ Carlan, Sys, & Vanelslander, 2016). Hence, Giuliano *et al.* ²⁷ developed a framework to categorize the innovation initiatives as either:

- 1) an internal decision made by the company for its own profit or efficiency motives;
- 2) an internal decision but influenced by external forces that created incentives or disincentives for the company; or
- 3) a response to a significant level of public subsidy or regulation.

In the case of ICT innovative concepts, a concrete problem (e.g. reducing dwell time, avoiding congestion at terminal gate, moving from paper to paperless, etc.) often lies at the root of the investment decision of the private innovators. For such a specific problem, the individual stakeholder cooperates with a software developer. Next, each innovation was categorized according to the framework for decision-making, as illustrated in Table 2.

²⁶ *ibid.*

²⁷ *ibid.*

Table 2: Framework for decision-making

1 Internal decision, no external incentives or disincentives	2 Strategic internal decision, external incentives or disincentives, no public subsidies or regulation	3 Responsive decision to public subsidies or regulation (responses to subsidies different from responses to regs)	
Administration	SEAGHA - port community system	IT data management	APCS
Advanced Gate automation	3PL - Primary Gate of Leixões Port	Paperless Customs flow: Export - paperless until deepsea terminal	APCS case: central port community system for breakbulk (initiative from the port)
BCTN Portal with clients	Central port community system for breakbulk (initiative from the association fo Traffic Flow Controllers)	Paperless Customs flow: import - extended gate up to the end consumer	E-freight system "E-port"
Container terminal landside	Corridor management system	Paperless Customs flow: import - paperless NCTS pilot (Port of Antwerp)	Port Wide Lighter Schedule Port of Antwerp
Autotrakker	Digital CMR	Platform Eurotranscom (import export + re-use)	
OCR capabilities	eTransfer	Port community system Portnet	
Truck appointment system	eTransit (previous to the extended gate)	Port Single Window	
Vado "Port Gate"	Extended-GATE 1.0	Pre-notification deepsea terminals ANTWERPEN	
	Extended-GATE 2.0	Pre-notification deepsea terminals ROTTERDAM	
	Extended-GATE 3.0		

Source: own composition based on ²⁸

From Table 2, initially, it is noted that relatively few innovation initiatives are initiated as a response to regulation or subsidies (4 over 32 cases). These are cases where a port or hinterland terminal operator is at the basis of the decision process aiming at accurate data entry. Equally, few (8 over 32) are initiated to improve efficiency independent from external influences (encouraged by port authorities / associations offering free web-applications). On the contrary, the majority of the innovation cases have been initiated as a response to external incentives and the need to address competition.

Stakeholders along the maritime supply chain should embrace new ICT applications with a more proactive attitude towards innovation, particularly the small and medium-sized companies. The latter is in line with non-ICT innovation projects.

²⁸ Sys, Vanelslander and Carlan (n 17).

5.3 Fuzzy set Qualitative Comparative Analysis

According to the third approach, fsQCA, the entire set of conditions together does not seem to lead to a unique combination that systematically leads to success. Equally, including the open or closed nature of the innovation as a variable does not add to changing the consistency of combinations. Hence, a split is made according to logical subsets of variables²⁹. Of all possible subsets, four combinations of selected variables appear to have reasonable consistency of success rates.

A first grouping of the conditions that features some consistency in success is related to the terminal: the latter's alignment with infrastructure, both at the level of development and implementation. Among the 12 cases in ³⁰ to which this applies, there are six ICT-related cases, as listed below.

- Autotrakker: the actors which were involved since the initiation process of the cargo measurement system (= infrastructure) were mainly the break bulk terminal and the system developer. The break bulk terminal in the development stage found itself twice in a lock-in situation because it already made some investments. The decision was to stop the entire process because of some faults of the development that could have made it unusable (due to costs, inaccuracy and incapacity to operate in open space) and the entire development process had to be retaken.

²⁹ Vanelslander T, Sys C and Carlan V, 'Innovation among Seaport Operators : A QCA Approach for Determining Success Conditions' (2016) 43:3 International journal of transport economics 291

³⁰ Vanelslander T, Sys C and Carlan V, 'Innovation among Seaport Operators : A QCA Approach for Determining Success Conditions' (2016) 43:3 International journal of transport economics 291

- 3PL - Primary Gate: the first actor involved is the port authority, the innovation champion. Next, terminal operators are also important players in the process since they are operating with the system (= infrastructure) and its coordination.
- SEAGHA - Port Community System: the main actors which had the demand for the ICT platform (= infrastructure) were the terminal operators and the trucking companies.
- Antwerp Port Community System: the focus is on the E-counter module, which had the main scope of enhancing the communication between the incoming vessels, the customs and the terminal operator. The analysis shows that the terminal operator was the driver behind the development of the ICT system (= infrastructure).
- Administration: The terminal operator, as the innovation champion, can be mainly situated in the development and the implementation stages of innovation initiative, viz. replacing of all administration by the Electronic Data Interchange (EDI) (=infrastructure). The innovation champion and the other terminal operators have invested in infrastructure and also the other shipping lines were interested in the EDI tool.
- IT Data Exchange platform: This innovation case refers to an IT data management platform (= infrastructure) within the logistics that has the aim to exchange data between interested actors in a smooth and efficient way. The current development first came as an idea of track and trace tool. The data which is now transferred is being used to reduce the delays and enhance the cargo transfer, so of immediate interest to the terminal operator.

A second grouping featuring consistent success is composed of the shipping line-related variables: shipping line alignment with infrastructure, both at development and implementation level. Of the 11 cases in ³¹ that adhere to this grouping of conditions, only two are ICT-related, as listed below.

- SEAGHA - Port Community System: shipping lines in this case are not the main actors but, not having them as prime clients of the port involved would lead to missing an important part of the communication flows in seaports.
- IT Data Exchange platform: The IT data exchange platform involves data contribution of stakeholders like: freight forwarders, shipping lines, terminal operators and cargo owners.

A third grouping of the variables featuring consistent success is related to soft-institutions, more in particular those related to the innovation champion in both the initiation stage, the development stage and the implementation stage. Of the 10 cases in ³² that fall under this grouping, again only two are ICT-related, as shown below.

- E-transit: the extended gate concept for the liner carrier (= innovation champion) started to be developed in 2012 being addressed to import containers which represented the first version of the development, followed by an improved form and then by a radically new development which is addressed to exporting containers. The failure threats were the technological hurdles and the lack of experience of partners. For E-gate 2.0, the previous failure factors became reasons of success: technology was

³¹ *ibid.*

³² *ibid.*

already available and building new extensions and functionality was not a problem anymore. A failure factor for the E-gate 2.0 was the change of legislation during the development process. For E-gate 3.0, which represented the adaptation of the previous achievements from import administration practices to export containers, the only threat was that of policies that had to be changed.

- Administration: the terminal operator (= innovation champion) can be mainly situated in the development and the implementation stage of EDI. There was a high demand (= soft institutions) for the use of a technological system that replaces paperwork.

The fourth and final combination of the variables featuring consistent success is related to the innovation champion, more in particular issues related to infrastructure and hard institutional issues, both at the initiation stage. Of the 9 cases in this grouping in ³³, three are digital innovations are included:

- Port Single Window – PT: The actors involved on the infrastructure side were the major port authorities (= innovation champion) and the APP (Portuguese Port Association), the Customs Authorities, terminal operators and AGEPOR (the national association of shipping agents and ship-owners), who all together had a strong relation and commitment to move the process forward. As to hard institutions, for obvious reasons (political and administrative protocols), port authorities were as much involved as possible
- E-gate 1.0: The initiation period for the present innovation case meant starting up the project by gathering technical documentation, and building the regulation framework

³³ *ibid.*

(= hard institutions) within which the system would function. The actors involved in this stage were the liner carrier (= innovation champion) and the customs offices on the regional side. The innovation champion made an application to obtain the extended gate agreement (= hard institutions) and several efforts had to be done in order to clear the envisaged working framework for the concept.

- Truck appointment system: The truck appointment system has the purpose of helping truck drivers who wish to collect or deliver containers at the deep-sea terminal (= innovation champion) to provide their administrative details in advance to terminal operator's e-portal (= hard institutions).

What can overall be observed is that, although 32 of the 75 cases in total are ICT-related, two of the above-mentioned paths (2 and 3) only feature two ICT cases, which is less than one in five. The cases adhering to path 1 are 50% ICT-related, while for path 4, one in three is a digital case.

The groups also are not fully separate: it appears that the same cases come back in several groups. Also the same company, with different cases, sometimes comes back in various groups. It seems then that there is more than one combination which turned that innovation into a success, or reinforced the success. That is true for two of the cases: SEAGHA - Port Community System and IT Data Exchange platform.

Finally, it can be observed that in total, 10 of 22 ICT innovation cases for which the success level could be identified, are somehow covered by one or more of the solution paths, which means that success of only less than one in two cases can be explained by a logical combination of conditions (Figure 7). In addition, the fact the hard institutions

(also including regulation) are found in only one set of conditions and this combination only refers to three innovation cases, is noteworthy.

Figure 7: fsQCA port ICT innovation groupings

fsQCA success condition	fsQCA 1	fsQCA 2	fsQCA 3	fsQCA 4
ICT Innovation cluster				
Electronic data interchange innovation (information flow)	APCS			
	Administration (EDI)		Administration (EDI)	
	IT data management			
	SEAGHA - port community system			
			eTransit (prior to the Extended GATE)	
			Port Single Window	
			Extended-GATE 1.0	
IT innovation supporting the cargo flow	3PL - Primary Gate of Leixões Port			
Monitoring innovation - vehicles & cargo	Autotrakker			Truck Appointment System

Source: ³⁴

5.4 Systems of Innovation Approach

In the context of an assessment of innovation, the Systems-of-Innovation (SI) approach seeks to identify relations between actors and institutions within the innovation (adoption) system that contribute to innovation uptake or inhibit it. The section below firstly describes the context and actors followed by the pattern analysis.

³⁴ *ibid.*

3.1.1 Context and Actors

Within the SI approach, cases are initially considered with respect to their scope.

Following findings can be derived for the three identified categories of cases (see section 1 and Table 1):

- IT innovation supporting cargo flow

Five innovation cases are included in this thematic category. Four concern inland terminals and, therefore, produce a system change. The key characteristic is the involvement of additional actors including Municipalities and Regulators. Market push and competition seem to be the basic driving force of this thematic innovation. Lock-in effects may hinder the adoption.

- Monitoring Innovation Vehicles & Cargo

Six innovation cases are included in this category. A key characteristic is the involvement of many actors due to the system nature of the application. In one case (Autotrakker) the potential key beneficiary is not the innovation champion. IT providers are the key source of capability provision but clear understanding of the process seems to be the key issue. Market push was identified in all cases.

- Electronic data interchange Innovation

Twenty-one cases are included in this thematic category. Again in most cases a strong market push has been identified. The involvement of software developers is again present. In many cases only in the implementation stage. Regulators and Customs Agencies are also involved. Shipping lines in most cases oppose the application. There is also the factor of competitive innovation influencing the final result as it

creates a lock-in effect for those actors already adopting another innovation of similar effect.

The next section will describe the innovation patterns that can be derived.

3.1.2 Pattern Recognition

The Systems of Innovation Approach in principal focuses on issues concerning the system of stakeholders involved in the innovation adoption process. When considering this approach, it is assumed that the Benefit-Cost balance of the innovation has been proven.

Pattern recognition follows on the identification of common trends of actor support or opposition with respect to outcome. This particular analysis is based on hypotheses testing. As described in the methodology, the following hypotheses are tested:

- (i) The importance of capabilities (external knowledge and financing).
- (ii) The accord of all actors involved,
- (iii) The importance of market push and
- (iv) The ability of the innovation champion to influence actors and outcome.

H1: Capabilities

This first hypothesis is in line with the linear theory of innovation uptake. The lack of capabilities (knowledge and financing gap) is considered, according to the linear theory of innovation uptake as the fundamental reason of failure and loss of innovation potential in the so-named “valleys of death”. Notably, capability is viewed as (i) knowledge and expertise with respect to the innovation provided by research institutes, the innovation providers or other external actors and also as (ii) financing contribution/interest from financing institutions.

The noteworthy point from this particular sample of cases is the absence of financial support. There were no cases where financiers were involved. This could be due to the ability of the particular sample of companies to self-finance their activities or an expression of risk-averseness on the part of the financiers or a combination of both.

When testing the entire sample for the importance of knowledge capabilities, these were found to significantly contribute to the successful adoption of the respective innovation (spearman's rho = 0.968, significant at the 0.01 level for the specific sample).

H2: Actor Support

This may be considered an “extreme” hypothesis, as it is hardly ever possible that “change” is widely endorsed. However, few cases within our set failed to meet the hypothesis criterion. Three cases, through the qualitative analysis, were found not to comply with the hypothesis. Further qualitative analysis of these cases suggested that for:

- i. the APCS case, this may be due to lack of sufficient market demand or the relatively small support from the Port Authority;
- ii. the Autotrakker, there was no market demand and, finally;
- iii. the Central port community system for breakbulk (initiative from the Association of Traffic Flow Controllers - KVBG), KVBG faced competition from an existing innovation (an initiative of the Port Authority).

H3: Market Demand

This hypothesis tested whether difficulties could be overcome, depending on the level of market demand. The qualitative analysis identified that potentially this hypothesis was also valid. For the one case that did not comply (Digital CMR), further investigation

verified that all actors required for the adoption of the innovation were not foreseen and that port competition was stronger than the push from market demand.

H4: The Innovation Champion

The importance of the Innovation Champion is identified in most literature reports ³⁵ .

This is in particular true for this set of cases. Only one case was found to be contrary to the hypothesis and was considered a failure (eTransit). A careful investigation indicates severe competition from a competing innovation adopted by Antwerp Port and the respective Port Community System (APCS). Hence, a mismatch in technology and a lock-in effect may be considered as contributing to the failed attempt to adopt the specific innovation.

6. Joint lessons for ICT-related port innovation

During the data collection phase already, interviewees indicated the following barriers to port-related ICT innovation: lack of collaboration by other actors, need for further integration along the maritime supply chain, uncertainty about legislation, and drifting apart of the local needs and the strategic decisions made by headquarters as a result of globalization. These preliminary observations show that regulation does not get immediate attention among chain stakeholders, if only that there should be consistency. The case analysis with the four methods suggests first of all, through the Cost-Benefit Analysis, that there are benefits and costs for every stakeholder. However, the benefits are not always readily visible, often resulting in a low willingness to pay. At the same time, concern about the cost elements definitely plays in a sector where margins are narrow. Hence, from a game-theoretical perspective, there is no willingness to co-operate

³⁵ DA Schon, 'Champions for Radical New Inventions' (1963) 41 Harvard business review 77; Jane M Howell, Christine M Shea and Christopher A Higgins, 'Champions of Product Innovations: Defining, Developing, and Validating a Measure of Champion Behavior' (2005) 20 Journal of business venturing 641.

(comparable with co-operation between ports). This is easily explained by formalizing the cost and benefits of adopting an IT application in a payoff matrix. The choice is simple: either to continue with the own IT system or to integrate systems. Unlike the innovation champion (e.g. trucking company, carrier...), the follower faces an entry cost that outweighs the benefits, and consequently the game stops. There could be a role for regulation here, to the extent that entry costs may be built excessively high by incumbents. The latter is also supported by the importance attached by port chain decision makers to economic objectives, including optimizing operations and minimizing costs in the first place, as shown by the objectives-success analysis.

Entry costs may also be the driver behind observed potential for imitation ³⁶. The innovation initiative fails or ends in endless discussions about data (ownership, availability, accessibility and modifiable). Opposed to that, if the cost is lower than the benefit or if everyone is in it from the start (cf. openness and trust), an innovative concept is likely to achieve greater success ³⁷.

The latter weakens the role of the innovation champion on its own in the process: according to the fsQCA analysis, only in a minority of cases, that actor manages to push through the innovation in a key role on his own. The role of partners like terminal operators and shipping lines, in particular in their alignment with infrastructure, are key. That is also confirmed by the Systems of Innovation approach, where capabilities of all involved partners, market demand and avoiding lock-in effects on behalf of the

³⁶ Athena Roumboutsos, 'Comparative Analysis of Cases: Systems' Innovation Approach'.

³⁷ Christa Sys and others, *Executive Summary* (2015) <<http://anet.be/record/opacirua/c:irua:127919>>.

innovation champion are important. First, innovation carries “newness” both in application and the knowledge which is needed to implement it. Respective capabilities are important to be included in the process from the earlier stages, when this knowledge does not exist in-house. Second, limitations and set-backs may be overcome given the level of market demand that may exist for a specific innovation or the need to improve on efficiency. Third, the “port environment” includes many interlinked and interrelated actors, who may not always share the same interests or their interests may not be achieved in the same way. It is therefore important to both motivate all actors involved and facilitate their involvement in the implementation of the innovation. To this end, a number of issues may arise connected to both existing technology, and thus lock-in effects, for actors as well as competition issues.

A strong role of the innovation champion has been identified through many previous studies³⁸. However, there is a particular interest in the port sector where market leaders may exist within the group of actors involved in the implementation of a particular innovation. Here, the combined effect of market leaders (hence representing to a large extent market demand or bearing knowledge of market needs) and the power position within the “port environment” may be witnessed. Hence, the combination of the above findings supports the need of stimulating co-opetition in order to support the successful adoption of innovation. That is again supported by the objectives-success analysis, as integrating with other chain actors is shown to be a key objective by chain stakeholders.

³⁸ Schon (n 32); Howell, Shea and Higgins (n 32).

Hard institutions (including regulation) moreover only appear as important in a minority of cases, according to the fsQCA analysis. Soft institutions (including informal standardization) are much more important. Of course, in such case, regulation of the market to support the free flow of information among actors and to give the best chances to the best standards becomes important.

The confrontation of objectives and success finally shows that the objectives that typically require public intervention (environmental and social) are not valued high.

Clearly, the role for public policymakers in this field is not key.

7. Conclusion

Digital innovation will change the business model of the actors along the maritime supply chain. In previous decades, forward thinking companies along the maritime supply chain invested in stand-alone IT systems to enhance their operations and maintain competitiveness (i.e. support new business models and deliver new services). A number of software companies specialized in the port sector and developed various innovative concepts for a particular stakeholder. With respect to integration in the maritime supply chain, those stakeholders find themselves in a lock-in situation. Moving to cloud-2-cloud applications will make it possible to move innovation forward faster. Inevitably, integrating such systems carries a price tag. Small and medium sized companies should also embrace the move to digital innovation. How to create positive awareness among those companies? What barriers are on the way, and what role can regulation play? Those are the questions answered by this paper.

The combination of analyses provides the opportunity for a holistic approach and improves understanding of the digital communication innovation process within the port sector.

First, in contrast to the non-ICT innovation cases, alignment exist between company strategies and success degrees in the port sector and efforts should be made to improve the strategic processes that lead to integration in the maritime industry. Economic objectives appear to be ranked higher in terms of importance than the other objectives such as environmental and social, which in many cases are imposed through regulation or through the social responsibility mandate of the initiating entity.

Next, no unique 'recipe' for innovation success does exist. However, some combinations of variables can be identified that lead for certain groups of cases to a higher chance of success. Overall, important variables turn out to be infrastructure, soft-institutional and hard-institutional issues at the initiation stage, and infrastructure at the development and implementation stages.

Furthermore, it was identified that capability building and early inclusion of actors that may provide respective capabilities is important for the successful adoption of digital innovation.

Financial support was absent in most cases and in the majority of cases self-financing was the preferred /adopted solution. In depth investigation of exceptions and failed cases highlighted the impact of "lack of market demand" and "port competition" and most importantly "innovation competition". The latter is also responsible of a lock-in effect and deserves further research, as well as the effect innovation systems have on each other.

In addition, market demand is equally important to bring about the change introduced by the innovation. This condition is, also, connected to market readiness and requires further research.

Fostering cooperation within the port is an important pre-requisite for the successful adoption of innovation. This consists of managing to achieve cooperation with respect to application of ICT in ports. Such cooperation, in many cases is targeted between ports. The innovation champion in this case is of significant importance.

In the present research and context, initial attempts at working with an upstream and downstream stakeholder often failed. Just a few were subsequently successful, but only in a closed innovation approach. Hence, co-innovation is expected to be the most important challenge for the port industry in the decades ahead. Co-innovation is a new form of innovation whereby the various stakeholders jointly acquire new expertise and create opportunities in the supply chain for new partnerships. In the long term, this will lead to a balance between costs and profits as well as a greater competitive advantage.

It is noted that regulation and standardization (or hard institutions) was not identified as either being a significant barrier or a facilitator to the process. If anything, within the port environment, existing ICT solutions are often considered “standard” bringing about a lock-in effect and creating hindrances for new applications. In combination to the need for cooperation and co-innovation within the port sector, there is an issue for further research as to whether regulation and standardization will be favourable for the uptake of ICT innovation, especially as technology trends are in support of more open access systems.

Research is furthermore required to validate the findings from this paper more in depth. The set of ICT cases analysed within this research effort may be considered adequate in number allowing for comparisons and potential transfer of lessons learned. However, it is also important to state that the sample may have a potential bias. For example, a great

share of the cases within our sample is considered successful. Another point of interest is the market position of the innovation champion and the fact that all the analysed cases were self-financed. Finally, only a minority of cases involve small and medium-sized enterprises. It would be useful to verify whether the findings of this paper still hold in sets of cases that are more diverse.

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