Environmental sustainability in seaports : a framework for successful innovation

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Environmental sustainability in the port industry is of growing concern for port authorities, policy makers, port users and local communities. Innovation can provide a solution to the main environmental issues, but often meets resistance. While certain types of technological or organisational innovation can be satisfactorily analysed using closed system theories, in the case of seaports and in particular in the area of environmental sustainability, more advanced conceptual frameworks have to be considered. These frameworks need to be able to account for the multiple stakeholder nature of the port industry and of the network and vertical interactions that environmental sustainability calls for. This paper investigates successful innovations improving environmental sustainability of seaports. The proposed framework builds in part on research concepts developed in the InnoSuTra EU FP7 project. From a methodological perspective, the paper develops a method for quantifying the degree of success of innovation with respect to a set of specific objectives.. Several case studies are used to test the framework against real innovation examples, such as onshore power supply, or alternative fuels. In the paper we will argue that only those innovations that fit dynamically port actors' demands and the port institutional environment stand a chance to succeed.

1. Introduction

The relation between transport and society is complex as logistics activities act as a facilitator and at the same time a contributor to economic activity (Markianidou 2011), providing jobs and tax revenue and through investments (Blauwens, De Baere, and Van de Voorde 2010). The management and organisation of the logistics chain is a major part of a firm strategy, and transport plays a critical role on production and distribution activities. Transport activities, however, are responsible for a number of negative external effects, often unaccounted for in firm strategies. These include infrastructure stress, congestion, accidents, pollution (e.g. air, noise, debris generation), and resulted in increasing pressure on the transport sector by governments, customers, environmentalists and other stakeholders (Sys, Vanelslander, and Adrianssens 2012). This is also true for the port sector, where the internationalisation of external costs, for instance, is meant to improve eco-awareness, increase the efficient use of resources and result in a fair competition between transport chains.

Notwithstanding the importance of the topic, there is to date limited literature on the management and operations of green ports, mostly focusing on ecological issues (Bateman 1996, Berechman and Tseng 2012, Dinwoodie, Tuck, and Knowles 2012, Liao, Tseng, and Cullinane 2010, OECD 2011), and monitoring port environmental impacts (Darbra et al.

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2004, Darbra et al. 2005, Darbra 2009, ESPO 2012, Wooldridge, McMullen, and Howe 1999, In the last decade, some authors have started analysing strategic issues (Haezendonck et al. 2006, Denkas-Sakar and Karatas-Cetin 2012), contribution to the identification of the value added that environmental performance might bring to ports.

Lam and Van de Voorde (2012) provide a review of the extant literature on green ports and sustainable supply chain management and provide one of the first frameworks for sustainable port strategies. In their framework, they postulate that '*a green port will lead to positive outcome on port's customer retention and economic performance*' (Lam and Van de Voorde 2012). Acciaro (2013) discusses the role that corporate responsibility plays in the port sector, suggesting that sometimes a focus on port environmental performance may stem from competitive pressure. Greening the firm profile is often just a nice additional benefit to efficiency pursuit or compliance need, as costs or regulation remain the main drivers behind environmental strategies. Efficiency, growth, regulatory compliance and environmental sustainability, however, can at times lead to diverging priorities.

The fragile balance among these objectives can only be established and maintained by going radically for innovations and innovative processes, which are crucial for the materialization of sustainable transport (Van Wee 2003). Technical innovations often require a long time to be adopted by an entire industry, while process innovations can typically be implemented much faster. Although innovation is one of the key success factors of private businesses, the network nature of transport and logistics, where freight and passengers interact, requires government intervention for the innovation process to take off. Furthermore, private investments in innovations are quite risky because of market imperfections and the interdependency among sector players.

Innovation can provide a solution to some of the main environmental issues faced by ports (Yap and Lam 2013), but also in this sector it is often met with resistance as a result of the associated large capital investments or the risks of being locked-in in unsuccessful technologies. Ports have been also the ground for the proposal of new technical innovation, and, often as a response to upcoming regulation, ports are faced with complex decisions aiming at selecting new approaches. In many cases, such decisions are characterised by large capital commitments and substantial lock-in effects.

Furthermore, innovation in general seems to happen very rapidly these days. It therefore very strongly steers the pace and the way with which economic sectors are developing, and manage to remain competitive. However, the poor innovative strength displayed by the transport sector in the broad sense often contrasts strongly with that evidenced elsewhere. A comparative study by the International Transport Forum (2010) has shown the transport sector to score less than the average for the economy as a whole when it comes to innovation. At the same time, it can be concluded from existing literature and studies that quite a lot of innovative concepts in transport have been studied in detail (e.g. Aronietis et al 2009, Kapros

2010, Gevaers, Vanelslander, and van de Voorde 2010, Arduino, Carrillo Murillo, and Ferrari 2011, Arduino et al. 2011).

The main focus hitherto however has always been on inventing or introducing new concepts and procedures. Hardly ever has the innovation process as such been assessed, and never have generic conclusions been drawn with respect to factors, which benefit or dis-benefit the successful adoption of innovative ideas in transport, and the role that transport actor strategies play into that. While most types of technological or organisation innovation[†] in transport can be satisfactorily analysed using closed system theories, in the case of seaports and in particular in the area of environmental sustainability, more advanced conceptual frameworks have to be considered. These frameworks need to be able to account for the multiple stakeholder nature of the port industry and of the network and vertical interactions that environmental sustainability calls for.

This paper investigates successful innovations improving environmental sustainability of seaports. This proposed framework makes use of a ranking system to assess the success of innovation types in relation to a set of predefined green objectives. The framework needs to be developed in this paper, as no existing literature did set up such system. Several case studies are used to test the framework against real innovation examples, such as onshore power supply, or alternative fuels. In the paper, we will argue that only those innovations that fit dynamically port actors' demands and the port institutional environment stand a chance to succeed. The paper also has a value as it addresses the issue of green objective definition and proposes a list of green objectives for ports based on the general strategic objectives of a port authority.

The paper is structured in the following way. Next section describes the methodology used to survey the innovation forms and rank them with respect to the green objectives. It also explains how the green objectives have been obtained and verified. Section 3 presents the selected green objectives and provides an explanation of what is meant by each of them. Section 4 presents the results of the ranking exercises and provides some interpretation of the results. Section 5 concludes.

2. Methodological approach

The methodology employed for answering the main research question follows four steps:

1. a sample of innovation and ports is identified;
2. a list of objectives is defined and validated;

[†] This is the classical subdivision between types of innovation. Technological innovations involve technological developments, while management innovations imply process changes. Arduino et al. (2011) qualify the dichotomical division, rather refer to a 'technology or management-related character' of innovations, and make more possible combinations: technology, technology-managerial-organisational-cultural, and managerial-organisational cultural, each of them split up in a business and a market type.

3. a ranking is determined with discussions with port representatives and through the development of case studies;
4. the rankings are compared using the H index and a Wilcoxon test.

The next subsections further explain each of the above-mentioned steps.

2.1 Sample definition (step 1)

The authors selected a sample of ports from a variety of regions so as to represent significant diversity in terms of size, locality, competitiveness, cargo handling characteristics and market positioning. It is in this perspective that the choice of the sample should be looked at. While our methodology suffers from a selection bias—different innovations at different ports could change the results of the analysis—two considerations should be made in support to the methodological choice.

Ports differ substantially in their geographical, social and historical contexts, and while for certain problems, rigorous sampling techniques can be used to generalise conclusions, in other cases, such as the one under analysis, the complexity of the managerial options available renders the use of rigorous sampling particularly difficult. Secondly, the innovations in ports have been selected among those ones that had at least some degree of success. Moreover, the ports under analysis are in general well-established organisations, professionally run and with a considerable degree of know-how. In this respect there are lessons to be learned from these case studies, and they can all be considered best practices. If any recommendation would emerge, as it will be discussed later, from these best practices, such recommendations would hold even more strongly for those ports that are less advanced in their management of environmental innovation processes. These considerations render the sample sufficiently valid for analysis.

The ports selected are: Antwerp, Genoa, Hamburg, Los Angeles/Long Beach, Rijeka, Singapore and Zeebruges. For each port the team selected one or two environmental policy actions and within each of such actions an innovation that could be ranked in terms of success. These actions and cases are again being selected following the suggestion of the port authority and because of their representativeness for the port under analysis. In the case of Rijeka it was felt that only one innovation fit the criteria of the paper in terms of information availability and strategic relevance, so that port only features one case in this paper.

2.2 Objectives definition (step 2)

A clear definition of *success* in the area of green innovation in ports is not available, as argued in section 1. It can be argued that success is in relation to the strategic objectives of the port authority. The authors decided to approach this problem by defining and agreeing a set of common, well accepted strategic objectives linked to the standard functions of a port authority, such as landlord, regulator, operator, community manager as discussed in

(Meersman and Van de Voorde 2010; Meersman, Van de Voorde, and Vanelslander 2005; Verhoeven 2010). These strategic objectives were revisited in a green perspective. A green strategy in fact cannot, and should not, be discussed independently from the overall port strategy, at least in general terms. A list of green objectives, which are compiled and presented in section 3, was then validated in this paper using the expertise of port authority officials using a Delphi methodology.

The Delphi methodology was selected for obtaining a validated set of port authority objectives, and scores associated to them. The applied Delphi approach worked in several steps. First, green innovation responsible managers from seven port authorities (Antwerp, Ghent, Zeebruges, Flushing, Rotterdam, Amsterdam and Genoa) were approached. All of them confirmed their willingness to verify a preliminary list of objectives as drafted by the authors of this paper. The comments and additions from the seven authorities were then processed in an updated version of the goals list. This new list was again submitted to the seven concerned authorities, for final commenting and approving. This led to a second updated objectives list, which was further used as basic list to apply the scoring.

2.3. Case study analysis and comparison (step 3 and 4)

Each case study has then been developed ensuring that the innovation selected is consistently ranked with the green objectives, so as to be able to assess the relative importance of each objective with respect to the action undertaken by the port authority. On the basis of these green success variables the team then proceeded to qualify each innovation with respect to the contribution to the port authority objectives (and to the overall port authority's green strategy). This approach is consistent with a focus on innovation, more than on individual ports. The data collection resulted in two separate rankings, one for the relevance of the objective for a specifically selected policy action and one for the success level of the innovation in achieving a targeted objective. The data has been analysed using a simple comparison of the results. In order to assess the consistency of the answer used, the homogeneity index H has been used for every objective.

The index H is a relative homogeneity index and is calculated as the standardized value of the square sum of the percentage frequencies of the ranking. So if we indicate as f_{ij} the percentage of innovation that ranked objective i with value j, with $j=1,...5$. We can define the index h_i, as:

$$h_i = \sum_j f_{ij}^2$$

h_i has value as 1, when all innovations in the sample are given the same ranking (maximum homogeneity), and value $0.2=5*(0.2)^2$, when all innovations are ranked uniformly on the ranking scale (maximum heterogeneity). We can then define a relative homogeneity index as:

$$H_i = \frac{h_i - \min(h_i)}{max(h_i) - \min(h_i)} = \frac{h_i - 0.2}{0.8}$$

When H has high levels it indicates that the respondents gave the same ranking for the objective, while when the value of H is low, there is disagreement on the ranking of the objective. The overall rankings can be further compared using testing procedures such as the Wilcoxon test or the Student's t statistic. In the rest of the paper the Wilcoxon test is preferred as it does not require any distribution assumptions.

3. Green objectives

The following is a list of green strategic objectives that has been put together reviewing the main functions of port authority and investigating how environmental sustainability is likely to influence or interfere with each main port authority function.

3.1. Landlord function

The main strategic objective linked to the landlord function is to manage the areas and activities entrusted to the port authority, specifically including the management, maintenance and development of the port estate, provision of port infrastructure and facilities, conception and implementation of policies and development strategies linked to the exploitation of the estate (e.g. port dues).

[Insert table 1 about here]

3.2. Regulatory function

Within their regulatory function port authorities aim at regulating the activities within the port, specifically including controlling, surveillance and policing functions in view of ensuring safety and security within the port but also concerning environmental protection.

[Insert table 2 about here]

3.3. Operator function

The operator function accounts for all the activities performed in the context of operating the assets within the port for profit (or non-profit), including physical transfer of goods and passengers between water and land, provision of nautical-technical services (pilotage, towage, mooring...), ancillary services, e.g. provision of onshore power for vessels.

[Insert table 3 about here]

3.4. Community manager

As a community manager the port's main purpose is to manage stakeholders' relations and manage the port community, structuring the port community and strengthening links between town and port and between port users, solving collective action problems in and outside the port area, mediate between conflicting interests in order to defend the 'license to operate' of the port, lobbying on different levels on behalf of the port community, providing incentives for port users towards more sustainable behaviour.

[Insert table 4 about here]

4. Selected ports and their green initiatives

This section provides a description of the port innovation initiatives used in this study. Those initiatives will be subject in next sections to the analysis mentioned in section 2.

4.1 Port of Genoa

Innovation 1: The Port Environmental Energy Plan (PEEP)

The Port Environmental Energy Plan (PEEP) aims at registering heat and electric energy consumptions of every port players in order to suggest/foresee possible interventions for reduction of consumptions. The plan dates back to 2010. PEEP also provides a wind power plant with 39 towers on the outer breakwater, 29 photovoltaic systems producing 5,600 kWh and three thermal collectors on the roofs of buildings in the port area. Several applications for the installation of photovoltaic panels on the roof of buildings and warehouses have already been granted, in order to produce energy from solar radiation

Innovation 2: Quay electrification of ship-repair docks

Quay electrification in the ship repair area of the port of Genoa will be the first step to prevent moored ships from running their auxiliary engines for a long time, thus emitting large amounts of greenhouse gases in the heart of the city (there are 12 berthing points), and to considerably reduce noise emissions in the area. Genoa Port Authority has already included the project—co-financed by Liguria Region, the Ministry of the Environment and Genoa Port Authority for a total value of about €15 million—in its environmental policy programme, expecting its completion by 2013. At the port of Genoa, quay electrification will reduce CO_2 emissions by almost 10,000 tonnes every year, the wind power plant by 6,000 tonnes, the photovoltaic systems by 3,600 tonnes, and solar panels by 100 tonnes every year.

4.2. Port of Antwerp

Innovation 1: Cold ironing

Shore power is already available for barges, as well as the Port Authority's tug and dredger fleet, floating cranes and dry dock complex, and will soon be supplied to pleasure craft and houseboats. Since 2009, also seagoing ships can be supplied - the segment that, in view of its size, has the most powerful effect on environmental performance. A pilot test was started with one shipping company, resulting in a reduction of CO_2 by 50% and of NOx by 97% for that company's calls. The installation required an investment of € 1.1 mn, co-funded by 45% by the Flemish Government.

Innovation 2: Reinforcing market position

Antwerp has been one of the most important ports in the world for several centuries. It is currently the second largest port in Europe. To further reinforce this market leadership position, the port of Antwerp will sail an environmentally friendly stance.

Shipping companies have a number of good reasons to choose Antwerp. In future, an other element will be an environmental one. The Port Authority of Antwerp aims to play a leading role in achieving environmental targets both at European and Flemish and local level. Therefore, it is needed to port users are rewarded when they make greater efforts than strictly is required. A corrective policy is required if they do not take their environmental responsibilities. This plan should reinforce market share.

4.3. Port of Singapore

Innovation 1: Green Port Programme

The Green Port Programme (GPP) was announced on 1 Jul 2011 under the Maritime Singapore Green Initiative to quicken ocean-going ships calling at the Port of Singapore to reduce the emission of pollutants like sulphur oxides and nitrogen oxides. Under this programme, 15% concession in port dues will be granted to those vessels that use type-approved abatement/scrubber technology or burn clean fuels with low sulphur content beyond MARPOL requirements during the entire port stay (of 5 days or less) within the Singapore Port Limits (from the point of entry into Singapore Port Limits till the point of exit). The Green Port Programme is voluntary and will be valid for 5 years. Registration of vessels under the Green Port Programme (GPP) must be made using a valid Marinet account.

Innovation 2: Green Technology Programme

The Green Technology Programme inspires local maritime companies to develop and adopt green technologies. To co-fund the development and adoption of green technological solutions, this programme provides grants of up to 50% of total qualifying costs. Singapore-registered companies involved in maritime related businesses like terminal operations, ship owning and/or operations and harbour craft operations are eligible for the project.

Projects should also meet the following criteria:

- Have verifiable emissions (Sulphur Oxide, Nitric Oxide, Carbon Dioxide) reduction results that comply with industry performance guidelines.
- Have not been commonly deployed in the maritime industry.
- Should be type approved where relevant.
- Have system integration design and retrofitting

4.4. Port of Rijeka

Croatia´s leading port is undergoing transformation into a key maritime hub supported by access to TEN-Ts motorways and rail links, while logistics operations are rationalized by the Škrljevo dryport. Within this process, the development of an environmental management system is a very important for the Port of Rijeka Authority. The purpose of the Development of Environmental Management System (EMS) is to provide an EMS system, which will be implemented in the different area and facilities on the jurisdiction of the Port of Rijeka Authority. The EMS system is projected to facilitate finding and fixing the root causes of potential environmental problems and to improve environmental performance, prevent possible pollutions, conserve energy and natural resources. An EMS should focus on issues such as: water quality, air quality, waste management, habitat conservation, noise, contaminated soils, and energy consumption.

4.5. Port of Zeebruges

Innovation 1: Cold ironing

The port strives to be a Clean Port. After all, the pure environment also constitutes a commercial trump card for amongst others the food industry. Currently, the port authority is examining the ecological footprint in order to decrease the CO_2 emissions.

Innovation 2: Windmills

Aspiravi NV is operating 71 wind turbines and 25% of 7 VLEEMO-wind turbines. The total installed capacity of this wind-generated energy is 114,6 MW and 25% of 15 MW. Aspiravi Offshore NV is participating in the Northwind project and the projects developed by Otary e.g. Seastar and Rental. Once operational, the total installed capacity in the North Sea area will be 750MW.

4.6. Port of Los Angeles / Long Beach

Innovation 1: Vessel speed reduction program

The vessel speed reduction program (VSR) is a voluntary program that began in 2001. The program requested that ocean vessel reduce speed within a 20 nautical mile zone on approach to the ports. The purpose of VSR is to reduce air emissions. Each port implemented the program in its own way. The program began with a relatively high participation rate which

then declined over time. Incentives offered in 2004 – 2006 resulted in increased participation. By 2007 participation was in the range of 80-90% and has remained at this level. Major incentives included berth labour pre-assigned so that docking and loading/unloading began immediately, and "Green Flag" recognition programs for shipping companies with very high compliance levels. Linder (2010) used compliance levels for 2002 and 2007 to estimate emissions reductions due to the VSR program. Estimated reductions were in the range of 40 – 50% for four criteria pollutants.

Innovation 2: Clean Truck Program

The Clean Truck Program (CTP) was implemented by the ports in 2006 as part of the ports' Clean Air Action Plan. The intent of the plan was to reduce port-related vehicle emissions by about 50% by 2010 by replacing the entire drayage vehicle fleet with trucks that met 2007 federal Environmental Protection Administration standards. In order to enforce the program, all trucks were required to be equipped with RFIDs (radio frequency identification devices) and registered in the ports' Drayage Truck Registry. In order to provide an additional incentive a Clean Truck Fee of $35/TEU was to be charged to the beneficial cargo owner for any loaded container carried by a non-compliant truck. The CTP was extremely controversial, because it also required licensed motor carriers (trucking companies) to enter into concession agreements with the ports, and only those carriers would be able to operate at the ports. The effect of this requirement was to replace independent owner-operators with employee drivers. In response to lawsuits, in 2009 the Port of Long Beach withdrew the concession requirement. The Port of Los Angeles has maintained the concession model, but the matter remains unsettled as lawsuits proceed through the US court system. The CTP achieved its goals. By 2009, 75% of all drayage truck trips were compliant with 2007 EPA standards. According to the Ports, heavy-duty diesel truck particulate emissions were reduced by nearly 90% by 2010.

4.7. Port of Hamburg

Innovation 1: Electrification of the Automated Guided Vehicles (AGVs) in the HHLA Terminal Altenwerder

The HHLA terminal Altenwerder is one of the most important container terminals in the port of Hamburg. The terminal operating company introduced in 2010 in cooperation with Gottwald, AGV's that are entirely operated through a battery (Free and Hanseatic City of Hamburg and Hamburg Port Authority 2012, Port of Hamburg 2012). The new generation battery allows the vehicle to operate for 12 hours and automatically go back to the recharging station when power levels become too low. In the recharging station the battery is replaced and the vehicle is operational within a few minutes. The battery-driven AGVs (B-AGVs) can carry up to 60 tonnes and consume 19 kWh per hour of operation. The benefits are that not only the vehicles do not generate any emissions, but are also silent and allowed for substantial

costs savings. The terminal is completely powered through certified green energy (Grossmann 2008, Port of Hamburg 2012).

Innovation 2: Use of a Market Consultation for the definition of the project Central Terminal Steinwerden (CTS) (based on Hurtienne 2010).

The future Central Terminal Steinwerden will be located in a central area within the port of Hamburg, now comprising of various basins and land areas. The terminal area will be approximately 125 hectares on the waterside and will be obtained dismantling existing facilities and filling various water basins. The final destination of the area is likely to be decided during 2013. In 2009 the Hamburg Port Authority launched an international market consultation with the objective of collecting ideas on possible uses of the area and alternative configurations. The consultation resulted in over 30 alternative proposals and shows the interest in such early stage consultations. In July 2010, an independent jury selected the winner of the consultation (Royal Haskoning). Among the criteria considered there were innovativeness of the approach to operations, how environmental aspects are handled and the feasibility of the financial models proposed (Port of Hamburg 2012).

5. Results and interpretation

The analysis provided two main outputs: one innovation success ranking and a ranking summarizing the relevance of the associated policy action with respect to a set of clearly defined green objectives. The ranking results are provided in the tables 5 and 6 below.

The results in the first table show that the innovation selected in the sample have been most successful in achieving the objectives in the categories of operator function and community manager function. Among the objectives listed under the category landlord function and regulatory function, there is more homogeneity among the scores, with most objectives scoring below 3.

The second table shows that actions are rather diverse with respect to the objectives that they target. Also in this case the objectives grouped under 3 and 4 are more heterogeneously ranked with lower scores, but higher average.

A possible interpretation of the ranking is provided by the analysis of how often an objective is indicated as successfully achieved by an innovation. This interpretation allows observing that independently of the innovation and of the port selected, certain objectives tend to rank higher than others. Such observation indicates that innovations are more successful in achieving some objectives than others, and that some objectives score higher more frequently in the sample.

The objective for which the innovation ranking consistently shows that it was successfully achieved is "*2.7. Share information with reference to environmental compliance*". This seems

to indicate that such objective is more easily achievable independently from the port and from the type of innovation, or that all the innovation selected had aimed at fulfilling such objective. If we compare this result with the relevance of the related action to such objective, we observe that the action is consistently ranked low, indicating that success in achieving such objective is probably incidental. It should be noted though that the degree of heterogeneity in the answer is also quite high in this case (almost half of the innovations score very low, but the remaining score 5 in this objective).

[Insert table 5 about here]

The next highest-ranking objectives are all belonging to the last group of objectives (category 4, community manager) and they are:

- *4.3. Market the port as green*
- *4.5. Stimulate and facilitate port users in adopting green practices*

[Insert table 6 about here]

Many of the innovations that are ranked as successful are then linked to the function of community manager for the port. From the action ranking it appears that actually the community manager function is in general at least partially also a stated objective of the action. In this case the scores are more homogeneous, although they tend to be more homogeneous for the innovation ranking than for the action ranking.

Table 7 shows the comparison of the two rankings. The Wilcoxon test was performed on the total ranking to verify if they could be significantly different. For the total sample, the test fails to reject that the median of the differences between the two rankings is zero. We therefore cannot say that the two total rankings are significantly different (at 0.01). If we approach the rankings though at a group objective level, we observe that the test indicates that for the objectives grouped under the landlord function, the rankings are significantly different (at 0.01). For the objectives listed in categories 2 and 4, the test fails to reject the hypothesis that the two rankings are significantly similar. For the objectives grouped under the operator function, the sample is too small to run the test, but it would be unlikely that the two rankings differ significantly.

[Insert table 7 about here]

This comparative analysis shows that the rankings are not statistically different in general, implying that as far as the overall degree of success, there is accordance between the relevance of the objectives for a specific policy action and the success ranking. When it comes to the landlord function is appears instead that the innovation success rate is at variance with the relevance of the policy action, indicating that as far as the objectives listed in category 1 are concerned, innovation is not successful when the objective is identified as important. This outcome highlights the risks of misalignment between priorities and

innovation processes. Certain types of objectives appear to call for different innovation implementation processes. One of the limitations of this analysis is that the innovation implementation process has not been investigated. The divergence may (partly) be the effect of a strategic vice due to the necessity to coordinate several actors, each of them with its own objective function. It would be advisable to carry out a more detailed analysis on this area in the future.

6. Concluding remarks

The paper looked at which green objectives are achieved successfully more often and which ones are most commonly associated with the green environmental actions performed by port authorities. It would be expected that the objectives prioritised in a policy action, should also be those achieved by successful innovations.

The analysis, based on an international sample of port cases, does not seem to support such conclusion entirely. There seems to be a divergence between the relevance of the stated objectives associated with a policy action and the level of success that the green innovations linked to such action are able to achieve. Green innovation therefore is not successful enough in those cases where it should be. The green innovation success is achieved incidentally, and in areas that were not prioritised in the policy actions. In particular for the objectives listed as part of the landlord port function, innovation success is significantly not aligned to action relevance.

While policy actions in the used sample were focusing on a variety of green objectives, objectives linked to the regulatory and the landlord port function seem to prevail. Innovation instead seems to be most successful when dealing with the function of the port as community manager or with the objective of sharing information with reference to environmental compliance.

Although the potential bias deriving from selection of the case studies and of the ports to be analysed constitutes a limitation of the current study, an important recommendation emerging from the analysis is to address in the selection of green innovation project their actual success potential, in order to ensure that the forms of innovation supported are strategically aligned with the policy actions selected. It would be useful to expand the analysis to other ports and innovations in order to assess the existence and significance of a selection bias in the applied methodology.

Future research should further develop the current methodology to widen the sampling process, also in terms of testing its effectiveness in identifying the divergence between strategic objectives and success of an innovation initiative. Furthermore, future research should investigate why such divergence appears, and how the failure in aligning strategic priorities and innovation processes could be corrected for. Future efforts should aim at further

identifying best practices in successful innovation and should contribute to developing a more general framework for successful innovation implementation. The area of sustainability offers a fertile ground where to test such innovation analytical framework.

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APPENDIXES

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Appendix 2 - Table used for the ranking

Objective	Action 1	Innovation1	Explanation/ comments	Action 2	Innovation2	Explanation/ comments
	Relevance action	Success ranking		Relevance action	Success ranking	
1. Landlord function						
1.1. Protect the port ecosystems						
1.2. Ensure environmental sustainability of the economic activities linked to the port						
1.3. Create optimal space allocation and green recreational areas						
1.4. Include environmental considerations in the selection and management of tenants and in the selection of cargo traffic or ship fleet						
1.5. Provide adequate waste reception facilities						
1.6. Attention for sustainable construction methods when building infrastructure						
1.7. Ensure the use of space is optimised in master planning						
1.8. Include a environmental considerations in the planning and execution of connectivity policy and infrastructure						
1.9. Adaptation to climate change						
2. Regulatory function						
2.1. Regulate environmental matters within the port						
2.2. Implement national/regional/global environmental regulation						
2.3. Monitor pollution, including noise and emissions						
2.4. Sanction/prescribe emergency measures						
2.5. Allow/prohibit activities within the port						
2.6. Reward/punish port operators over/under performing against specific environmental goals						
2.7. Share information with reference to environmental compliance						
3. Operator function						
3.1. Minimise impacts from operations						
3.2. Improve energy efficiency and energy conservation within the port						
3.3. Ensure operators include environmental considerations in the selection and management of subcontractors						
4. Community manager						
4.1. Share information/increase visibility of green activities						
4.2. Ensure coordination of environmental activities						
4.3. Market the port as green						
4.4. Ensure environmental awareness among employees of both the port authority and the port operators						
4.5. Stimulate and facilitate port users in adopting green practices						
4.6. Sustainable resource management						

TABLES

Table 1 – Landlord function.

Linked "Green objectives"	*Explanation*
Protect the port ecosystems	Protect the ecosystem in the port or neighbouring the port, including access channels, dredging, integral water management, soil, beaches, nature areas, etc.
Ensure environmental sustainability of the economic activities linked to the port	Limit the negative environmental effects of port economic activities, such as fisheries, tourism, cargo handling, power generation etc.
Create optimal space allocation and green recreational areas	Manage the balance between areas dedicated to economic activities and areas aimed at natural preservation or recreation
Include environmental considerations in the selection and management of tenants and in the selection of cargo traffic or ship fleet	Formulation of contracts and tendering agreements as well as overall policy aiming at limiting certain types of cargo or certain types of ships
Provide adequate waste reception facilities	Provision of waste reception facilities, waste management and adequate waste recycling
Attention for sustainable construction methods when building infrastructure	Include specific provisions in the construction specification of infrastructure
Ensure the use of space is optimised in master planning	Avoid as much as possible unnecessary use of space, or visual intrusion, community severance in the planning and development of port infrastructure
Include a environmental considerations in the planning and execution of connectivity policy and infrastructure	Development of hinterland transport strategies, including modal shift, congestion, traffic management, road, rail, etc. infrastructure
Adaptation to climate change	Any action taken to account for climate change induced impacts such as weather disruptions, flooding, etc.

Source: own compilation.

Table 2 – Regulatory function.

Linked "Green objectives"	***Explanation***
Regulate environmental matters within the port	Port/harbourmaster regulation concerning pollution, waste management, energy efficiency, and any other environmental issues
Implement national/regional/global environmental regulation	Translate national/regional/global regulation into port regulation
Monitor pollution, including noise and emissions	Definition, adoption and use of any metrics aiming at monitoring external effects of port activities, such as air pollution, noise, water pollution, congestion, etc.
Sanction/prescribe emergency measures	Regulate with reference to emergency measures related to external effects of port activities, such as air pollution, noise, water pollution, congestion, etc. but also oil and dangerous substances spills.
Allow/prohibit activities within the port	Port/harbourmaster regulation prescribing what activities can be performed within the port areas
Reward/punish port operators over/under performing against specific environmental goals	Incentives and penalty schemes either within lease contracts or as voluntary actions, either at a port specific level or among various ports (e.g. Green-award)
Share information with reference to environmental compliance	Regulatory requirements to publish environmental reports, or to make such information available to the port authority, delegated agencies, or the public

Source: own compilation.

Table 3 – Operation function.

Linked "Green objectives"	*Explanation*
Minimise impacts from operations	Any technical or operational action aiming at minimising the external impacts from operation such as air pollution, noise, water pollution, congestion, accidental oil and other substances spills
Improve energy efficiency and energy conservation within the port	Any technical or operational action aiming at reducing the energy consumption within the port, or the shift towards renewable forms of energy
Ensure operators include environmental considerations in the selection and management of subcontractors	Any contractual terms and conditions that aim at limiting the impacts from activities performed by subcontractors

Source: own compilation.

Table 4 – Community function.

Linked "Green objectives"	*Explanation*
Share information/increase visibility of green activities	Any action aiming at improving visibility of environmental information and/or any green project or action
Ensure coordination of environmental activities	Any action aiming at improving information exchange among actors and stakeholders with the objective of harmonising or coordinating activities
Market the port as green	Marketing and communication activities improving the environmental sustainability of the port
Ensure environmental awareness among employees of both the port authority and the port operators	Policy, campaigns, actions and activities targeting employees of the port authority, operators and delegated agencies with the objective of increasing environmental awareness or greener behaviours
Stimulate and facilitate port users in adopting green practices	Guidelines, handbooks, support activities, workshops etc. aiming at stimulating and facilitating the adoption of new technologies or environmental practices
Sustainable resource management	Any action aiming at facilitating recycling, scarce resource conservation (e.g. water, metals) and closing material loops within the port and along the chains involving the port

Source: own compilation.

Table 5 – Innovation success ranking.

Objective		Frequency of score					Prevailing score
	TL	1	2	3	4	5	
1. Landlord function:							
1.1. protect the ecosystems in the port or neighbouring the port	12	17%	0%	42%	17%	25%	3
1.2. ensure environmental sustainability of some of the economic activities linked to the port (e.g. fisheries, tourism,…)	11	9%	36%	18%	9%	27%	2
1.3. create green recreational areas	12	58%	17%	17%	8%	0%	1
1.4. include environmental considerations in the selection and management of tenants and in the selection of cargo traffic or ship fleet	11	18%	9%	36%	27%	9%	3
1.5. Provide adequate waste reception facilities	8	63%	13%	0%	25%	0%	1
1.6. Attention for sustainable construction methods when building infrastructure	8	38%	0%	25%	13%	25%	1
1.7. Ensure the use of space is optimised in master planning	8	63%	0%	25%	0%	13%	1
1.8. include environmental considerations in the planning and execution of connectivity policy and infrastructure	8	25%	13%	13%	38%	13%	4
1.9. Adaptation to climate change	8	38%	13%	13%	38%	0%	1;4
2. Regulatory function							
2.1. Regulate environmental matters within the port	11	27%	18%	18%	18%	18%	1
2.2. implement national/regional/global environmental regulation	10	30%	20%	30%	0%	20%	1;3
2.3. monitor pollution	10	20%	10%	30%	20%	20%	3
2.4. sanction/prescribe emergency measures	10	80%	20%	0%	0%	0%	1
2.5. allow/prohibit activities within the port	11	45%	27%	18%	9%	0%	1
2.6. reward/punish port operators over/under performing against specific environmental goals	11	36%	18%	9%	27%	9%	1
2.7. share information with reference to environmental compliance	11	36%	9%	9%	9%	36%	1;5
3. Operator function							
3.1. ensure minimisation of impacts from operations	10	10%	10%	40%	10%	30%	3
3.2. ensure energy balance within the port	11	27%	9%	27%	27%	9%	1;3;4
3.3. Ensure operators include environmental considerations in the selection and management of subcontractors	6	33%	0%	50%	17%	0%	3
4. Community manager							
4.1. share information/increase visibility of green activities	10	10%	10%	50%	0%	30%	3
4.2. ensure coordination of environmental activities	11	9%	9%	45%	27%	9%	3
4.3. market the port as green	11	9%	0%	18%	45%	27%	4
4.4. ensure environmental awareness among employees of both the port authority and the port areas	11	9%	27%	36%	18%	9%	3
4.5. Stimulate and facilitate port users in adopting green practices	6	0%	17%	33%	50%	0%	4
4.6. Sustainable resource management	6	17%	17%	33%	33%	0%	3;4

Source: own compilation.

Table 6 – Objective relevance with respect to selected actions.

Objective		Frequency of score					Prevailing score
	TL	1	2	3	4	5	
1. Landlord function:							
1.1. protect the ecosystems in the port or neighbouring the port	11	18%	0%	45%	18%	18%	3
1.2. ensure environmental sustainability of some of the economic activities linked to the port (e.g. fisheries, tourism,…)	10	0%	30%	10%	40%	20%	4
1.3. create green recreational areas	11	64%	18%	0%	18%	0%	1
1.4. include environmental considerations in the selection and management of tenants and in the selection of cargo traffic or ship fleet	11	9%	27%	18%	9%	36%	5
1.5. Provide adequate waste reception facilities	8	63%	13%	13%	13%	0%	1
1.6. Attention for sustainable construction methods when building infrastructure	8	38%	0%	0%	38%	25%	1;4
1.7. Ensure the use of space is optimised in master planning	8	63%	0%	13%	25%	0%	1
1.8. include environmental considerations in the planning and execution of connectivity policy and infrastructure	8	25%	25%	25%	25%	0%	1
1.9. Adaptation to climate change	8	38%	25%	13%	13%	13%	1
2. Regulatory function							
2.1. Regulate environmental matters within the port	11	18%	9%	9%	27%	36%	5
2.2. implement national/regional/global environmental regulation	10	30%	10%	30%	10%	20%	1;3
2.3. monitor pollution	10	20%	20%	20%	10%	30%	5
2.4. sanction/prescribe emergency measures	10	80%	0%	20%	0%	0%	1
2.5. allow/prohibit activities within the port	11	36%	18%	18%	18%	9%	1
2.6. reward/punish port operators over/under performing against specific environmental goals	11	27%	9%	36%	0%	27%	3
2.7. share information with reference to environmental compliance	11	36%	9%	18%	18%	18%	1
3. Operator function	0						
3.1. ensure minimisation of impacts from operations	11	9%	9%	18%	36%	27%	4
3.2. ensure energy balance within the port	11	27%	0%	36%	27%	9%	3
3.3. Ensure operators include environmental considerations in the selection and management of subcontractors	6	33%	0%	67%	0%	0%	3
4. Community manager							
4.1. share information/increase visibility of green activities	10	0%	10%	50%	10%	30%	3
4.2. ensure coordination of environmental activities	11	9%	9%	55%	27%	0%	3
4.3. market the port as green	11	0%	0%	27%	36%	36%	3;4
4.4. ensure environmental awareness among employees of both the port authority and the port areas	11	9%	36%	27%	18%	9%	2
4.5. Stimulate and facilitate port users in adopting green practices	7	0%	14%	43%	29%	14%	3
4.6. Sustainable resource management	6	17%	17%	33%	17%	17%	3

Source: own compilation.

Table 7 – Comparison of action and innovation ranking prevailing scores (mode) and homogeneity indexes.

Objective	Action		Innovation	
	Mode	H	Mode	H
1. Landlord function:	22%	18%	11%	17%
1.1. protect the ecosystems in the port or neighbouring the port	3	12%	3	12%
1.2. ensure environmental sustainability of some of the economic activities linked to the port (e.g. fisheries, tourism,…)	4	13%	2	6%
1.3. create green recreational areas	1	34%	1	25%
1.4. include environmental considerations in the selection and management of tenants and in the selection of cargo traffic or ship fleet	5	6%	3	6%
1.5. Provide adequate waste reception facilities	1	31%	1	35%
1.6. Attention for sustainable construction methods when building infrastructure	2.5	19%	1	11%
1.7. Ensure the use of space is optimised in master planning	1	35%	1	35%
1.8. include environmental considerations in the planning and execution of connectivity policy and infrastructure	1	6%	4	7%
1.9. Adaptation to climate change	1	7%	2.5	15%
2. Regulatory function	29%	13%	0%	15%
2.1. Regulate environmental matters within the port	5	6%	1	0%
2.2. implement national/regional/global environmental regulation	2	5%	2	8%
2.3. monitor pollution	5	3%	3	3%
2.4. sanction/prescribe emergency measures	1	60%	1	60%
2.5. allow/prohibit activities within the port	1	4%	1	14%
2.6. reward/punish port operators over/under performing against specific environmental goals	3	10%	1	6%
2.7. share information with reference to environmental compliance	1	4%	3	10%
3. Operator function	33%	21%	0%	13%
3.1. ensure minimisation of impacts from operations	4	6%	3	10%
3.2. ensure energy balance within the port	3	10%	2.7	4%
3.3. Ensure operators include environmental considerations in the selection and management of subcontractors	3	45%	3	23%
4. Community manager	17%	14%	50%	14%
4.1. share information/increase visibility of green activities	3	20%	3	20%
4.2. ensure coordination of environmental activities	3	24%	3	12%
4.3. market the port as green	3.5	17%	4	14%
4.4. ensure environmental awareness among employees of both the port authority and the port areas	2	6%	3	6%
4.5. Stimulate and facilitate port users in adopting green practices	3	14%	4	23%
4.6. Sustainable resource management	3	3%	3.5	9%

Source: own compilation.