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Innovation ecosystems in ports: a comparative analysis of Rotterdam and Valencia

Jonas Mendes Constante^{1*} , Peter W. de Langen² and Salvador Furió Pruñonosa¹

*Correspondence:
jmendes@fundacion.
valenciaport.com

¹ Valenciaport Foundation,
Valencia, Spain

² Copenhagen Business School,
Frederiksberg, Denmark

Abstract

The term ‘innovation ecosystem’ has become popular among stakeholders involved in innovation. The core idea is that innovation does not thrive through isolated actions of individual companies, but rather depends on a broad array of interrelated actors, institutions and policies. In this paper, we apply the concept of innovation ecosystems to ports by first providing a theoretical overview of its components and then comparing the efforts to build such an ecosystem in the port cities of Rotterdam and Valencia. Our main findings are as follows. First, the importance of innovation for the ability of ports to continue to create ‘value for society’ is widely acknowledged. Second, research and development (R&D) activities in both Rotterdam and Valencia are relatively limited and the dominant innovation challenge is the early application of new technologies developed outside the ports industry. Third, a ‘systemic approach’ is required to understand the innovation ecosystem in ports, given the strong interrelations among companies in the port and the need for broad coalitions to implement new technologies. Fourth and fifth, human capital formation and research cooperation, respectively, play a central role in improving the port innovation ecosystem. Finally, the ecosystem in Rotterdam is ‘distributed and connected’ while Valencia is more centralised.

Keywords: Port innovation ecosystem, Port transition, Port of Rotterdam, Port of Valencia, Port innovation governance, Port innovation

Introduction

Ports face huge transition challenges due to emerging trends such as the energy transition, the transition towards a circular economy, urbanisation (which puts more pressure on land use in port areas), digitalisation and the transition of manufacturing activities, often summarised under the label ‘Industry 4.0’. The core challenge in ports is to ensure that the port cluster (i.e. the port activities including logistics and industrial activities in the port area, see De Langen 2004) remains economically vital and sustainable.¹ Success in developing and applying innovations is central to this transition. Hence, innovation

¹ Sustainable is used in the broad sense, i.e. able to continue to create value for users and society at large without negatively impacting future generations.

plays a hugely relevant role in creating value for ports as clusters of economic activity and key components of global commodity chains (Ng et al. 2014; Acciaro et al. 2018).

Innovations in ports have the potential to provide significant value to society. Benefits range from higher safety levels, infrastructure and logistic chain resilience, reductions in emissions and other negative externalities, to more publicly accessible waterfronts and creation of job opportunities for local communities. This societal value justifies strong support for and involvement in efforts to promote innovation, by national and/or regional government as well as the port authorities or port development companies. The transition challenges faced by port clusters are related to the transition challenges of the port region. Most ports are located in metropolitan areas (Hall & Jacobs 2012), which often aim to diversify their economic base and to promote innovation performance, amongst others in the port cluster (see for instance an OECD report, Merk 2013).

Innovation in ports is especially complicated for two main reasons, both stemming from the fact that ports are clusters of interrelated activities, with a need for coordination and cooperation between firms (De Langen and Haezendonck 2012).

First, port clusters consist of a diverse set of *operational* activities. Port activities include terminal operations, transport operations, warehousing, manufacturing and associated services (see De Langen and Haezendonck 2011) across numerous supply chains (such as food, energy, automotive, steel and so on). Ports, as well-connected nodes for freight flows, offer location advantages for capital intensive operations, but less so for advanced services and R&D activities.² This is radically different to the widely-studied 'high-tech clusters' and is an impediment to an effective innovation ecosystem in a port. Second, given the international nature of the abovementioned activities in ports (transport, logistics, manufacturing and trade), subsidiaries of *multi-national corporations* (MNCs) make up the vast majority of firms active in port clusters. These MNCs have operations in various countries and are embedded in a variety of port clusters. As a consequence, in most port clusters, very few of the involved firms (or sometimes none at all) are headquartered in the port. In addition, as is the case with MNCs in general (see Patel and Pavitt 1991), MNCs that are active in ports clusters generally have one central R&D department, often located in their home country. Thus, in most port clusters, the vast majority of its MNCs have no local R&D departments, and often not even an allocated 'budget' for innovation. This also represents an impediment to a local innovation ecosystem (Pavitt and Patel 1999).

The large number of interrelated firms in the port industry (for instance, Rotterdam's port cluster has well over 2000 firms; see De Langen 2004), requires intense cooperation between them to achieve the successful implementation of innovative technologies. Therefore, as argued in Hall et al. (2013) and Cahoon et al. (2013), innovation does not thrive through isolated actions of individual companies, but rather depends on the joint actions of a broad array of interrelated actors (firms, research institutes, incubators, governments, industry associations). Furthermore, innovative output deeply depends on institutional factors such as risk-taking culture, regulation, and attitudes towards cooperation.

² Even the port-related advanced producer services (such as maritime insurance, port engineering and so on) tend to locate in 'world cities' drawn by the talent pool and presence of other advanced producer services (see Jacobs et al. 2010).

Given the importance of understanding innovation in port clusters and the relevance of cooperation, the objective of this paper is to advance the understanding of how innovation in ports can be advanced. We do so by applying the concept of innovation ecosystems to ports. This paper makes two contributions to the body of knowledge on innovation in ports. First, we develop a framework for studying the innovation ecosystem in ports, defining the different actors and components that are relevant for the innovation process. Second, we use this framework to analyse the port innovation ecosystem of two major European ports: Valencia and Rotterdam. This analysis is carried out through a detailed analysis of available documents as well as semi-structured interviews with professionals active in innovation in both ports. The results allow a comparison between these two port innovation ecosystems, their characteristics and strengths and weaknesses. These findings are relevant for other ports aiming to improve their innovation ecosystem.

The rest of the paper is structured as follows: we first provide a theoretical overview of the concepts of innovation systems (IS), the application of IS components in the port context. Next, we describe efforts to improve/develop the innovation ecosystem in the ports of Rotterdam and Valencia. The paper ends by presenting the conclusions as well as avenues for further research on innovation ecosystems in ports.

Innovation systems: a short overview of the literature

The analysis of the interactions amongst actors in relation to innovation has a long history. The *innovation system* approach was designed to describe, understand and explain the structure, processes, and dynamics of innovation (Edquist 2004).³ In line with this approach Storper (1997) and Kirat and Lung (1999) points out that innovation is localized and locally embedded, being the benefits deriving from localization advantages and spatial concentration (rules, culture, norms) the key elements that can foster innovation in a particular region. The successes of some clusters or regionally concentrated networks of SMEs (Asheim and Gertler 2004) explains the development of a regional innovation system approach as an instrument to promote innovation (Almeida et al. 2011; Kramer et al. 2011). However, Edquist (2004) acknowledges systems of innovation may be supranational, national and/or regional.

Collective learning process between firms (startups, SMEs, MNCs, knowledge providers (research centres, universities, etc.), financing (venture capital, public funding, etc.), and education and training centers are widely accepted as one of the main pillars of an innovation system. (Cooke 2000; Chesbrough 2003).

The concept of innovation ecosystems extends and adds to the innovation system approach (see Stam 2015 and Suominen et al 2019). The term innovation ecosystem was defined by Jackson (2011) as the “complex relationships that are formed between actors or entities whose functional goal is to enable technology development and innovation”. Although it is still fairly new, the innovation ecosystem concept has become popular both in the academic literature (Cohen 2006; Adner and Kapoor 2010; Isenberg 2010; Feld 2012) and managerial case studies (Rao and Jimenez 2011; Tweedie 2014).

³ This regional approach is complementary to the widely used sectoral perspective (Malerba, 2004).

The existing studies on innovation ecosystems use the term in several different contexts, as pointed out by Oh et al. (2016) in their literature review. A shared characteristic of all these approaches is a focus on interactions and mutual learning between the different stakeholders (Moulaert and Sekia 2003). Based on the results obtained by the previous studies using the term ecosystem, Oh et al. (2016) point out that adding the prefix 'eco' to the 'innovation system' approach adds nothing of substance and introduces a flawed analogy to natural ecosystems. However, they recognise new insights from 'ecosystem' studies: perhaps most importantly the greater emphasis on differentiated roles of firms; for instance, with a distinction between the focal firms and firms that occupy niche positions in the ecosystem (Frenken et al. 2014; Raven 2005).⁴ In line with this approach, various studies focus on the activities of a central actor (or a group of central actors) to 'orchestrate' innovation ecosystems (see Autio 2022 and Daymond et al 2022). As discussed below, this approach is especially relevant for 'port innovation ecosystems'. However, to our knowledge, no previous studies have systematically analysed such port innovation ecosystems, (or regional innovation systems in ports⁵) even though the importance of innovation in ports is widely acknowledged (Bjerkan and Seter 2019; Jun et al 2018).

A port innovation ecosystem

The analysis of innovation in port clusters benefits from a framework that incorporates these port-specific characteristics discussed in section one. Based on the innovation ecosystem literature (section two), we identify the components of a 'port innovation ecosystem'. To our knowledge, this is the first paper to identify and discuss the components of a port innovation ecosystem. In doing so, we draw on existing insights into innovation ecosystems, while at the same time adjusting this concept to the specifics of port clusters. For instance, a port innovation ecosystem needs to account for linkages with port hinterlands, whether regional, national or international (see Witte et al. 2017).⁶

We argue that the main distinguishing characteristic of a port innovation ecosystem is the focus on *absorptive capacity*. Given the characteristics of port clusters (diverse, specialised in operations, with predominantly local branches of MNCs), R&D activities in port clusters are limited and the dominant innovation challenge is the (early) application of new knowledge and technologies developed outside the port cluster such as digitalisation (see Del Giudice et al 2022 for a review of the relevance in ports) recycling technologies, (see de Langen and Friese 2019, for the relevance for ports) autonomous freight transport, biobased chemicals, and smart grids. Absorptive capacity can be defined as the capacity to absorb, enhance, diffuse and exploit knowledge from extra-cluster sources (this definition is adapted from Cohen and Levinthal 1990). Thus, absorptive capacity is determined both by the formation

⁴ We agree with Oh et al. (2016) that the term innovation ecosystem is ambiguous. In addition, specifically for ports, the 'systemic' dimension may be as important as the analogy to biological ecosystems.

⁵ Cahoon et al (2013) did describe the role of the port in the process of assessing regional innovation challenges and developing institutions to address those challenges, but these authors do not undertake an analysis of the components of a regional innovation system.

⁶ We argue that the use of partially overlapping units of analysis can be instrumental for a better understanding of innovation networks and performance. Thus, our focus on 'port innovation ecosystems' is not at odds with studies on 'urban innovation ecosystems' in general.

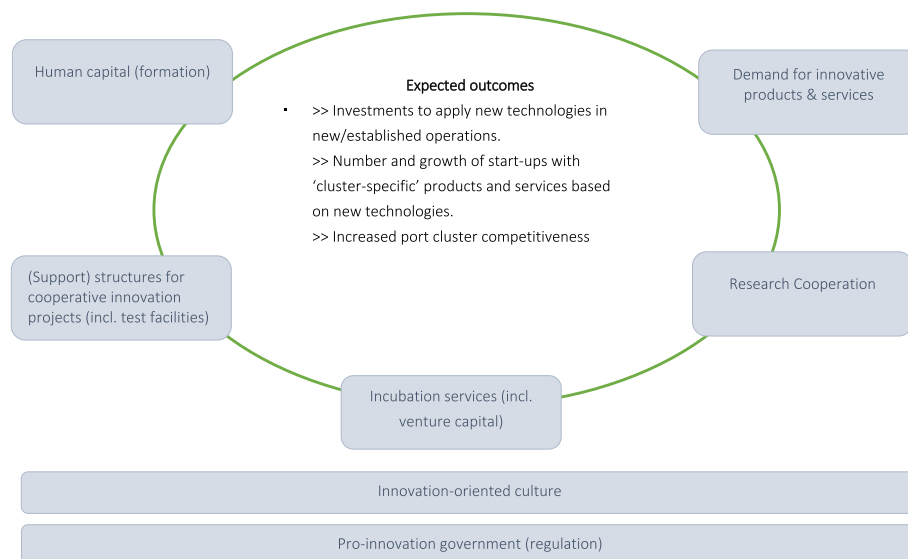


Fig. 1 Components of the innovation ecosystem for port clusters

of linkages with extra-cluster sources of knowledge *and* the intra-cluster knowledge system (see Bell and Albu 1999). The focus on absorbing (and in the process enhancing) knowledge rather than creating knowledge implies that measures of the innovation performance of a port differ from the indicators commonly used for innovation clusters, such as R&D spending and number of patents (see Nicotra et al. 2014). We argue that for ports the most relevant indicators are (1) investments made in the port cluster to apply new technologies in new or established operations (this reflects the absorption of new technologies) and (2) the number and growth of start-ups with 'cluster-specific' products and services, based on new technologies. The focus on start-ups is because they are critical in transferring new technologies to established industries; see Benson and Ziedonis 2009). Especially for operationally focused firms, working with external start-ups is a way to absorb new technologies. In addition, the innovation performance of start-ups depends on their embeddedness in the innovation ecosystem (Zhang et al 2021) and (the growth of) start-up activity is generally regarded as an important performance indicator of innovation ecosystems (Isenberg 2014).

The level of absorptive capacity of a firm “determines its ability to recognize and assess the potential value of external knowledge and then to assimilate and integrate it into innovation activities” (Nicotra et al. 2014, pp. 90). This firm-level definition is broadly in line with that of Giuliani (2005), who considers the absorptive capacity of a cluster and suggests that it is directly related to the growth of the cluster and depends on the “capacity of firms to establish intra- and extra-cluster knowledge links”. The author proposes a classification of basic, intermediate and advanced absorptive capacity for each cluster/system.

Based on a review of studies on innovation ecosystems, we have developed the framework depicted in Fig. 1, which is specifically tailored to ports, as clusters where the main challenge is enhancing the *absorptive capacity*. To the best of our

knowledge, this is the first framework in the academic literature that identifies the components of an innovation ecosystem specifically aiming to increase the absorptive capacity of operationally focused and mostly foreign-owned firms embedded in a local cluster. In our view, this framework is well suited for all ports that embark on 'smartport' initiatives to promote innovation (see Molavi et al 2020). Each of the components is briefly discussed below.⁷

The two components at the bottom can be regarded as the 'environment' of a port innovation ecosystem. They are largely external to the port cluster and dependent on regional and national institutions. An innovation-oriented culture has been widely described as a relevant part of an innovation ecosystem (see e.g., Uhlaner and Thurik 2007). For instance, education plays an important role in the attitudes towards risk-taking and starting up a company. Likewise, the success of the well-documented shift towards 'open innovation' approaches partly depends on cultural factors (see Van de Vrande et al. 2009). In addition, governments influence innovative activity. The term 'pro-innovation government (regulation)' encompasses both the role of governments in removing regulatory obstacles to innovative products and services, and their potential role as a user of innovative products and services (a government role detailed in Witte et al. 2017).

Five components shape the port innovation ecosystem. These five components depend on the actions of the firms in the port cluster. They relate to absorptive capacity as they deal with the ability to create connections, including the quality of its human capital, and its potential for establishing valuable external linkages (Giuliani 2005). The two items in the middle of the circle represent, as noted in the previous section, the main outcome of the innovation ecosystem in ports: investments in new technologies and the growth of start-ups offering port-specific products & services (see Witte et al. 2017).

The first of the five components is *human capital (formation)*, which is widely acknowledged to be a relevant factor. Given the strong local effects of universities and other educational institutions (on both the quality of the local workforce and the ability to attract outside talent), the formation of human capital through education is highly relevant (see Carayannis and Campbell 2009).

Second, *market demand for innovation* is a relevant driver of innovative activities. This demand for innovative products and services often comes from a specific group of companies, called lead users (Von Hippel 1986). In the port context, the challenge is to identify and cater for the (latent) demand for innovation from MNCs that are active in the port.

Third, *research cooperation* plays a key role. This component encompasses cooperation in research, as well as efforts of cluster-oriented initiatives to disseminate research results to companies.⁸ University R&D has a proven impact on regions' innovation

⁷ Such a framework is needed as the concept of an innovation ecosystem has not, to our knowledge, been applied to analyse ports. In line with Isenberg (2011), we acknowledge that the distinction between components is somewhat arbitrary, as the number of underlying items is much larger and these are 'conveniently' (in the words of Isenberg) grouped together in a number of components. We have opted to visualize the components in a 'circle' showing their loose association with various phases in an innovation cycle, starting with culture and human capital, through development to launch and growth.

⁸ This factor is not included in Isenberg's framework, even though it is widely acknowledged to be an important determinant of innovation and start-up success.

performance (Woodward et al. 2006) and links between SMEs and research institutes improve the innovation performance of SMEs (Zeng et al. 2010).⁹ Cooperation in research helps make sense of information and knowledge (see Weick et al. 2005).

Fourth, *incubation services* are relevant. These incubation services (see Bruneel et al. 2012) include financing and monitoring, and general enhance the survival rate and growth of new start-ups. A key aspect is the support for internationalisation, as most commercialisation opportunities lie outside the ecosystem (Autio et al. 2017).

Lastly, *support for innovative projects*, especially for SMEs (Bougrain and Haudeville 2002) is a part of the port innovation ecosystem. This support goes beyond applied research, covering the financial and organisational support needed to carry out innovative projects. Test facilities for new products, services and technologies (in some cases referred to as 'labs' or 'living labs') are included in this component. Such labs can be regarded as places where various stakeholders collaborate for the creation, prototyping, validating, and testing of new technologies, services and products in real-life contexts (see Leminen and Westerlund 2017).

The above components reflect the existing literature on innovation ecosystems as well as more industry-oriented efforts to integrate all the relevant aspects in a holistic framework such as those developed by Isenberg (2011) and WEF (2013).¹⁰

As discussed above, these components describe a 'spatially delimited' port innovation ecosystem. However, its international integration has become necessary for local knowledge development (Bathelt et al. 2018). Knowledge is transmitted through networks, both social networks (Malmberg and Maskell 2002) and ties within or between organisations (Lorenzen and Mudambi 2013). Thus, for each of the five components, it is crucial to understand the role of international networks.

In addition, in ports, a port authority or port development company (PDC, see De Langen 2020) has a central role. PDCs are increasingly responsible for developing a 'key-stone' strategy (Iansiti and Levien 2004, De Langen 2020), which entails providing an advanced platform where other companies can thrive. Various port authorities/PDCs have stressed the importance of innovation in their strategic plans and aim to enhance innovation in their ports, suggesting that they regard the port innovation ecosystem as part of the platform they offer. As stated by Cahoon et al. (2013), a port authority is a key player in shaping an innovation ecosystem. In recent decades, the port authority's role has evolved from being 'only' the infrastructure manager to taking on other roles such as port cluster developer (see, among others, Verhoeven and Vanoutride 2012). More recently, it seems that modern port authorities are acting as innovation ecosystem orchestrators, fostering and orchestrating innovation opportunities for the port community. Thus, the role of the PDC in each of the components described above merits attention.

⁹ However, various studies find that policy instruments aimed at strengthening ties between SMEs and universities are often not fully successful (Zeng et al. 2010).

¹⁰ Isenberg's (2011) approach focuses on start-ups and lists six components. In comparison, our framework includes 'research cooperation'. In addition, we use 'incubation services' while Isenberg uses 'finance'. Unlike the World Economic Forum's eight components (WEF, 2013), we merge 'human capital' and 'education and training' into one component. While the specific terms that are used differ, overall, our framework is similar to the one developed by WEF.

Table 1 Components of a port innovation ecosystem and its relevant research questions

Component	Research questions
Innovation oriented culture	Are there port-specific prizes and awards or events and institutions aimed at promoting an innovative/entrepreneurial culture?
Pro-innovation government	Does the port authority implement or support any initiatives to bolster the innovation performance of the port cluster?
Human capital (formation)	Do educational institutions in the region provide port-oriented education programmes? Does the port community support such education programmes, and if so, how? Are there structural ties to promote the uptake of graduates in the port?
Demand for innovative products & services	Does the port authority or port development company cooperate with suppliers in (open) innovation partnerships? Are there structures through which MNCs share their demand for innovative products with the port community?
Research cooperation	Is there established cooperation between research institutes and the port community? Does such research cooperation involve international extra-cluster partners?
Incubation services	Are there incubation services for start-ups with products and services aimed at port-related industries? Do such incubation services help start-ups with contacts and contracts in the business community? Do such incubation services help start-ups with establishing international ties? Are there structures in place to promote start-ups from universities?
Support for innovative projects	Are there specific test facilities, labs or other testbed partnerships for the port cluster? Has the port authority developed specific instruments to support innovative projects of port companies?

Analysing the port innovation ecosystem in Valencia and Rotterdam; method

Rotterdam and Valencia were selected as they are large ports. Rotterdam is Europe's largest port by volumes handled, (Port of Rotterdam 2022), while Valencia is Spain's largest container port by volumes handled and the largest container port in the Western Mediterranean (Puertos del Estado 2022). Furthermore, both ports have a substantial track record and ambition regarding innovation (Port of Rotterdam 2022 and Fundación Valenciaport 2020). Finally, in both ports a state-owned port development company (often also termed port authority) plays a central role in shaping the port innovation ecosystem. This similarity makes the ports more comparable.

Based on the framework presented in the previous section, we have developed the research items presented in Table 1. Following the systemic approach applied in the analysis of the innovation ecosystem, we focus on identifying the presence of structures/institutions, and do not analyse or describe specific innovation projects (as is done in Vanelslander et al. 2016 and Acciaro et al. 2018, for example). In this paper, we do not provide a detailed description of all activities going on in each of the components in both ports and their effects on innovation outcomes. Such an approach would be too extensive to report in one article and also would deviate the analysis away from the 'systemic focus' that is central in this paper. Thus, when translating the components discussed above into research items, we have focused on presence (or absence) of institutions with a key role for each of the components of the port innovation ecosystem.

Regarding human capital, the focus is on human capital formation through port-specific education institutions. Furthermore, given the importance of international knowledge networks, we assess the inflow of international students in educational programmes oriented towards the port cluster.

Regarding the role of lead users, the role of the port authority as a potential lead user is assessed, as well as efforts to let MNCs share their demand for innovative products within the port community. Concerning research cooperation, we identify the presence of a structure for cooperation and assess the openness of such a structure to ‘extra-cluster’ knowledge partners. With respect to incubation, we determine whether there is an incubation service and evaluate its role in establishing intra- and extra-cluster relations. Finally, we identify the presence of initiatives such as ‘living labs’ or ‘testbeds’ focused on developing a network of innovative companies around a specific technology, and evaluate policies implemented by the port authority or the regional or national government to foster investment in innovative projects in the port. Table 1 shows the research items that guide the empirical analysis presented in the next chapter.

We answer the research questions for each of the components, provided in Table 1, for the ports of Rotterdam and Valencia.

This comparative analysis is mainly based on desk research. All relevant documents, such as annual reports, documents related to the long-term ambitions of both ports (such as the Port Vision from Port of Rotterdam) and news items and press releases were analysed in detail. In addition, relevant organisations in the port innovation ecosystem were identified and their organisational structure was analysed. In a second stage, interviews were held with key port community stakeholders with a direct experience in shaping the port innovation ecosystem—five in Valencia and five in Rotterdam—to confirm and expand the findings from the desk research.¹¹ The interviews were held from June 2020 to September 2020. The interviews with experts were semi-structured, based on the framework (Fig. 1) together with the questions (Table 1). Table 2 details the interviewed experts as well as the public reports included in the desk research.¹²

The port innovation ecosystems in Rotterdam and Valencia

In this section, the port innovation ecosystems of two large European ports, Rotterdam¹³ and Valenciaport, are described.

In both ports, the importance of innovation is widely acknowledged. In Rotterdam’s Port Vision, developed jointly by the PDC, the port business community and relevant public administrations, the innovation ecosystem is frequently mentioned, for instance as follows:

The quality of the innovation ecosystem is a decisive factor in the digital and energy transitions and in the efforts to widen the portfolio. The ambition to be an international leader requires an innovation ecosystem in which all the components are world-class. Those components include a training infrastructure, the encouragement

¹¹ Access to these experts could be arranged as two of the authors work at Fundación Valenciaport and are personally involved in Valencia’s port innovation ecosystem, while one of the authors worked at Port of Rotterdam and was later directly involved in the development of their port vision. We acknowledge that besides the advantages of this direct involvement there are also risks associated with direct involvement of scholars in the study matter (see Flick 2019). We mitigated the disadvantages through a focus on publicly available sources and interviews.

¹² The websites, press releases and news items are not included in table 2, but when directly referred to, these are included in the references.

¹³ The components that together constitute the Rotterdam innovation ecosystem, as defined by Port of Rotterdam, the municipality of Rotterdam and various other partners, is provided at <https://www.portofrotterdam.com/en/doing-business/port-of-the-future/innovation/innovation-ecosystem>.

Table 2 interviewed experts and used public documents

	Rotterdam	Valencia
Interviewed experts	Former director of Incubator Port XL; Director of research collaboration platform Smartport Professor at Erasmus University Rotterdam Former head of department Corporate Strategy Port of Rotterdam Scientific Director Dinalog, Dutch knowledge and innovation partnership in logistics	Strategy Director of the Port of Valencia IT Director of TIBA, the leading freight forwarder company in Valencia area Professor at University of Valencia Director of Incubator Insomnia Logistics Manager of MSC Valencia Manager of COSCO Valencia
Used documents	Annual Report Port of Rotterdam Port Vision 2030, Port of Rotterdam Port of Rotterdam Innovation Monitor, Erasmus University Rotterdam Innovation in the Rotterdam Port Region, Report Erasmus University Rotterdam Scaleup & startup monitor and the innovation ecosystem in the Rotterdam the Hague Metropolitan Area, report by Erasmus University Rotterdam	Annual Report Port of Valencia Valenciaport Innovation Plan Fundación Valenciaport Annual Report

of entrepreneurship, targeted recruitment of talent, research, test facilities, support for start-ups and scaleups, the availability of venture capital, regulations that encourage innovation, suitable meeting and working places for innovative entrepreneurs, and high-quality demand for innovative products and services (Port of Rotterdam, 2019,¹⁴ p. 16, translation by authors).

In Valencia, the development of the innovation ecosystem is a key action in the port cluster's innovation plan, which underlines the critical role played by institutions in leading port clusters, aligning the port community and establishing a common agenda on the development of human capital, research and innovation (Fundación Valenciaport 2020).

Innovation-oriented culture

In Rotterdam, port innovation is fostered through the Port Innovation Barometer, conducted by Erasmus University Rotterdam.¹⁵ In addition, various events aim to showcase the benefits of engaging in innovative projects, including the World Port Hackathon and the SmartPort Summit.¹⁶

In Valencia, the focus on innovation is fostered through FV,¹⁷ a centre for applied research, innovation and training that serves the port logistics cluster. It is a private, non-profit entity created in 2004 by the Port Authority of Valencia (PAV) with other key port cluster companies, associations, universities, the city, the region and other institutions in the port community. Its creation was a deliberate effort to promote the innovation culture in Valencia's port cluster.

¹⁴ See <https://www.portofrotterdam.com/nl/havenbedrijf/over-het-havenbedrijf/havenbedrijf-in-de-samenleving/havenvisie-rotterdam>

¹⁵ See <http://smart-port.nl/project/haven-innovatie-barometer-2016/>.

¹⁶ In addition, the Dutch Maritime Awards are held annually. This is a national initiative, which is not specifically linked to Rotterdam, but given the importance of the greater Rotterdam area in maritime technology, the organisation is located in Rotterdam.

¹⁷ See <http://www.fundacion.valenciaport.com>

FV's main goals are promoting innovation and providing training for the continuous professional development of the port-logistics community's human capital. FV supports the port-logistics community by developing innovation projects, encouraging cooperation within the sector and supporting the internationalisation of the companies in the cluster.¹⁸

However, one of the interviewees, the director of an incubator in Valencia, highlights the need for change in the culture of innovation. In addition, he also points out a "provincial mentality" in the city of Valencia, which may prove to be an obstacle. "There is a desire for short-term results, but a long-term vision and greater collaboration are needed," he explains. His view is corroborated by a Valencian freight forwarder director, which points to the "limited culture of innovation" as the main problem in the sector in Valencia.

To contribute to this situation and foster the open innovation culture, in 2021 FV and PAV initiated OpenTop,¹⁹ which aims to provide a full package of supporting services (including the realization of hackathons) that connects corporates and entrepreneurs willing to develop new products and services for the maritime and logistics sector.

Likewise, in Rotterdam, the former director of the accelerator (PortXL, see below) also argues that the most important next step is to increase the level of ambition and aim to develop innovation projects aimed at international success, rather than 'just' aiming to address local challenges.

Although respondents mention challenges, the interviews also reveal the general perception of improvements in the sector, both in the public and private sectors, in both port clusters. A director of the port authority of Valencia reports greater interest from port cluster companies in innovation issues, while the director of the centre for industry-oriented research in Rotterdam points out that the need for innovation and research is widely acknowledged.

Pro-innovation government

Government impacts the port innovation ecosystem as a regulator as well as through innovation policies. The most pressing issue in Rotterdam concerns waste regulation, which may impede the introduction of innovative methods to re-use waste; for instance, the transport of products categorised as 'waste' is regulated. To prevent unnecessary regulatory hurdles, the inspection agencies together with the industry association developed a 'walk-in desk' where potential problems were solved at short notice.

In addition, the central, regional and municipal government all embrace the importance of innovation for sustainable economic development and acknowledge the relevance of the sectors included in the port cluster. For instance, a major component of the Dutch innovation policy is the focus on nine so-called 'top sectors,' which include chemical, energy, logistics, and water & maritime sectors, all of which have a strong presence in Rotterdam's port complex. Public investment in R&D partially focuses on these sectors, and fiscal measures to promote innovation are in place.

¹⁸ FV develops projects for PAV ports as well as internationally, in more than 60 countries, mainly in the Mediterranean, Europe, Asia and Latin America.

¹⁹ See <https://opentop.es/>

In Valencia, the central and regional government acknowledge the relevance of the sectors in the port and logistics cluster. The development of the innovation ecosystem in Valencia is attributed, by a director of the PAV, to several initiatives driven “by the local government, institutes and universities”. For instance, the Ministry of Public Works developed the Innovation Plan for Transport and Infrastructures 2018–2020 with four strategic axes: user experience (mobility), intelligent platforms (including intelligent port), intelligent corridors, and sustainability. At the regional level, the Valencian Agency for Innovation designs and coordinates the innovation strategy of the region and promotes the development of the overall Valencian innovation system. Three of the five strategic innovation committees developed by this agency have a direct link with the port cluster (circular economy, sustainable mobility and enabling technologies for the new economy).

Human capital (formation)

Various educational institutions have developed programmes tailored to meet the needs of Rotterdam’s port cluster. Important programmes include ‘Urban, Port and Transport Economics’, ‘Logistics Management’, ‘Maritime Economics & Logistics’ (all Erasmus University Rotterdam); ‘Industrial Ecology’, ‘Transport, Infrastructure and Logistics’ and ‘Hydraulic Engineering’ (all Technical University Delft); and Logistics Management (Rotterdam University of Applied Science). All of these programmes are open to international students. Overall, the annual inflow of students in port-oriented masters programmes is more than 250, of which more than 100 are foreign students.

Most of the education programmes mentioned above are supported by the port business community. For instance, the Maritime Economics and Logistics programme has a ‘corporate network’ of well over 50 companies. The port business community is also active through guest lectures in all these programmes. Finally, there is a variety of initiatives aimed at showcasing interesting job opportunities in the port and promoting the uptake of graduates in the port, including the ‘talent dinners’ organised to match graduates to companies. This is an annual event aimed at students and young professionals, where prizes are awarded for the ‘port talent’ (a young professional), the best ‘port idea’ (an idea for an innovative solution) by a student, and the best port-related thesis.

In Valencia, FV serves as a reference training centre for the port logistics community. Since 2004, more than 10,000 students have participated in its courses and seminars. Universities such as the Universidad Pontificia Comillas, University of Valencia and the Polytechnic University of Valencia have partnered with the FV in these initiatives. The port business community is actively involved in the different programmes through guest lectures and internships.

FV training activities have been developed over the years by its training department, which was founded in 1992, the year of the first Masters in Port Management and Intermodal Transport. FV has also provided this programme in Brazil, Panama, Argentina and Colombia.

Demand for innovative products & services

Port of Rotterdam (PoR), the landlord port development company, exerts a demand for innovation. PoR has an innovation partnership with a number of engineering companies,

with which it works on 'futureproof port infrastructure'. PoR also provides funding for new and innovative initiatives to reduce waiting times specifically for inland modes, a persistent problem (See van der Horst and De Langen, 2008). In addition, PoR acts as a launch customer for some of the start-ups in the PortXL program (see below). PoR is also actively involved in international innovation partnerships, for instance with Singapore's Maritime & Port Authority (MPA). MPA and PoR have an ongoing innovation partnership in which they work together in areas such as maritime cybersecurity, LNG bunkering and Next Generation Vessel Traffic Management Systems.

Similar to the role of PoR as player with a demand for innovative products, some MNCs also coordinate their demand for innovation through PortXL or through one of the various 'labs' for open innovation. Many MNCs are embedded in the innovation ecosystem and serve as lead users. These firms are active in the research phase (for instance APMT in SmartPort), the testing phase (for instance IBM and Shell in RAMLAB), and incubation (for instance Van Oord and Vopak in PortXL).

In Valencia, even though the port authority and some key MNCs coordinate the demand for innovative services, FV mostly identifies innovation needs and demands through interaction with the port community. FV, supported by the PAV²⁰ and the Valencian Agency for Innovation, recently developed an R&D plan for the logistics community of the Port of Valencia. The plan includes the creation of an Innovation Committee as a stable structure for monitoring the actions defined in the plan. The committee comprises representatives from different groups that make up the cluster and will be responsible for the follow-up and promotion of the innovation plan, as well as for its periodic update.

According to a professor at the University of Valencia and a director of the PAV, the fact that the PAV plays a central role in proposing collaborative innovation projects can be considered a 'second best solution' made necessary by the lack of a strong demand for innovative products and services.

After the establishment of OpenTop's incubator and acceleration program in 2022, the orchestration of innovation demands gained a new traction. Corporates in the port community were invited to present their challenges to these programs.

Research cooperation

In Rotterdam, the organisation SmartPort is specifically aimed at developing industry-oriented research. SmartPort is a joint venture between the Port of Rotterdam Authority, Deltalinqs, the Municipality of Rotterdam, TNO, Deltares, Erasmus University and Delft University of Technology. SmartPort provides financial and organisational support for setting up projects and has a portfolio of nearly 50 projects, with total funding of over 9 million euros.²¹ SmartPort was set up in 2014 and partners have extended their commitment until 2023, with two new knowledge partners (TNO & Deltares) joining in 2018. The lead researchers in the SmartPort 'Roadmaps' are embedded in international networks, but SmartPort has not established structural international cooperation. The

²⁰ In Valencia, the port authority, as the main shareholder of the FV, provides an annual subsidy of around 1.5 million euros to support the development of an annual, jointly-developed action plan. Most of it is devoted to the co-financing that European research and innovation projects often require.

²¹ See <http://smart-port.nl/en/about-smartport/>

director of SmartPort underlines the ‘systemic’ nature of the innovation challenges and thus regards open data sharing and the involvement of various academic disciplines as a condition for support and funding by SmartPort.

In Valencia, FV is central to research cooperation and has developed 242 R&D projects with local, national and international partners, which have led to new hardware solutions, simulators, industrial prototypes and software solutions for the management and planning of logistics chains. The partner companies that have taken part in these projects cover the whole transport chain.

The type of projects fostered and carried out by FV has gradually changed in response to clients’ and partners’ demands. While 80% of projects in 2004 were basic research, currently such research accounts for only 10% of the activities; meanwhile, the innovation projects (aimed at prototype development) and applied research projects account for more than 60% of the total.²² FV plays a leading role in developing R&D proposals for public funding, mostly European funds.

According to one of the interviewees for this research paper, without FV, the sector’s level of innovation would be very low.

Incubation services

In Rotterdam, various incubation services are provided, the most prominent being PortXL. PortXL selects and helps accelerate innovative start-ups, partly by providing pilot contracts with ‘corporates’ that are also active in PortXL. PortXL is active internationally, in Singapore, Houston and Antwerp. This provides additional value for the start-ups in the program.

An additional incubator is the ‘Rotterdam Port Fund’, an independent investment fund comprising the PoR, a bank, and various private partners, which invest venture capital in companies attempting to grow through innovative products and services.²³

In Valencia, OpenTop (direct supported by FV and PAV) is the initiative responsible for the incubation and acceleration programs. FV in the past has also partnered with local technology incubators for specific calls or projects. Puertos del Estado, the entity responsible for the Spanish port system, launched a fund (called Ports 4.0) to finance the incubation of start-ups related to port-logistics. The OpenTop model includes an additional financing instrument (venture capital fund) to fund startups with high potential technologies and solutions for the maritime, port and logistics sector. However, as the funding service although is planned, has up to date not been put in place.

According to a PAV director, the possibility of participating with seed capital in start-ups is being considered. She also mentions that “a great success story of a Valencian logistics start-up” would be a key factor in securing stakeholder support for the sector’s innovation initiatives.

²² As an example, the SAURON project deals with physical security and cybersecurity for protecting European ports; the STM VALIDATION project aims to test the concept of Sea Traffic Management for shipping; and the Transformation Transport project analyses the transformative effects of Big Data on the logistics market.

²³ See <http://www.rotterdamportfund.com/about?lang=en>

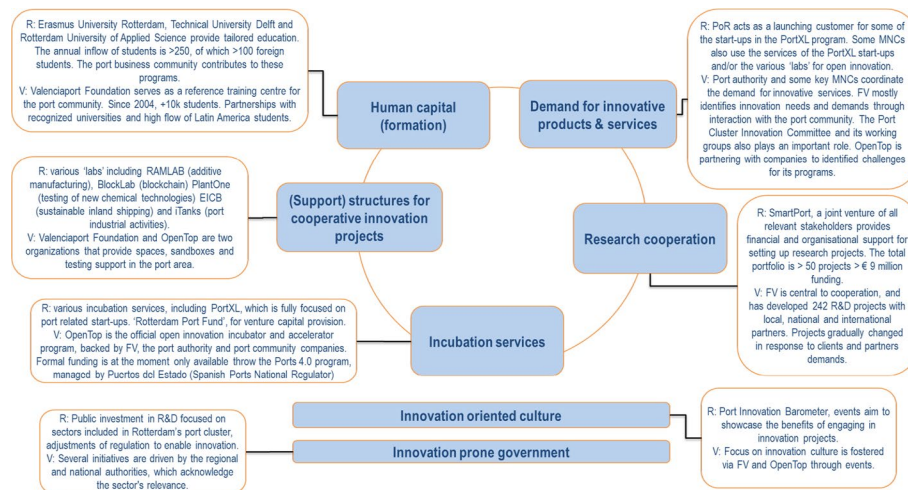


Fig. 2 The innovation ecosystem components in Rotterdam and Valencia

Support for innovative projects

Rotterdam has various ‘labs.’ The first is a lab for developing and testing additive manufacturing (3D printing) applications for the port cluster, called RAMLAB. RAMLAB is an initiative of the PoR, InnovationQuarter and RDM Makerspace, which has developed a strong community of users and producers of additive manufacturing.²⁴ Second, a lab dedicated to blockchain technology, called BlockLab, has been developed by the PoR and the city of Rotterdam, with educational institutions, STC, the Rotterdam University for Applied Sciences and TU Delft as partners. BlockLab started in 2017 and provides support for building and testing ‘use cases’ of blockchain technology. Third, PlantOne provides a site where companies can test new chemical technologies. Benefits include shared use of facilities, availability of utilities (such as steam, compressed air, nitrogen and water) and a smooth environmental permit (as the site already has a permit). Fourth, specifically for inland shipping, the organisation EICB provides financial and organisational support for innovations by SMEs, partially through support in attracting external funding.²⁵ Finally, iTanks provides support for innovative projects in the port, with a focus on industrial activities.²⁶

In Valencia, FV, PAV and EIT Climate-KIC implemented in 2018 an initiative called ‘Super Labs Ports.’ It provides a variety of spaces inside the PAV offices for users who are willing to co-create, design and implement innovative solutions to address climate change in the maritime and port sector. This space is now managed by OpenTop for its innovation incubators and acceleration programs. The initiative also supports startup’s tests within the port area and connections with other labs in the Valencia region. Figure 2 below presents the an overview of the innovation ecosystem components in Rotterdam and Valencia.

²⁴ See <https://ramlab.com/>

²⁵ See <https://www.eicb.nl>.

²⁶ See <https://itanks.eu>

Conclusions

Based on a review of the literature on innovation ecosystems and a case study of two leading European ports, the following conclusions can be drawn:

First, the literature review shows that given the mega-trends that are affecting the port industry, the importance of innovation for ports' ability to continue to create 'value for society' is widely acknowledged. The cases demonstrate the increasing focus on and investments in innovation, both in Valencia and Rotterdam.²⁷

Second, the literature review has led to the conclusion that the drivers of a port's innovation performance differ from those in 'high tech' clusters. Given the specific characteristics of port clusters—specialised in operations and dominated by multinationals companies—R&D activities in port clusters are relatively limited and the dominant innovation challenge is the early application of new knowledge. The focus on absorbing new knowledge rather than creating knowledge implies that measures of a port's innovation performance differ from the indicators commonly used for innovation clusters.

Third, in ports, a 'systemic approach' is required for understanding the innovation ecosystem. A huge number of players are involved in smooth port operations. All of these independent public and private players form a port cluster tied together by a common interest in seamless and sustainable logistics. Thus a 'systemic approach' towards innovation is relevant in ports. The framework developed in this paper can be used to assess a 'port innovation ecosystem'. The cases of two large European ports (Rotterdam and Valencia) confirm the relevance of these components and the show efforts in both ports to strengthen each of the components of the port innovation ecosystem.

Fourth, the cases of Rotterdam and Valencia show significant efforts to improve the human capital (formation) component. In Rotterdam, university-led initiatives supported by the port community (especially MNCs) attract students from around the world. In Valencia the port foundation stands as a training and education hub for the port community, attracting leading professionals from the Spanish and Latin American ports sector, and connect students with cluster's companies. This finding may be relevant for other ports aiming to improve their port innovation ecosystems.

Fifth, in both ports efforts to strengthen research cooperation also play a central role. In both ports, one institution (SmartPort in Rotterdam, and FV in Valencia) plays a central role in establishing research cooperation. In both ports, significant public funding goes into this institution, and in both ports, the aim is to work with a 'multiplier model' as the institution is tasked with developing/coordinating proposals to attract additional public funding. This suggests that given the specific characteristics of ports, institutions to support research cooperation may be valuable for other ports as well.

Sixth, the port innovation systems of Rotterdam and Valencia are different. Rotterdam's ecosystem could be characterised as 'distributed and connected' while Valencia's port innovation system is more centralised, with a central role of FV in all the seven components. Further analysis both into the explanation of such differences and their effects on outcomes is both academically and practically relevant. The main difference in

²⁷ While we have not studied other ports in detail, it is clear from public information (vision documents, website items, annual reports, etc.)—that many other ports, such as Hamburg, Algeciras, Antwerp, Barcelona and Genoa, also increasingly invest in innovation.

the port innovation ecosystem paths of Valencia and Rotterdam was that Rotterdam had a prior focus on incubation services and a greater availability of venture capital funds. A deeper analysis of the relevance of cultural aspects for explaining these differences could lead to relevant new insights, especially for the relevant public stakeholders (see Arundel et al 2015) who did find cultural differences in public administration affect innovation outcomes).

Finally, avenues for further research on innovation ecosystems in ports are numerous, given that this is still an unexplored field in port management.²⁸ The following streams of research are relevant. First, how can the innovation performance of ports be measured and compared? Further research may be directed at developing methods to compare the use of new technologies in port clusters or to compare the success of innovation projects across ports, potentially building upon methods to evaluate port innovation projects used in Acciaro et al. (2018) and Vanelslander et al (2019). Second, in line with general work on location choices of start-ups and scale ups (see Curran et al. 2016) how do innovative start-ups and scale ups make location choices and how important (if at all) is the port innovation ecosystem in these location choices? Third, using insights from other industries, (see e.g., Mudambi 2008), the question how do the leading MNCs in the ports industry organise R&D, and how do they decide on the level of involvement in the innovation ecosystems in the ports in which they are active.

Abbreviations

EICB	Expertise- en InnovatieCentrum Binnenvaart
FV	Fundación Valenciaport
IS	Innovations systems
MNC	Multinational corporation
OECD	Organisation for Economic Cooperation and Development
PAV	Port Authority of Valencia
PDC	Port Development Company
PoR	Port of Rotterdam
R&D	Research and development
RIS	Regional innovation system
SME	Small and mid-size enterprise
WEF	World Economic Forum

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JMC and SFP were responsible for the interviews in the Port of Valencia. PWDL was responsible for the interviews and secondary data collection in the Port of Rotterdam. All authors reviewed and approved the final manuscript.

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Declarations

Competing interests

The authors declare that they have no competing interests.

²⁸ In addition to further research on ports, we also note that the framework developed in this paper is specifically designed for understanding the innovation system of a cluster of firms that are mostly foreign-owned and focused on operations (as opposed to exploration). While the analysis in this paper has focused on ports, applications of this framework to similar clusters, such as logistics clusters or a chemical clusters could also yield relevant new insights.

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