EMERGING ICT AND PORT COMMUNITY SYSTEMS: A SURVEY OF SCIENTIFIC LITERATURE

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ABSTRACT
Emerging information and communication technologies (ICTs) were identified as the main pillar of the fifth-generation ports. Ports' issues were solved with stand-alone ICT solutions adopted by each stakeholder. Today new benefits and challenges are connected with the introduction of shared emerging ICTs among port stakeholders, generating efficiencies in the solution of shared decisions. One of the tools that supports the interaction between port stakeholders is the Port Community System (PCS), which has been the object of numerous studies in recent years aimed at defining its benefits in terms of reducing the costs, or disutilities, of port operations. The paper presents a state of the art relating the Port Community Systems (PCS), in which a classification of scientific papers selected from the scientific databases present on the web is reported according to some classification criteria. The results of this analysis show that in the last decade the study and implementation, even experimental, of the PCSs inside ports has undergone a relevant acceleration. This is due to the fact that for port communities, being equipped with the PCS is now of strategic importance since its presence increases the competitiveness of the whole port. The work is useful both for port planners and for technicians of port manufacturing equipment companies, because it allows to identify the potential advantages obtained with the introduction of advanced evolutions of PCS.
Keywords: fifth-generation port, port community systems (PCSs), emerging ICT, IoT.

1 INTRODUCTION

Since ancient times ports are the gate for the exchange of freight and people. The evolution of ports may be described according to the concept of generation (see [1]–[3] and the references included). The first-generation of ports was built close to the cities, and it was the dominant model for centuries [4], [5]. The second-generation of ports was built close to industrial areas to support the supply of raw materials and final products of industrial plants in the second half of the 20th century [6], [7]. The third-generation of ports emerged after 1980s, principally due to worldwide diffusion of container and to the growing requirements of the international trade, becoming generators of added value. A set of publications presents the structural factors of a European container hub port in transition towards a third-generation. The limits and weaknesses of the port area and the general actions to reduce the port costs were identified in Russo and Chilà [8], [9]. The external structural factors of the port generated by the relationship with the hinterland and with research and development centers have been studied respectively in Russo et al. [10] and Russo and Rindone [11]. The internal structural factors of the port in relation to three industrial sectors (logistics, agri-food and mechanics) were analyzed in Musolino and Chilà [12], Musolino and Rosaria Trecozzi [13] and Musolino et al. [14]. The introduction of a SEZ in a third-generation port was described in the following publications. The publications by Russo et al. [15] and Musolino et al. [16] present respectively the modelling framework and the aggregate economic impact of a SEZ on the port and its hinterland. The territorial attractiveness and the urban planning connected with the activation of SEZ is presented in Musolino and Panuccio [17], while the impact of SEZ on the system of higher education and research is described in Rindone et al.


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[18]. The study by Pellicanò and Trecozzi [19] shows a comparison of times connected to the export/import of goods for European countries having similar technical-administrative structure. The fourth-generation of ports raised in the last two decades, when ports adopted a cooperative attitude with closer ports (see Russo and Musolino [20] and references included). Today fifth generation of ports is characterized by the use of emerging information and communication technologies (ICT) in the interaction between port stakeholders. The introduction of emerging ICT inside ports has shown that ICT is a further pillar of port competitiveness alongside the traditional ones as the port closeness to the cities or to the industrial plants, and the capacity to generate added value, the dotation of infrastructures and shared services (see Russo and Musolino [21], [22] and references included).

Financial and information transactions inside ports are supported by the adoption of stand-alone ICT systems. They increase the efficiency of the individual port operations associated the stakeholders, but they do not increase the efficiency of port operations that imply shared decisions between the stakeholders. Shared decisions are relevant in the three main flows present in the port: cargo, information and financial. In terms of cargo flow, cargo management involves the exchange of data connected to port operations (e.g. dock and yard operations). By considering the thousands of handled containers on ships, the complexity increases exponentially, and the traditional approach to container management generates a low degree of capacity utilization of ships and port infrastructures.

The dissemination of potentialities offered by emerging ICT was made possible by the capabilities of Port Community Systems (PCSs). The role of emerging ICT in the ports was presented in Russo and Musolino [21], in terms of assessment of stakeholders' utilities in sharing decisions about port operations. Some case studies of emerging ICT in ports operations are reported in Russo and Musolino [22], with a focus on internet-of-things. The impact of PCS characteristics on port performance is presented in Caldeirinha et al. [23], while a structured literature review on PCSs through the definition of the "wave" concept is reported in Moros-Daza et al. [24]. Finally, in Carlan et al. [25], it was developed a cost–benefit framework to assess the impacts of PCS on port competitiveness. PCSs aim to increase cooperation between port stakeholders, and consequently to increase their competitiveness compared to other ports. Cooperation is possible by integrating procedures, and by sharing of information and documents.

In the above context, the paper presents a survey regarding the scientific literature on PCSs and regarding the interactions that PCSs could have with emerging ICT. In particular, the interactions between PCSs and the Internet of Things (IoT), or Physical Internet (PI), are examined. A selection of "OpenAccess" publications was made from the scientific literature existing in some academic web portals. The selected publications were classified according to the following criteria: (prevalent) typology of content, PCS evolution (wave), port work-area, and geographical distribution of case studies [26].

The remaining part of the paper is articulated in four section. Section 2 describes the survey on the scientific literature about PCS and emerging ICT. Section 3 presents the distributions of the selected publication according to each selected criterion. The conclusions and the research perspective are reported in the last section.

2 SURVEY DESCRIPTION

The survey on the scientific literature about PCS and emerging ICT was conducted in two steps:

- Step I: search of scientific publications in the main academic web portals, according to specific keywords;

- Step II: classification of selected publications according to identified criteria.

Step I concerned the search of scientific publications, that included papers published in scientific journals, chapters of volumes, papers in conference proceedings.

The search was conducted through some keywords (or a combination of keywords) such as: “Port Community System”, “Physical Internet” and “Port”, and “Internet of Things” and “Port”.

Preliminarily, one of the most popular academic web portals, “ResearchGate”, was queried. It emerged that, by using the above keywords, the number of selected publications were very high. A more selective and in-depth search was performed on “Google Scholar”, “Scopus” and “Web of Science” portals. Finally, a specific search was conducted in scientific journals belonging to the “Transportation” Q1-quartile of Scimago, finding very few publications.

As the keywords could recall publications that marginally deals with PCS and emerging ICT, papers without a specific focus on these issues were discarded, reducing the set of scientific publications to 170. This set was analysed and a further selection was made of publications that explicitly put in relation the PCS with port transport and logistics topics, selecting 53 publications. A final selection was made by introducing the criterion of “OpenAccess”, obtaining a number of 43 scientific papers.

Step II concerned the classification of selected publications according to the following criteria.

a. *Contents*
   - Literature review (LT); state of the art on the topic of PCS and emerging ICT;
   - Theoretical (TH); theoretical approaches based on transport system model (TSMs);
   - Framework (FR); conceptual frameworks, or procedures, concerning the PCS, or concerning the use of emerging ICT within the PCS;
   - Case study (CS), case study of PCS and emerging ICT implemented inside ports;
   - Experimental data (ED), experimental data concerning the use of PCS, that allow a quantitative analysis of the impacts of PCS on port operations and on port stakeholders.

b. *PCS wave (emerging ICT)*

   The wave IV, according to Moros-Daza et al. [24], is characterized by the experimentation, and in cases the implementation, of PCS with the following emerging ICT categories: blockchain and artificial intelligence. The wave V, according to Russo and Musolino [22], is characterized by the initial experimentation (and in cases of implementation) of PCS with the enabling technologies already of wave IV, together with internet of things and big data technologies.

   According to the above considerations, the following two main classes are identified:

   - PCS-wave IV, if the publication deals with one of the following categories of emerging ICT (the relationship with PCS may be explicitly mentioned or not):
     - BlockChain (BC), to support for documental and financial transactions;
     - Artificial Intelligence (AI), to support forecasting and decision-making on maritime and land transport operations, as well as to automate some repetitive (albeit sensitive) manual activities, such as loading/unloading goods;
   - PCS-wave V, if the publication deals with one the following category of emerging ICT (the relationship with PCS may be explicitly mentioned, or not):

- Internet of Things (IoT), to support the identification of "objects" present in ports and facilitate the exchange of information between them (IoT can be defined as a "transversal" technology, as it is related to the other emerging technologies);
- Big data (BD), that enrich information from traditional data, in terms of volume and variety; and that are so quickly elapsed to improve the representation of real phenomena and their modelling.

A one more general class was identified, named PCS, which gather publications that deal with PCSs (potentially belonging also to I, II and III wave). However, it was not possible to associate the PCS described to any specific wave.

c. *Port work-area [21], [25]*
   - Logistics and transport (L&T): logistics and transport of goods from land to sea (and vice versa) by road and rail transport (short and long distances);
   - Customs (CU): import and export, administrative and custom control processes;
   - Navigation (NA), management and planning of ship arrivals and departures;
   - Dangerous goods (DG), traffic of dangerous goods, and related procedures.

d. *Geographical distribution of case studies:* North Europe (NE); Mediterranean (ME); Asia: Middle and far East (AS); North America (NA); South America (SA).

Table 1 shows the results of the classification of selected publications according to the above identified criteria.

3 ANALYSIS OF SELECTED PUBBLICATIONS

The section presents the distributions of the selected publication according to each selected criterion. It is worth noting that the selected publications generally belong to more than one identified category, as shown in Table 1. In this paragraph, however, a further filter has been introduced by identifying the prevalent type of contribution inside the publication.

3.1 Contents

The most numerous class is the CS one (44.4%), followed by FR (35.6%) one, as shown in Fig. 1. This is due to the fact that several studies are based on case studies of application of one single class of emerging ICT inside ports, followed by theoretical architectures (which can be explicitly related to a PCS in the publication, or not). The publications with theoretical content (TH) are a small percentage (5.8%), but not of lesser importance. The lack of theoretical publications is due to the fact that, both model specifications and experimental data, ED, (3.8%) related to PCS and emerging ICT are lacking. At the end, a number of publications, based on a literature review, are presents (11.1%).

3.2 PCS wave (emerging ICT)

The solution of stakeholders' interactions in port operations is a crucial point for increasing the overall port efficiency [21]. In this context, there are single categories of emerging ICT in the selected literature, which operate in relation with PCSs. There are no, or in any case no identifiable, ports that have internalized all emerging ICT inside a PCS.

The most common class of emerging ICT is IoT (39.5%), followed by BC (25.6%) and Big Data (20.9%), as showed in Fig. 2. IoT is currently one of the most developed emerging ICT, able to bring tangible benefits in port operations. BC is a technology that still does not

Table 1: Classification of selected publications according to the identified criteria.

Criteria	Publications				
Contents	LT	TH	FR	CS	ED
	[21] [23] [28] [29] [30] [32] [33] [34] [35] [38] [40] [44] [45] [46] [47] [48] [49] [51] [53] [54] [56] [57] [59] [63] [64] [67]	[21] [62] [68]	[23] [24] [27] [28] [29] [30] [31] [32] [33] [36] [37] [39] [40] [41] [42] [43] [44] [45] [46] [47] [49] [50] [52] [53] [55] [57] [58] [59] [60] [61] [63] [64] [66] [67]	[23] [27] [28] [30] [31] [33] [34] [35] [36] [37] [39] [40] [41] [43] [44] [45] [53] [54] [55] [57] [58] [59] [62] [68]	[38] [59]
PCS wave (emerging ICT)	PCS	PCS-wave IV		PCS-wave V	
	[24] [27] [28] [30] [32] [34] [35] [41] [46] [47] [49] [50] [52] [53] [54] [55] [56] [57] [58] [64] [65] [66]	BC	AI	IoT	BD
		[21] [36] [37] [44] [45] [51] [53] [54] [59] [62] [67]	[36] [37] [44] [48] [50] [51]	[21] [23] [29] [31] [33] [36] [37] [38] [40] [43] [50] [51] [53] [59] [61] [68]	[21] [23] [29] [33] [36] [37] [44] [61]
Work-area	L&T	CU	NA	DG	
	[27] [28] [29] [30] [31] [34] [35] [37] [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] [51] [52] [53] [54] [57] [58] [59] [60] [61] [64] [65] [66] [67]	[34] [35] [41] [42] [44]	[27] [28] [42] [44]	[34] [41] [44] [34]	
Geographical distributions	NE	ME	AS	NA	SA
	[23] [31] [37] [40] [43] [48] [60]	[23] [27] [28] [30] [35] [37] [41] [42] [43] [50] [52] [53] [54] [58] [59] [64] [65]	[37] [53] [63]	[64]	[36] [55]

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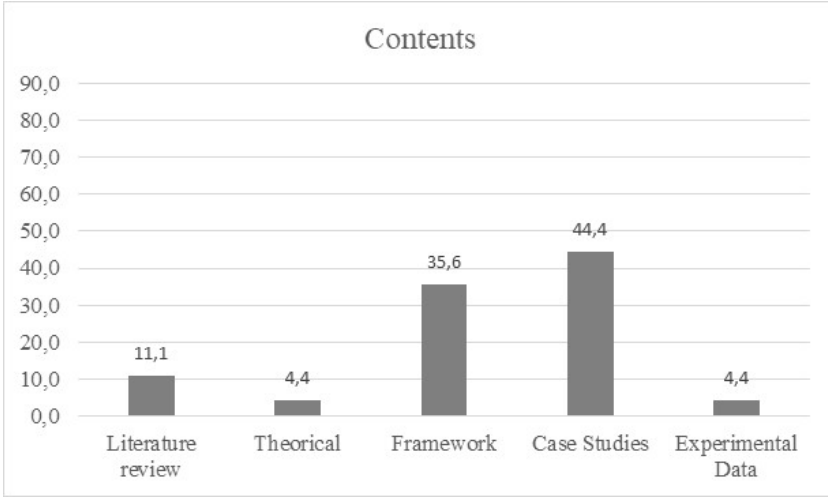

Figure 1: Distribution of selected publications for prevalent type of contents.

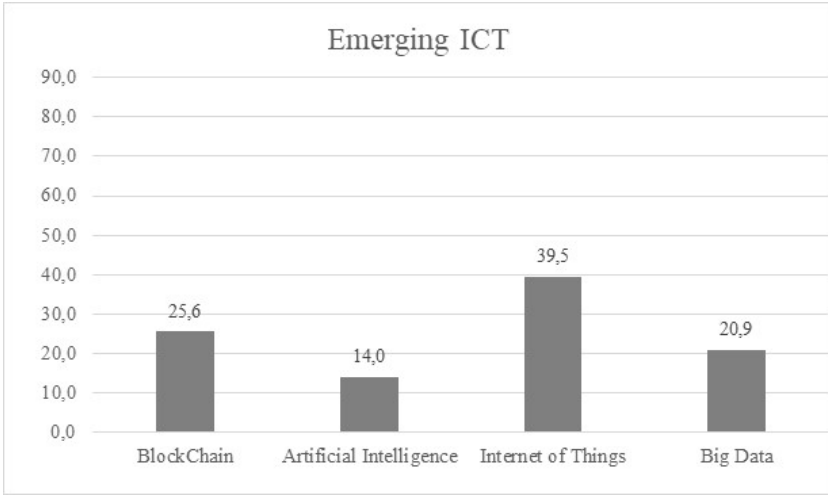

Figure 2: Distribution of selected publications for prevalent class of emerging ICT.

give sufficient guarantees from the point of view of security, and consequently no market applications are expected in the short term (e.g. bitcoin, smart contract). As far BD is concerned, the "cloud computing" represents today a valid solution, but it is not easy to implement, since it involves the information transfer and sharing by port stakeholders within the "cloud".

3.3 Port work-area

As shown in Fig. 3, the great part of the selected publications refers to the work-area "Logistics and transport" (84.8%), followed by the work-area "Custom" (9.1%).

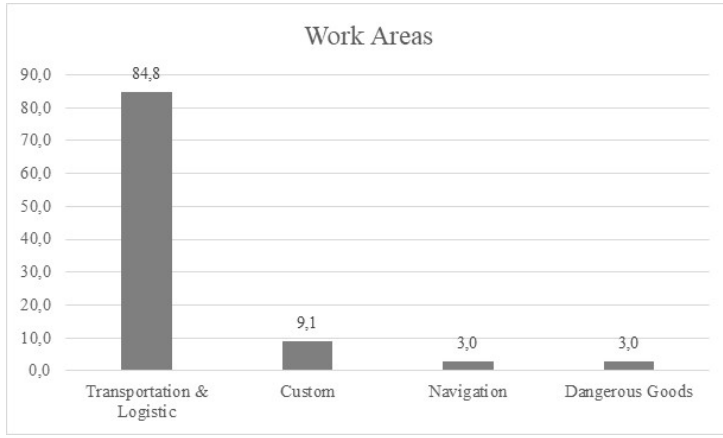

Figure 3: Distribution of selected publications for prevalent port work-area.

3.4 Geographical distribution

A further classification was made in relation to the geographical distribution of the case studies regarding the existing PCS. As showed in Fig. 4, many selected publications report case studies in European ports. The highest percentage concerns Mediterranean ports (40.0%), followed by Northern Europe ports (15.6%). These percentages are due to the fact that many European ports are already equipped by a PCS, as Rotterdam, Hamburg, Antwerp in Northern Europe. The reduced percentage of case studies related to Asian (6.7%) and North American (2.2%) may be misleading, but there is the awareness that both Asian ports (e.g. Shanghai, Singapore, etc.) and North American ones (e.g. Los Angeles, New York/New Jersey, etc.) are also equipped with PCS. There are case studies of PCS and emerging ICT related to South American ports (4.4%), indicating that also these ports are in line with the main ports.

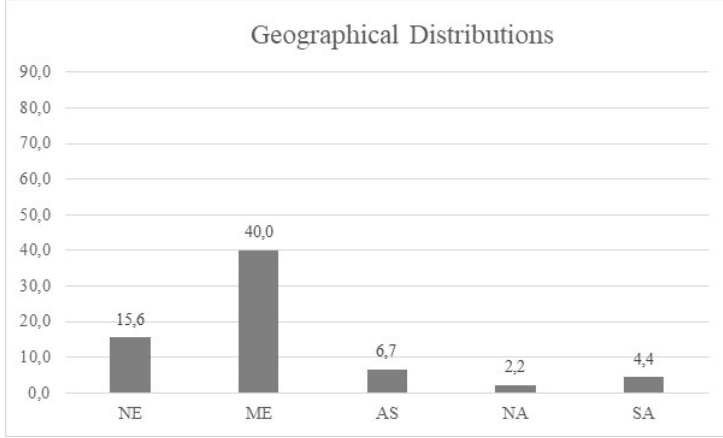

Figure 4: Distribution of selected publications according to geographical areas.

4 DISCUSSION AND CONCLUSIONS

Ports entered nowadays in a generation, the fifth, where benefits and challenges are connected with the introduction of emerging ICTs supporting interactions among port's stakeholders. The potentialities offered by emerging ICT are amplified by means of PCSs, which aim to increase cooperation between port stakeholders, and consequently to increase their competitiveness compared to other ports.

The paper presents a survey regarding the scientific literature on PCSs and the interactions between PCSs with emerging ICT. The survey was conducted in two steps: the search of scientific publications in the main academic web portals and the classification of selected publications according to identified criteria.

The main results of the survey are discussed in the following.

As far as concerns the analysis of single criterion, the "Contents" criterion shows that the greatest number of publications presents conceptual frameworks of PCSs, even if they are not prevalent in the publications. According to the criterion of "PCS wave", there are several publications dealing with PCS from which it is not possible clearly identify the wave. Among the emerging ICTs, the most numerous group of publications concerns the IoT. By considering the criterion of "Work area", the Logistics and transport is the one more studied among the selected publications. At the end, according to the "Geographical distribution" criterion, several publications deal with Mediterranean ports.

As far as concern analysis of combination of criteria, all couples of criteria were compared in order to determine the couple of classes (the "cells" in the Table 1), that have the highest number of shared publications. As result, the following main elements emerge. By comparing the couple of criteria "Contents-PCS wave (emerging ICT)" (excluding the more general category "PCS"), the couple "FR-IoT" presents the highest number of publications in common (12). The comparison of criteria "Contents-work area" identified the couple "FR-L&T" as the one with the highest number of publications in common (25). The comparison "PCS wave-work area" identified the couple "IoT-L&T" as the one with the highest number of publications in common (10). The comparison "PCS wave-geographical distribution" identified the couple "IoT-ME" as the one with the highest number of publications in common (7). The comparison "work area-geographical distribution" identified the couple "L&T-ME" as the one with the highest number of publications in common (16).

The above results show that there is an "ideal line connecting some emerging dots", along with the studies on PCS and emerging ICTs are concentrated. The "dots" are the conceptual frameworks (FR), the IoT technology (IoT), the Logistics and transportation work area (L&T), and the Mediterranean ports (ME). Therefore, the main conclusion is that there is a considerable interest in the combination of L&T with IoT, as core elements of advanced PCSs.

According to the above considerations, the future research could concern the quantitative analysis of the benefits of the IoT, and more generally of emerging ICTs, on L&T work area focusing on the interactions among the different stakeholders. The analysis could concern the quantitative estimation of the utility connected to goods handling and manipulation inside ports, in terms of added value growth and of reduction of port operations costs. The quantitative estimation could be supported by transportation system models (TSM) that incorporate the impacts of the emerging ICTs on port operations, on the stakeholders and on port functions.

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