Port 4.0: Accounting, controlling and reporting tools in the organizational and operational processes for sustainable performance?

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Abstract. This study investigates the main implications of Industry 4.0 within seaports, outlining which role can be played by accounting, controlling and reporting tools, in the information management for making the organizational and operational processes more effective and efficient in meeting the issue of sustainability. Through the literature review on the topic, we analysed accounting, controlling and reporting fields for evidencing how new technologies, specifically Industry 4.0, can make the port industry environmentally sustainable perform through effective information management and consequently the same organizational and operational processes more effective and efficient in the perspective of sustainable performance. The study shows the crucial role paid by new technologies for accounting, controlling, and reporting tools in managing the organizational and operational processes for sustainable smart ports.

Keywords: Port 4.0; Accounting, Controlling, and Reporting Tools; Environmental Sustainability; Organizational and Operational Processes; Environmental Management Accounting.

1. Introduction

Over the last thirty years the seaports aim to increase the effectiveness and the efficiency, especially with respect to sustainability issue. For achieving this goal, the seaports face many challenges and, also, took into account new technologies, typically connected to the Industry 4.0. Specifically, we can observe two major challenges faced by seaports: on one side, the need to quickly respond to Industry 4.0 and, consequently, making strong investments in automation and digitalisation to improve the operational efficiency in their organizational and managerial processes (Heilig *et al*., 2019); on the other side, the seaports have to meet the sustainability

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issue, trying to significantly perform being in line to the triple bottom line of the sustainability, that is the economic, social and environmental sustainability (Tichavska *et al*., 2017; Shipper *et al*., 2017; Lam and Notteboom, 2014; Girard, 2013).

Thus, the seaports have to follow the new rules and instructions from both frameworks, the Industry 4.0 with its new technological instruments and applications (Internet of Things – IoT, Artificial Intelligence – AI, and so forth) and the sustainability model. In some cases, the seaports face many difficulties in being very advanced, following the Industry 4.0 system but, at the same time, the new technologies, also, can represent a very crucial factor in achieving the sustainability goals.

Through the literature review on the topic we analysed the accounting, controlling and reporting fields for outlining how new technologies, specifically related to Industry 4.0, can support the port industry to environmentally sustainable perform making the connected organizational and operational processes more effective and efficient in the perspective of sustainable performance. The study shows the crucial role paid by new technologies for accounting, controlling, and reporting tools in the organizational and operational processes for sustainable smart ports.

The paper is structured as follows: sections 2 and 2.1 focus respectively on the implications of Industry 4.0 on seaports and the need of the same seaports to achieve the sustainability goals. The section 3 investigates the accounting, controlling, and reporting fields with the support of new technologies for sustainable smart ports. Sections 4 provides some final considerations and possible research developments in the future.

2. Port 4.0: Implications for the Organizational and Operational Processes

In the last three decades, the seaports for facing the new challenges derived from the numerous changes occurred in the world, such as the high competitiveness of markets and the increasing innovativeness of the supply and demand, need to adopt the international regulations regarding the organizational and managerial models and information technologies (IT) in the decision-making process. The seaports have to manage specific criticisms concerning "the evolution of the international trade and container throughput, the introduction of ultra-large container vessels, the deep changes of customers' demand, and the development of IT, addressing the same seaports to assume a strategic position as 'hub ports' (Keceli *et al*., 2008: 3). Otherwise, in the last decades, one of the most relevant change occurred within the world, especially the port and maritime industry, concerns the advent and spread of Industry 4.0.

Industry 4.0 (the Fourth Industrial Revolution) presents many implications for the overall business world, especially due to the introduction of new paradigms related to most managerial approaches. After the previous significant industrial revolutions,

Industry 4.0 mainly concerns the combination of different technologies, such as the artificial intelligence (AI), advanced robotics, internet of things (IoT), cloud technology, making deep transformations in the production processes, operations management and in general in the business models within industries. The global supply chain management, including seaports, because of Industry 4.0, is being re-thought, re-designed and re-shaped, by revolutionizing the ways traditionally used for creating value through the new technological solutions adopted. In general, we observe several phenomena recognized as major positive and negative implications of Industry 4.0. The existing contributions in the literature provide significant knowledge about the implications of Industry 4.0 for the future industries (Hofmann and Rüsch, 2017), but less attention is paid to its practical application (Ford, 2015; Drath and Horch, 2014) in terms of effects of new technologies on operations management (OM) (Fetterman et al., 2018; Almada-Lobo, 2016), with focus on the port and maritime organizations.

Industry 4.0 represents the combination of cyber-physical systems, the IoT, and the Internet of Systems: that supports the idea of smart factories in which machines are augmented with web connectivity and connected to a system that can visualize the entire production chain and make decisions on its own. Industry 4.0 is a partial transfer of autonomy, intelligence and autonomous decisions to machines and to the edge, but at the same time supply chain and logistics in Industry 4.0 is very similar, although with different applications, technologies, human and business aspects, and elements. When logistics is considered with the many intermediary steps and the components of the supply chain and intelligent and efficient movement across all these different steps in a holistic way (adding the aspect of autonomy to it), then what types of applications are really possible is quickly evident: from driverless transportation to intelligent containers, smart warehousing, smart ports, smart airports, smart shelves to the human and information exchange in all possible logistical chains and contexts (Oleśków-Szłapka and Stachowiak, 2019).

Also, as per usual it is not just about the technologies, even if newer technologies keep being added, for instance on the level of interfaces, new advancements in artificial intelligence and machine learning, better drones in logistics, the list goes on. It is about the way logistics and the overall supply chain, especially the seaports, meet the needs of all stakeholders, knowing that flexible, smart supply chain decisions, enabled by the human, organizational and technological components of Industry 4.0 and logistics 4.0 make the difference in gaining competitive benefits: but also in surviving in a hyper-connected age where the need for speed is high and regardless of the supply chain, performance and speed are crucial but so is quality. In other words, having a smart container is one thing, but another thing is being able to track what is inside it, where it comes from and in what state it is: then, it is possible to found benefits of a strategic and holistic approach that looks at the value and customer demand (Ismail *et al*., 2017). Thus, the seaports more and more have to adopt IT tools for supporting all their processes, in particular, the requirements related to containerized and passengers traffic. Thanks to new technologies, the seaport users are able to manage data and information in real time about cargo and passenger flows, availability of port facilities, and also IT supports ships and terminals to collaborate

by working together, thus they assume a collaborative orientation as parts of an integrated office infrastructure.

The automation and digital transformation of port operations has become crucial for driving innovation and modernization in seaports (Heilig, *et al*., 2019). Ports acquire new relevant skills and competences responding to the challenges of the new digital era, that is sharing information between all the actors and tracking cargo for reducing uncertainties (Zhou and Benton, 2007), increasing reliability (Panayides and Song, 2009), and improving the coordination in integrated transport processes (Crainic *et al*, 2009; Wiegmans *et al*, 2008). Many contemporary ports show the significant effect derived from the automation and digitalisation that it is possible to name as the generation of smart procedures (Heilig *et al*., 2019), with specific concern of Industry 4.0 and consequently Logistics 4.0, strongly related to the development of cyber-physical systems and IoT infrastructures. Examples of ports which broadly and significantly follow the concepts and tools related to Industry 4.0 defining themselves as smart ports are the following important experiences: The port of Hamburg (Germany)(through a collaboration with SAP and T-Systems it was developed a cloud-based platform to improve traffic flows in the port area); the Maritime Port Authority of Singapore (MPA) (through a collaboration with IBM it was possible to tap big data solutions for improving maritime and port operations).

In this perspective, seaports adopt IT tools for effectively and efficiently carrying out customs control (Long, 2009). Thus, in the seaports which implement IT, all the actors involved, that is terminal operators, port administration, customs, truckers, freight forwarders, carriers, ship agents, and other organization, are electronically linked by the IT systems, make better information and data gathering and sharing within the port community (World Bank, 2007).

In the very articulated and big portfolio of IT implementations, it is possible to mention the port community systems (PCSs) introduced to facilitate the communication process and the development of the inter-organizational relationships among the actors in the port community. Srour and colleagues (2008: 3) defined PCSs as "holistic, geographically bounded information hubs in global supply chains that primarily serve the interest of a heterogeneous collective of port related companies". This definition concerns the heterogeneous companies, mainly the terminal operators, carriers (ocean, road, and rail), freight forwarders, enforcement agencies (i.e. customs), port authorities, various lobby groups (including workers' unions, environmentalists, and other policy makers), and also other shareholders of maritime transportation (Srour *et al*., 2008; Aydogdu and Aksoy, 2015). Moreover, PCSs can be also conceived as "networks which link up the port with all the companies that use it" (Rodon and Ramis-Pujol, 2006), where the focus is on network according to the European Port Community Systems Association (EPCSA, 2015), which conceptualized PCS as an electronic platform that allows at connecting the multiple systems operated by numerous organizations that make up a seaport community explaining the integration of each organization to the port community system (EPCSA, 2015).

Although we can observe numerous and relevant developments in terms of a high degree of automation and digitalisation, especially in container terminals, in the

direction to meet also the sustainability development goals for ports, there is still the lack of specific studies addressed to search for accounting, controlling and reporting systems able to support ports in being smart but also sustainable performed. Hence, there is the need to further investigate this topic and provide a better integration of existing information systems and data sources, as well as a more intelligent use of data for helping the improvement of planning, controlling, and management of intra and inter-organizational operations (Heilig *et al*., 2019; Heilig and Voß, 2018).

2.1 Port 4.0 and sustainability

Industry 4.0 provides companies a new way of designing their service supply chain management (SSCM), which can allow companies to answer to new customer's requirements, challenges on the supply side and other expectations in efficiency improvement (Pfohl *et al*., 2015). This new supply chain has potentialities: faster, more accurate, more granular and more efficient. As a matter of fact, delivery time can be reduced up to a few hours; real-time, end-to-end transparency provides throughout the supply chain. Mass customization realizes thanks to management of customers in granular groups, thus allowing offer of better suited products; the automation of both physical tasks and planning increases efficiency.

In order to bridge the gap in implementation of new technologies within supply chain (Tjahjono *et al*., 2017), areas most affected by introduction of Industry 4.0 are fulfilment of order and logistics of transport, as already outlined especially the maritime ports. Yet, some technologies can translate into both threats and opportunities: the reason is that all the different areas are interrelated, without clear boundaries between them and, depending on where it was analyzed, could have a negative or positive implication. The new used technologies are able to introduce organizational and technical improvements and advantages. Moreover, the same technologies are able to contribute in several ways to performance of production processes (Lee *et al*., 2014). The difficulties which present an obstacle to Industry 4.0 implementation are the lack of highly skilled labour capable of developing algorithms (enabling self-learning intelligence) and high costs of implementation of these technologies (Tortorella and Fettermann, 2018).

Industry 4.0 within port industry, defining the so called Port 4.0, also plays a crucial role significantly contributing to the development of the business world and the global community toward more “sustainable” industrial value creation (Kamble *et al*., 2018; Stock and Seliger, 2016). In the existing research and practice sustainability is characterized by three principal components, i.e., social, economic and environmental dimensions (Glavič and Lukman, 2007; Quak and De Koster, 2007), that is the named “triple bottom line” for sustainability development that emerged in the early ’80s (Bebbington and Unerman, 2018; Elkington, 1994). The social dimension concerns the needed reduction of any negative impacts from industrial activities. The economic dimension focuses on the efficiency of business operations, creating a balance between the use of resources for manufacturing products and the

offering of services to people. The environmental dimension pays attention to the future generations through the preservation and protection of natural resources. In the existing literature on Industry 4.0, the economic and environmental dimensions represent the major dimensions of sustainability considered (Kamble et al., 2018). Therefore, another challenge for Industry 4.0 is to produce respecting environmental sustainability (Bonilla *et al*., 2018). In particular, the requirement of adopting renewable energy systems is to be met.

Environmental sustainability frames production within specific limits. Exploitation should not exceed regeneration, waste generation should not exceed assimilation allowed by biosphere, and depletion of non-renewable resources should be integrated by substitutes (Fetterman *et al*., 2018): satisfaction of these requirements by Industry 4.0 is necessary in order to achieve sustainability.

According to literature, a sustainable development could be expected through new business models and new processes (Tsvetkova, 2017). Digital technologies, in general, could integrate renewable energy sources. However, factors such as quantity of used materials, primary energy consumption, and working conditions will negatively affect this development. If companies manage and improve social, economic and environmental performance in the supply chain, they can avoid waste, optimize processes, discover new product innovations, reduce costs, increase productivity.

Although numerous studies provide a clear reading of Industry 4.0 era evidencing its main characteristics, functions and implications, still unclear and underdeveloped is its practical application through a specific procedure (Fetterman, *et al*., 2018; Ford, 2015; Drath and Horch, 2014), especially with concern about how new technologies, and in general the overall Industry 4.0, can impact on operations management (OM)(Almada-Lobo, 2016), particularly considering some specific organizational settings, like the airport industry.

Industry 4.0, especially regarding the new technologies, requires to redesign and reorganize the operations by adapting the technology and management to a different level of operating systems, tools able to create the potential value of activities (Saucedo-Martinez et al., 2017). In this direction, the organizational change is necessary involving all the resources within firms (human, financial and technical resources), by applying new techniques able to generate value for providing market stability. For instance, the integration of business operations represents an important practice which allows to improve business activities along the entire value chain (Ltifi and Gharbi, 2015; Neeraja *et al*., 2014; Arca *et al*., 2011). Furthermore, the role of accounting, controlling, and reporting tools should be crucial for making the organizations, especially ports, to be smart and sustainable performed.

3. Accounting, Controlling and Reporting fields in Port 4.0

The concept of 4.0 concerns the fourth industrial revolution, as already evidenced, addressing towards the digitalisation of the value chain thanks to the integration of

physical assets into digital systems and networking (Mrugalska and Wyrwicka, 2017; Geissbauer, 2016). Information technology (IT) and information systems (IS) play a key role for the competitiveness of ports; indeed, their implementation facilitates the communication and decision-making improving the visibility, productivity, efficiency, and safety in port procedures (Heilig *et al*., 2017). IT redesigns the business processes, especially in terms of increasing of the flexibility of the organisational structure, collecting and sharing information, coordinating and controlling information and activities, as well as planning and adopting decision-making processes (Davenport, 1996). Digitalisation presents a relevant impact on seaports. In details, the digital transformation in the ports can be divided in three pillars: paperless and automated procedures, and smart procedures involving ports and port users (Heilig *et al*. 2017). These authors have proposed three generation about the technology evolution of ports. First, the development of electronic data interchange (EDI) systems in the 1960s and 1970s paved the way for the first digital transformation in the maritime shipping industry, e.g. Inter-organizational platforms in form of PCSs reduced paper-based processing, but these are highly dependent on the port community's willingness to adequately participate.

Second, in the 1990s and 2000s, established and new IT and IS solutions provided a relevant foundation to automate container handling procedures, especially in container terminals. The adoption of those technologies has generated changes in affected processes. In particular, the change was the collection and allocation of internal information, requiring an alignment of IT/IS with those processes and information management. Moreover, the creation of a global e-market place has established trade networks growing traffic and environmental issues (Heilig *et al*., 2017).

Third, IoT, big data, analytics, mobile computing, and cloud computing have been discussed among the stakeholders in the maritime industry, especially for the effects on the operations and the information management. This identifies the third generation (2010s-today), that is the smart procedures. This includes an integration of traffic and infrastructure management, allowing thus to route traffic flows dependent on the current traffic situation in the port. A central cloud-based information system shall facilitate the integration and provides the necessary resources to flexibly fulfil the computational requirements of those applications. The port further aims to improve the accessibility by deploying wireless network hot spots. The third generation of digital transformation ports aims to actively have an impact on the behaviour and decisions of actors in order to increase the efficiency in the overall port operations and to address certain issues, such as traffic and environmental problems.

Otherwise, Industry 4.0 establishes the intelligent machinery for manufacturing and services processes, but also new processes along the value chain (Tupa *et al*., 2017) focusing this approach on the development of smart chains (Özüdoğru *et al*., 2018). The introduction of Industry 4.0 has a significant impact on the global economy and it influences the inter-industry business (Schwab, 2017), that is changes on customer expectations, improvement on asset efficiency by increasing data efficiency, new partnership establishments as learning about the importance of new forms of cooperation, digital transformation of operating models into new business models, in particular, open web-based platforms create new opportunities and increase the competition (Özüdoğru *et al*., 2018). However, it would seem that the

size of ports justifies and highlights a different approach adopted by ports to the digitalisation. Heilig and colleagues (2017) believe that the financial resources and IT skills that characterize the small ports represent the main cause of the digitalisation transformation in the ports.

Thus, it is clear the benefit for ports of the digital transformation related to Industry 4.0 that requires the management and sharing of information between more port users. Otherwise, the adoption of digital transformation is linked to the sustainability concept, and more specifically to the environmental sustainability. In this direction, if Industry 4.0 changes the organizational and operational processes in their management and the overall business models (Özüdoğru *et al*., 2018), it is necessary to consider, also, the need to make significant changes in the accounting, controlling and reporting systems in the environmental sustainability perspective. This issue is still under investigated, especially, in the port industry oriented to the digital transformation. Burritt and Christ (2016) highlight that even if the attention paid by scholars and practitioners to the environmental accounting is being increased, there are still limitations in terms of management and defining the techniques to adopt. Otherwise, two main issues are interrelated to the environmental accounting, that is external environmental accounting, and internal environmental management accounting (Schaltegger and Burritt, 2000). The first one (external environmental accounting) has the specific task and role to give environmental accounting information to external stakeholders, while the second one (internal environmental accounting) is addressed to support the decision-making processes adopted by internal managers following the environmental sustainability approach. However, the external environmental accounting, that represents a reply to the increasing information requests on the environmental issues, not always has been separated from the conventional financial accounting (Schaltegger *et al*., 2003). Therefore, both the availability and the quality of external environmental accounting disclosures seem to be locked between financial and non-financial issues disclosure (Burritt and Christ, 2016). On the other side, also the environmental management accounting shows difficulties to guide the decision-making processes for the unavailability and poor quality of data. Thus, the need to change information gathered by extant management control systems, and the need to introduce infrastructure for information gathering and sharing become critical in the supply chains (Kokubu and Kitada, 2015).

According to Burritt and Christ (2016), the accounting, controlling and reporting tools, that also include water and energy, can be a solution through which to gather physical and monetary material flow information. This does not resolve the issue linked to the accountable management for the losses about the material where the monetary measures are a key part of Material Flow Cost Accounting (MFCA) useful to assist with eco-efficiency calculations, linking economic and environmental performance. Indeed, if the data about environmental costs are unavailable can also be transferred between departments, or between parties in supply chains, as well as in the port supply chain, but according to these authors, it is critical the role of the cost-effective technological infrastructure to help gather and share environmental management accounting information.

In this direction, Industry 4.0 might be used to improve both external environmental accounting and internal environmental management accounting (Burritt and Christ, 2016). Especially, for the port industry, the improvement in

external environmental accounting initiatives from Industry 4.0 could consider the best data quality, in terms of timeliness, accuracy, reliability and comparability of reported environmental accounting data; less management discretion over what is measured, and how it is measured and reported, and finally the higher credibility of data (Burritt and Christ, 2016). Therefore, although in the literature on the port industry 4.0 in the environmental management accounting (external and internal) is still under investigated the accounting, controlling and reporting fields can find an interesting setting linking Industry 4.0 and environmental sustainability. However, it is crucial to remove barriers between supplier systems and adopt a more open approach to communication and control platforms.

4. Concluding Remarks

This research contributes to the existing literature on Industry 4.0, sustainability, accounting, controlling and reporting systems, focusing on the organizational and operational processes, within the port industry, making ports to be smart and to sustainable perform with the main contribution of new technologies. Through the literature review on the topic we analysed the accounting, controlling and reporting fields for evidencing how new technologies, related specifically to Industry 4.0, support the port industry to environmentally sustainable performs, with innovative environmental management accounting tools.

In details, the literature highlights that IoT, big data, analytics, mobile computing, and cloud computing have been discussed among the stakeholders in the maritime industry, especially for smart procedures related to the operations and the information management. Besides, the third generation of digital transformation or Industry 4.0 about the ports, that is Port 4.0, aimed to have an impact on the behaviour and decisions of port users to improve the efficiency in overall port operations, including the improvement of the environmental issues. Changing the port business model it is relevant to adopt digital architectures to manage and share information, especially related to the accounting systems. Some authors (Heilig *et al*., 2017) think that the accounting structure for the ports depends on the financial resources of the ports, but this perspective does not include the propensity of the port management and of the whole port community in adopting the technology to share the data.

The literature review shows that the external environmental accounting not always has been separated from the conventional financial accounting, thus, the availability as well as the quality of external environmental accounting disclosures seem to be locked between financial and non-financial issues disclosure (Burritt and Christ, 2016). Moreover, the environmental management accounting presents some limitations to support the decision-making processes because the data are often unavailable or their quality is very poor. In this case, the need to change information gathered by extant management control systems, and the need to introduce infrastructure for information gathering and sharing, become critical in the supply chains (Kokubu and Kitada, 2015). Some solutions can be identified in the MFCA, even if an efficient system about the accounting, controlling and reporting, requires to

include more information about the operations and processes of the port organizational structure.

Although in the literature on Port Industry 4.0 in the environmental management accounting (external and internal) is still under researched, especially within the accounting, controlling and reporting fields, the link between Industry 4.0, environmental sustainability, and accounting should be analysed through the study of specific experiences in the port industry (e.g. ports of Hamburg, Rotterdam, Antwerp, Singapore), by observing and analysing systems and tools of accounting, controlling and reporting as architectures to support the information needs from external and internal stakeholders.

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