Business process management in the port sector: a literature review

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Abstract

Purpose – This paper aims to review the application of business process management (BPM) in the port sector. Its objective is to understand whether BPM principles are applied in the port sector, the role of the procedural factor in port performance evaluation and whether electronic data interchange systems have been used for process management purposes.

Design/methodology/approach – The objective of this research is to conduct a critical review of existing academic literature in the domain of BPM and its application in the ports sector. This paper assessed more than a hundred recent publications, from key journals in the domains of port economics, BPM and information technology. The two principle platforms used are the online databases of the World Bank Group and the University of Antwerp.

Findings – Academic literature reviewed reveals a partial application of BPM in the port and maritime sector. BPM related research is conducted via the utilization of modeling algorithms or optimization and simulation tools. There exists evidence that electronic data interchange (EDI) data extracted from EDI platforms can be used to model inter-organizational business processes in several industries. Yet, to the best of the author's knowledge, no research investigates Port Community System (PCS) or single window (SW) data utilization for BPM purposes, although PCS and SW benefits are well documented. Port performance is largely assessed based on the production theory, and limited number of studies use elements of procedural efficiency as variables for their analysis.

Originality/value – The holistic application of BPM has been researched in numerous industries but in the port sector. This paper constitutes the first section of an original research study to define key components, assumptions and constraints for developing a comprehensive BPM framework in the port sector.

Keywords Business process management, Electronic data exchange, Electronic single window, Port community systems, Port effectiveness, Port efficiency

Paper type Literature review

1. Introduction

Business process management (BPM) is a relatively new management discipline which includes activities to identify, design, execute, document, measure, monitor, control and promote improvements in an organization's processes and consequently effectively meet business objectives (Association of Business Process Management Professionals, 2009). It focuses on the management of entire chains of events, activities and decisions (processes) that ultimately add value to the organization and its customers (Dumas *et al.*, 2018) and achieve the firms' goals and objectives toward the fulfillment of the customers' expectations (Lindsay *et al.*, 2003).

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There are three broad approaches to BPM:

(1) work simplification and quality control;

(2) business management; and

(3) information technology and process automation (Harmon, 2014).

The science of managing business process follows a cyclical approach. A typical BPM follows the cycle methodology (Lodhi *et al.,* 2014), which comprises four distinct stages: process design, system configuration, process enactment and diagnosis (van der Aalst, 2004). There is a plethora of methods, techniques and tools to support the design, enactment, management and analysis of operational business processes (van der Aalst, 2013). However, the three concepts most frequently met in the academic literature are the ones of process mining, modeling and re-engineering.

Process mining aims at the extraction of processes from event logs available in information systems (van der Aalst, 2004) and is linked to a plethora of techniques, the key ones focusing on process discovery (van der Aalst, 2004), event log data analysis (van der Aalst *et al.,* 2005; van der Aalst and Song, 2004), trace classifications (Ferreira, 2009), process metrics (Dijkman *et al.,* 2011) and specific application areas (Günther and van der Aalst, 2007; Jans *et al.,* 2011). In their paper, Van der Aalst *et al.* (2011) demonstrate how discovered process models can be used to conduct reliable time predictions.

Process modeling identifies, maps and analyzes as-is processes (Weske *et al.,* 2004) with the objective to understand inefficiencies and act toward improvement. Key business process modeling tools used include Business Process Model and Notation, Case Management Model and Notation and Decision Model and Notation (Cummins, 2017), while modern software solutions allow the process maps automatic modeling and visualization.

Process re-engineering comes as a natural next step after process modeling and aims at process streamlining and enhancement. Vanwersch *et al.* (2016) introduce a new technique for generating process improvement ideas while Huang *et al.*, (2015) show a positive relationship between IT investment and the implementation of business process re-engineering. Information technology acts as an enabler for process discovery and re-engineering (Kirchmer, 2017), and IT systems which seamlessly integrate all the information flowing through a company support the process approach.

Research has demonstrated several benefits from the BPM application, including cost reductions, increase in operational cycle speed, customer satisfaction improvement, quality enhancement and response time reduction (Hirzel, 2008; Kohlbacher, 2010; Fernando Sentanin *et al.,* 2008). Business process orientation also leads to better non-financial outcomes and indirectly to better financial performance (Škrinjar *et al.,* 2008). Nevertheless, the BPM discipline remains largely atheoretical. Trkman (2010) proposes a theoretical framework under the premise of proper fitness between the business environment, business processes and information systems and critical success factors of success. Similarly, Meerkamm (2010) compares management practices to relevant theoretical concepts and draws conclusions on their major differences.

This paper is part of a broader research effort to develop a BPM methodological framework for the port sector. The multidimensional nature of the topic dictates the necessity to obtain a holistic view of existing knowledge, focusing on the three thematic areas:

(1) process management at ports and maritime logistics;

(2) port electronic platforms; and

(3) port performance.

In this context, this paper seeks to answer three key research questions:

RQ1. Has the potential application of BPM been researched in the port sector?

RQ2. Can electronic data interchange (EDI) platforms be utilized to discover and improve port processes?

RQ3. Do current port performance evaluation approaches incorporate the procedural factor?

2. Methodology

The methodological approach adopted for this review includes the adoption of five distinct steps as outlined in Figure 1. Research focuses on the assessment of 130 publications issued within the past 20 years (2000-2018). However, some exceptions are made for articles published beyond this timeframe and constitute academic milestones in their respective areas. The two principle resource platforms utilized are the online databases of the World Bank Group and the University of Antwerp, in which the author has access rights. Journals reviewed correspond to major publications mainly in the port economics, BPM disciplines and information technology domains.

A total of 23 research databases were searched for publications from 2000 through to 2018, with key articles obtained primarily Scopus (Elsevier), ProQuest SciTech Collection, ProQuest Technology Collection, ABI/INFORM Complete, Business Premium Collection, and ABI/INFORM Global. A complete list of the databases searched is included in Appendix.

To ensure that relevant studies were not missed, research followed the following five distinct stages:

(1) *Identification*: During this stage, a number of records are identified through a simple Boolean search based on certain keywords per thematic area[1].

(2) *Screening*: The initial list of records was reduced by the application of specific criteria such as publication date (ranging from 2000-2018), type (peer-reviewed articles, books, book chapters and conference papers), subject fields (constrained to

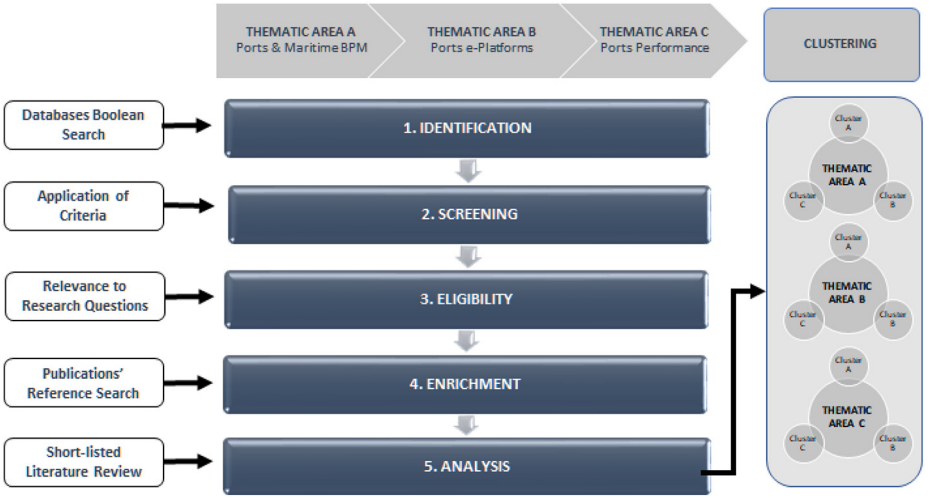

Figure 1. Methodological approach

the ones of: ports, economics, business and policies) and full-text publications accessibility.

(3) *Eligibility*: At this stage, publications are reviewed per thematic area with the objective to assess their relevance to the respective research questions. The most relevant studies are grouped while the irrelevant ones are eliminated.

(4) *Enrichment*: In this stage, the list of references of the most relevant studies is reviewed and further research resources are recorded. Key publications which could not be identified due to the constrains applied in the second stage were identified and included.

(5) *Analysis*: The final stage includes the actual literature review and the clustering of the studies into respective sub-themes.

3. Theoretical application of business process management in the ports and maritime sector

The topic of port logistics processes has been researched from a variety of angles and through the application of diverse methodological approaches. We group identified research in two clusters based on their relationship to the specific phases of the BPM project cycle.

The first cluster of academic papers focuses on the upstream stages of process mining, discovery and modeling. Wang *et al.* (2013) and Wang *et al.* (2014) construct a logistics process modeling methodology for highly and loosely structured processes, by using declarative and imperative approaches, but neither paper investigates process modeling as an integral phase of a BPM cycle. Elbert *et al.* (2016) reveal how maritime transport chains work and model key processes with the objective to examine the inter-organizational information systems (IOS) share in the communication of individual organizations. Likewise, Lyridis *et al.* (2005) apply a "port-to-port" business process modeling methodology to identify time and cost savings after the application of technology on maritime and port operations. Both above-mentioned papers reveal how maritime transport chains work on a granular business process level, but process improvement and re-engineering are examined outside the goals and objectives of the BPM cycle. Focusing on process discovery, Pulshashi *et al.* (2015) presents an automated tri-dimensional process discovery algorithm to solve the problem of "duplicated tasks". Sutrisnowati *et al.* (2015) discover processes from event logs in port information systems and analyze the activities' lateness probabilities in container handling by generating a Bayesian network. Cabanillas *et al.* (2014) examine the monitoring phase of logistics processes and discover key challenges related to the discretization of streaming events, aggregation of fine-granular event sets to activities and the correlation of events related to the same cargo unit.

Another set of papers focus on the improvement of process mining techniques via the development of sophisticated algorithms. In their paper, Lau *et al.* (2009) propose a process mining algorithm (i-PM) within a supply chain network with the objective to assist organizations to improve service quality and customer satisfaction. Kim and Shin (2014) propose a process mining methodology to discover and analyze receiving and shipping processes by extracting event logs from a Warehouse Management System by proposing a combination of process mining and simulation techniques. Besri and Boulmakoul (2017) investigate the relationship between port business processes and organizational structuring and recommend a software solution as a framework for organizational structure re-design. Gonzalez *et al.* (2006) propose an algorithm applied for workflow mining and compression purposes and construct supply chain workflows based on Radio Frequency Identification

(RFID) data. Using the same method, Gerke *et al.* (2009) investigate how the EPCglobal standard for processing RFID events can make supply chain data accessible for process mining and develop an algorithm which is evaluated in the context of Supply Chain Operations Reference model.

The second cluster of papers focuses on the downstream stages of BPM cycle, mainly on the process improvement and re-engineering phases, analyzed via optimization and simulation techniques. These studies aim at capturing the improvement potential of niche port operations such as yard space management, intra-port truck movements and berth assignment. Angeloudis and Bell (2011) provide an academic review of the domain of container terminal simulation and discuss several classifications of models that predict analytically how the container terminal will operate under specific layouts and configurations by distinguishing between generic simulation tools, simulation programming libraries and purpose-built container terminal simulation tools. Wong and Kozan (2010) propose an optimization model, based on the List Scheduling and Tabu Search algorithms, to solve the yard operation planning and scheduling problem. In their paper, Legato *et al.* (2009) apply both optimization and simulation techniques on yard operations and propose a model to evaluate the best policy for assigning yard cranes to yard blocks. Casey and Kozan (2012), present a heuristics and meta-heuristics based optimization model for multimodal container terminals, dealing with assigning containers to positions within the storage area, re-handling of containers and calculation of processing times to perform these actions.

A berth-scheduling optimization policy is presented by Golias *et al.* (2009), and via the use of real data, they demonstrate that proposed policy optimizes waiting time at the port and minimizes the effects of late arrivals to the ocean carriers' schedule. Alvarez *et al.* (2010) recommend a hybrid simulation-optimization methodology to evaluate the potential benefits of new berthing policies and ocean shipping contracts in the place of the legacy ones which support first-come, first-served allocations. In his paper, Golias (2011) formulates the berth allocation problem as a bi-objective mixed-integer programming problem, and by using a combination of an exact algorithm and a Monte Carlo simulation, he shows the effectiveness of the proposed modeling approach. Zeng *et al.* (2017) develop an integrated model to optimize berth allocation, the storage space assignment and the direct transshipment plan simultaneously and via the application of a heuristic-based algorithm, conclude that the direct transshipment mode can significantly decrease operational costs for both terminal operators and carriers.

Rida (2014) examine the optimization of unloading and loading processes of container ships and uses a Markov decision process (MDP) technique with value iteration and policy iteration algorithms to identify the optimal decision-making strategy. Kang *et al.* (2008) present a modeling framework for optimal planning and management of marine terminal fleets to unload cargos from container vessels and introduce a hybrid approach using a cyclic queue and a MDP. Zhen (2016) develops quantitatively models for truck interruptions in the port yard and proposes a mixed-integer programming model that minimizes the total expected travel time of moving containers around the yard. Wasesa *et al.* (2017) present a seaport transport service rate prediction system that could help drayage operators to improve their predictions of the duration of the pick-up/delivery operations at a seaport. Kondratyev (2015) proposes a process-oriented discrete-event simulation technique for modeling cargo port activity for a comprehensive evaluation of port efficiency. Therefore, it proposes an object-oriented architecture of a port model and a visual model specification technique based on reusable library blocks. Similarly, Beškovnik and Twrdy (2010) propose a container terminal planning organization and productivity simulation tool and argue that

the application of an adequate model frame can possibly measure and increase the productivity of the whole maritime container terminal subsystem. Elbert *et al.* (2017) introduce the concept of order process efficiency hence processing times and costs. In their paper, they analyze the impact of different container transport order release times to ports, which define the timing of order transmission and order process efficiency. Zhao and Goodchild (2013) uses truck appointment system's data and adopts a hybrid approach of simulation and queuing theory to illustrate that reducing the duration of the appointment time window or increasing the appointment lead time could further enhance yard performance. On the same subject, Guan and Liu (2009) also apply a multi-server queuing model to balance the gate operating cost and trucker's cost associated with excessive waiting time and prove that with an optimized appointment system, the total system costs, especially truck waiting cost, can be drastically reduced. Chen and Yang (2010) explores the effectiveness of a time window management program by using a genetic algorithm to flatten the peak traffic of export container trucks.

The common denominator of the above-mentioned papers is they use optimization techniques as a tool to achieve process re-engineering and improvement of specific port operations as opposed to the entire nexus of port services. Yet, the approaches they follow are not viewed as part of or incorporated into the broader context of a comprehensive BPM methodological framework.

Closer to a holistic application of BPM, Islam *et al.* (2013) develop a process re-engineering framework for maritime terminals and propose a truck-sharing model which has the potential to reduce the number of empty-truck trips throughout the export cycle. To do so, they structure an "as-is" export process and suggest a "to-be" process integrated with the truck appointment system concept and via the use of the shared-transportation concept and by assuming that all truck operators have an equal chance to get benefits to optimize the whole supply chain. Similarly, Meng *et al.* (2009) propose a decision support framework for port efficiency discovery based on intelligent data integration and provide some innovative approaches to measure and analyze port efficiency from a supply chain point of view by utilizing massive operational data accumulated in scattered information systems. They use a case study of a Chinese port to demonstrate that the prototype system is capable of get some useful insights into port efficiency.

Many BPM concepts are applied in these studies, including process discovery and re-engineering, thus providing an approach closer to a BPM methodology (Table I).

4. Utilization of electronic data interchange platform data for process discovery and improvement

Digitization of port and maritime processes and utilization of information and communication technology (ICT) can deliver benefits related to efficiency, reliability and security of port operations. In this context, Heilig and Voß (2016) survey and classify enabling technologies and information systems applied in maritime ports and conclude that, if combined with optimization methods, can provide a foundation for extracting process-related knowledge and supporting long- and short-term decision-making. However, their analysis does not explain how this process extraction can take place. Fruth and Teuteberg (2017) provide an overview of the current state of digitization in maritime logistics and show a clear homogeneity regarding the benefits of digitization with the optimization of maritime logistics and the reduction of costs being the key ones.

Several papers are clustered around the wide concept of "smart ICTs" for port and maritime logistics. For instance, Cimino *et al.* (2017) present a review of the smart ICT for marine container terminals and evaluate their on port logistics via business process

Description	Authors
Port operational improvement and re-engineering studies are based on optimization and simulation tools and grouped by niche port operations	Angeloudis and Bell (2011), Wong and Kozan (2010), Legato *et al.* (2009), Casey and Kozan (2012), Golias *et al.* (2009), Alvarez *et al.* (2010), Golias (2011), Zeng *et al.* (2017), Rida (2014), Kang *et al.* (2008), Zhen (2016), Wasesa *et al.* (2017), Kondratyev (2015), Beškovnik and Twrdy (2010), Elbert *et al.* (2017), Zhao and Goodchild (2013), Guan and Liu (2009), Chen and Yang (2010)
Papers dedicated to process mining, discovery and modeling focus on algorithm development or improvement and on specific sub-process or niche port operations	Wang *et al.* (2013), Wang *et al.* (2014), Elbert *et al.* (2016), Lyridis *et al.* (2005), Pulshashi *et al.* (2015), Sutrisnowati *et al.* (2015), Cabanillas *et al.* (2014), Lau *et al.* (2009), Kim and Shin (2014), Besri and Boulmakoul (2017), Gonzalez *et al.* (2006). Gerke *et al.* (2009)
Only a few port studies incorporate both upstream and downstream concepts of the BPM project cycle	Islam *et al.* (2013), Meng *et al.* (2009)

Table I.
Key findings on the theoretical application of BPM in the ports and maritime sector

modeling, simulation tools and a real-world analysis of the Port of Leghorn. Although they do not use process mining techniques to extract port process, research results show that their adoption could lead to substantial potential savings on processing time, machinery and staff. Coronado Mondragon *et al.* (2017) use institutional-related theories to identify key elements that influence the adoption of ICT to show that both government legislation and dominant organizations running ports in various geographical locations exert major influence regarding ICT adoption. Lee *et al.* (2016) state that e-transformation in container ports, including the adoption of EDI systems, can affect customer satisfaction and port competitiveness, while Carlan *et al.* (2017) prove correlation between corporate strategies and success degrees of the ICT innovation initiatives, including EDI systems, and conclude that essential elements of success turn out to be infrastructure, soft institutional and hard institutional issues, while regulation was not identified as a barrier nor as a facilitator. Taking a slightly different perspective, Scholliers *et al.* (2016) discuss the technological possibilities to improve containers' integrity in port supply chains via the addition of monitoring equipment and their optimal use via information sharing between different stakeholders. Looking at data exchange strictly from a security point of view, they conclude that a uniform set of processes for container security devices operations and a uniform messaging set and exchange processes could improve the level of supply chain integrity at ports.

Examining the utilization of EDI in corporate business process extraction, Engel *et al.* (2015) show that mining EDI messages can provide business intelligence for investigating inter-organizational business processes as they are executed, and not as they were merely planned and/or modeled and propose a framework for enabling the application of process mining techniques and supporting inter-organizational performance evaluation. Engel *et al.* (2012) apply process mining techniques on electronic data that an automotive supplier company received from business partners and show that inter-organizational business process models can be derived by analyzing EDI messages exchanged in a network of organizations. Engel *et al.* (2011) highlight that lack of process awareness in traditional EDI systems hinders organizations from applying BPM and develop choreography models from EDI message exchanges, which enable the discovery of inter-organizational business information. Bhatt (2001) explores the effect of EDI systems on business process

improvement (BPI) and the effect of industry's information intensity on the relationship between EDI systems and BPI and concludes that EDI systems have a direct and significant relationship with BPI factors. Engel and Bose (2014), present a case study in which a physical activity mining (PAM) methodology is used to identify events and process instances, based a real-world EDI data set obtained from a German manufacturer of consumer goods. Results demonstrate that EDI messages may serve as a rich base for insights on inter-organizational business process performance via the generation of fine grained event logs for mining detailed process models. Bhatt and Troutt (2005) analyses data samples from Fortune 500 firms and examine the relationship between BPI initiatives (BPII), information systems (ISs) integration, and customer focus. One of the key findings is that BPII and data integration and communication networks' flexibility, directly affect customer responsiveness and product/service innovation.

Results from the application of process mining and discovering techniques to discover inter-organizational business processes in the private sector demonstrate the potential to convert EDI messages into event logs and eventually to process instances.

According to EPSCA[2], "a Port Community System (PCS) is an electronic platform which connects the multiple systems operated by a variety of organizations that make up a seaport, airport or inland port community." A useful overview of the PCS history and a presentation of the Felixstowe PCS is offered by Long (2009), who outlines potential benefits for governments and the trade, transport and logistics communities and concludes that PCS can reduce the time required to release cargoes. Keceli *et al.* (2008) develop a model for determining the factors affecting PCS and user acceptance of port community and concludes that most of the users perceive PCS as a tool for port and customs-related document submission, rather than a means for added value creation. Srour *et al.* (2008) define the four stages of designing and implementing a PCS project (initiation, system analysis and design, implementation and adoption, and maintenance and growth) and identify five factors of success. Arduino *et al.* (2013) prove that public policy actions/interventions could provide effective support for the initiation, development and implementation phase of technology-based innovations, in general, including PCSs. This support is translated into the introduction of new or modified rules in the form of laws, regulations, standards, taxes, grants and loans to facilitate or motivate innovations. Tsamboulas *et al.* (2012) propose a methodology to evaluate port performance changes with the introduction of PCS and respective key port performance indicators (KPI) and conclude that PCS implementation can improve both port performance and the services provided to stakeholders. However, the impact of the PCS implementation was higher for the port authority than for the stakeholders. Aydogdu and Aksoy (2013) develop a simulation model to capture the differences between conventional port logistics business with and without a PCS and estimate that TL29.5m can be saved annually at a national scale upon the PCS implementation.

Carlan *et al.* (2016) recognize the inconsistency in the existing literature with respect to PCS costs and benefits quantification and propose a comprehensive framework to quantify costs and benefits. Through a combination of in-depth literature review, interviews with experts and case analysis, they suggest that there is a positive cost–benefit balance for PCS users, who have a competitive advantage over other port stakeholders outside the community. Irannezhad *et al.* (2017) estimate the efficiency of a PCS at the Port of Brisbane and insights into the benefits of adopting the PCS for private actors in terms of increasing efficiency, profit and infrastructure utilization. In their paper, they conclude that if all agents (shipping lines and road carriers) communicate through a single portal and cooperate in sharing vehicles and creating tours to deliver shipments to several importers, then the

efficiency of the whole logistics process improves. Interestingly, the savings in logistics costs are generally higher for shipping lines who have fewer shipments to deliver, while cooperation sometimes imposes a higher logistics cost upon the major shipping lines, thus explaining why some shipping lines would prefer individual action over cooperation. Vieira *et al.* (2015) suggest that the development of a port single window (PSP) at the Port of Santos will simplify existing bureaucratic procedures, maximize the use of port infrastructure, decrease costs and improve service level to customers by reducing dwell times of import and export. Following a qualitative approach based on in-depth interviews with key actors of the Santos port logistics chain, they prove that this kind of solution can generate results in a shorter timeframe and with less investment than traditional solutions based on port infrastructure expansion. Bisogno *et al.* (2015) provide a PCS model that aims to replace the old interorganizational routines of maritime logistic processes with new more efficient and highlight the importance of going beyond a myopic vision based on the adoption of the viewpoint of each actor, without considering the relationships between them.

Research on trade and transport electronic platforms identifies the concept of single window (SW), which according to UN/CEFACT[3] is a facility that allows parties involved in trade and transport to lodge standardized information and documents with a single entry point to fulfill all import, export and transit-related regulatory requirements. Bal *et al.* (2017) examine the concept of international single window environment (ISWE) from a transaction cost and information asymmetry theory perspectives and argue that its full potential can be realized through integration of transport and commercial requirements thereby improving G2G, B2G and B2B information flows. Niculescu and Minea (2016) present current regulations and ongoing or finalized projects related to SW systems in Europe, analyze the main differences between the Maritime SW and the Customs SW and propose the development of a National Single Window Integrated Platform. On the same subject, Pugliatti (2011) proposes a shared, cloud-based supranational SW that will not be based on a bilateral exchange of electronic documents, but on on-line repository of shared data providing real-time data visibility.

Aman *et al.* (2017) provide clarity on the challenges of an electronic SW (eSW) implementation and offer recommendations to overcome those challenges. Urciuoli *et al.* (2013) propose a theoretical framework which identifies drivers and barriers for usage of e-customs platforms including SWs and conclude that factors like cost-savings and ease of use significantly influence the usage of e-customs platforms while barriers preventing adoption of information sharing platforms include: technical constraints and costs, and quality and trust. Raus *et al.* (2009) identify facilitators and barriers that can influence the adoption of standardized e-customs solutions in the context of the European Union (EU). Nizeyimana and De Wulf (2015) provides an overview of the implementation of the Rwanda electronic SW and its impact on trade facilitation and conclude that the use of the eSW has resulted in reduced clearance times and direct and indirect costs associated with international trade. Similarly, Tosevska-Trpcevska (2014) analyses the effects of implementing the SW concept and simplified customs processes and procedures in the Republic of Macedonia. Wang (2018) uses a case study of a SW development in Korea to highlight the need for improved and institutionalized interagency coordination to promote its implementation.

Despite a fair amount of research conducted on PCS and SW benefits and drivers of success, to the best of our knowledge, we could not identify analysis focusing on the utilization of data found in these platform for process discovery and improvement purposes (Table II).

5. Incorporation of procedural factor into port performance methods

Port efficiency is measured in terms of technical, allocative and economic efficiency. Reviewing papers in this domain, we conclude there is little consistency in terms of inputs and outputs used or even so in the definition of the port as a decision-making unit. In their paper, González and Trujillo (2009) offer a systematic examination of existing studies assessing the economic efficiency and productivity of the sector and admit that in most studies examined, the port activity whose efficiency is being analyzed is not clearly defined and therefore produces a certain degree of confusion.

Efficiency analysis is often conducted to benchmark port performance at a national level. Focusing on Spanish ports, Díaz-Hernández *et al.* (2014) show that the static DEA cost models overstate all components of cost inefficiency which may lead to faulty investment decisions. Tovar and Wall (2015) prove that if ports are operated efficiently then cargo volumes could be expanded and González and Trujillo (2008) show that while reforms resulted in significant technological improvements, technical efficiency has in fact changed little. Wanke *et al.* (2011) explain differences in port efficiency levels in Brazil, while efficiency assessment of Chinese ports shows that those with higher container cargo proportion have higher cost efficiencies (Zheng and Yin, 2015).

Port efficiency is also analyzed at a regional or sub-regional level. Chang and Tovar (2014) conclude that Chilean terminals were more efficient compared to the Peruvians due to greater agility in the implementation of the reform process, while Zheng and Park (2016) show that the efficiency of major terminals in Korea displayed similar efficiency with China's terminals. Serebrisky *et al.* (2016) reveal a positive and significant association between technical efficiency and private port operations in Latin America and the Caribbean ports, and Kutin *et al.* (2017) analyze the relative efficiencies of 50 ASEAN container ports and terminals including both "inland seaports" and "seaports". Almawsheki and Shah (2015) evaluate the technical efficiency of 19 container terminals in the Middle East and rank them based on performance and Schøyen and Odeck (2013) evaluate the technical efficiency of Norwegian container ports compared to other Nordic and UK ports. Similarly, Kim (2012) focuses on the evaluation and comparison of port efficiency of nineteen European container ports.

Other research papers focus on the identification of drivers, determinants and factors of port efficiency. Suárez-Alemán *et al.* (2016), show that private sector participation, the reduction of corruption in the public sector, improvements in liner connectivity and the existence of multimodal links increase the level of port efficiency in developing regions, while Merkel and Holmgren (2017) argue that the vast majority of port efficiency studies estimate partial production functions accounting for only supplier inputs, while a substitution between producer and user inputs should be accounted for. Low technical

Table II.
Key findings on utilization of EDIs for process discovery and improvement

Description	Authors
Benefits of PCS and SWs are analyzed and well documented but not supported by BPM methods and techniques	Heilig and Voß (2016), Fruth and Teuteberg (2017), Vieira *et al.* (2015), Cimino *et al.* (2017), Irannezhad *et al.* (2017), Tsamboulas *et al.* (2012), Aydogdu and Aksoy (2013), Nizeyimana and De Wulf (2015), Tosevska-Trpcevska (2014), Wang (2018)
There is evidence from private sector industries that data extracted from EDI platforms can be used to model inter-organizational business processes with supply chains	Engel *et al.* (2015), Engel *et al.* (2012), Engel *et al.* (2011), Bhatt (2001), Engel and Bose (2014), Bhatt and Troutt (2005)

efficiency can be attributed to both the lack of managerial skills and scale effects according to Niavis and Tsekeris (2012), while Bichou (2013) links technical efficiency to variations in operating conditions and interpret service and waiting time from a terminal operations point of view. Simões and Marques, 2010 argue that the increase in cargo volumes has not necessarily corresponded to an improvement in the productive efficiency as increase in inputs can lead to decrease in outputs. Wu *et al.* (2010) test the sensitivity of individual inputs and outputs and conclude that the number of berths and the capital deployed are the most sensitive measures impacting port performance.

The relationship between governance reforms and port efficiency improvements remains inconclusive in terms of evaluating governance outcomes, identifying governance elements and discussing governance actions (Vieira *et al.*, 2014), and improvements of the performance indicators cannot be linked in a straightforward manner to port corporatization. In their paper, Van de Voorde and Verhoeven (2014) refer to non-monetary cost elements and their distinction between those related to time, risk and reliability and use respective indicators for the time ocean carriers, inland carriers and cargo shipments spend at the ports, defined as annual average figures. Akinyemi (2015) shows that, despite post-reform rise in technical efficiency, there are some issues which are affecting the performance of the ports, such as high port charges, delay in cargo clearance, multiple taxation and development of intermodal transport. Coto-Millán *et al.* (2016) claim that reforms related to the promotion of port autonomy, privatization and inter-port competition had a positive impact on efficiency Wanke (2013), indicates that private administration exert a positive impact on physical infrastructure efficiency levels.

The literature covers a wide range of port efficiency techniques, specifications and objectives. However, as far as we are aware, no studies of port efficiency have used elements of procedural efficiency, in terms of costs or benefits, as variables for their analysis.

Some researchers, such as Tongzon (2001) use the "waiting time" variable which can be considered as a proxy of procedural inefficiency while Roll and Hayuth (1993) introduced uniformity of service as input and levels of service and user satisfaction as outputs of port performance. Tongzon and Ganesalingam (1994) categorize port efficiency indicators into two broad groups: operational efficiency measures and customer-oriented measures, which include direct charges, ship's waiting time, minimization of delays in inland transport and reliability. Port users are more concerned with indirect costs associated with delays, loss of markets/market share, loss of customer confidence and opportunities foregone due to inefficient service, than with port charges (Tongzon, 1995). Similarly, Murphy *et al.* (1992) have shown that some users are willing to accept higher port costs in return for superior and more efficient service.

Port efficiency in also viewed through the eyes of the users. Highlighting this need, Brooks and Pallis (2008) claim that port reform effectiveness is largely neglected, with user perspectives not being an integral part of an effort to improve performance. Brooks and Schellinck (2015) examine service delivery effectiveness and conclude that port managers, governments and stakeholders bring different perspectives in terms of identifying and prioritizing port investments. Schellinck and Brooks (2013) develop address conflicting signals generated by user perceptions of satisfaction and effectiveness, while Brooks *et al.* (2011) examine how carriers, cargo interests and port logistics service suppliers evaluate port effectiveness and conclude that the evaluation criteria influencing their perceptions of effectiveness are different. Taking a step further, Brooks and Schellinck (2013) explore effectiveness issues for major supply chain participants and demonstrate how conflicting recommendations, generated by inconsistencies between performance effectiveness and

user expectations may be resolved as a comprehensive means of guiding investment decisions.

Thai (2015) develops a Port Service Quality model and show that its dimensions of outcomes, management, process and image and social responsibility all have significant positive impact on customer satisfaction. Talley and Ng (2016) claim that port outputs are services rather than physical products and derive port cost functions for which port outputs are "service outputs" e.g. cargo, vessel and vehicle services. Cho *et al.* (2010) compare the Incheon and Shanghai ports based on the levels of service quality and their effects on customer satisfaction, loyalty, and referral intentions. Vishuen *et al.* (2010) identify key service attributes that characterize the port service proposition and assess quality of service and show that among the most relevant dimensions are "reliability," "responsiveness" and "assurance." In their paper, Yeo *et al.* (2015) prove that failure or unreliability of port services can significantly influence shipping lines and cargo owners and result in their dissatisfaction (Table III).

6. Conclusions and further research

This paper conducted a scanning of recent publications in three thematic areas, with the ultimate objective to provide answers to three key pre-defined questions. With respect to *RQ1* and whether the potential application of BPM been researched in the port sector, the review revealed that the following:

- Current literature does not examine the application of BPM, defined as the discipline of strengthening organizational performance via procedural modeling, re-engineering and cross-organizational (holistic) performance monitoring, in the port and maritime logistics sector.
- Sporadic research papers have focused on the development of algorithms for the mapping or modeling of niche port sub-processes at intra-organizational or inter-organizational levels.
- Many papers reviewed, process improvements coincide with efforts to re-engineer certain terminal operations via optimization and simulation techniques.

In our attempt to answer the question whether EDI platforms-can be utilized to discover and improve port processes (*RQ2*), we conclude that the following:

- Benefits and challenges of PCS and SWs implementation are analyzed and well documented but not supported by BPM methods and techniques.

Table III.
Key findings on incorporation of procedural factor into port performance methods

Description	Authors
The literature covers a wide range of port efficiency techniques, specifications and objectives. However, only a few studies have used – even remote – elements of procedural efficiency as variables for their analysis	Tongzon (2001), Roll and Hayuth (1993), Tongzon and Ganesalingam (1994), Tongzon (1995), Murphy *et al.* (1992)
Several papers discuss the merits of decomposing performance into two different, although related components, namely efficiency and effectiveness; the latter tend to be more customer-focused approach of assessing port performance	Brooks and Pallis (2008), Brooks and Schellinck (2015), Schellinck and Brooks (2013), Brooks *et al.* (2011), Brooks and Schellinck (2013), Cetin and Cerit (2010), Talley *et al.* (2014)

- There is evidence from private sector industries that data extracted from EDI platforms can be used to model inter-organizational business processes with supply chains.
- However, to the best of our knowledge, no research has been conducted on the utilization of PCS data for process mining, discovery, re-engineering or any other BPM purposes.

Finally, research findings related to *RQ3* and whether current port performance evaluation approaches incorporate the procedural factor, reveal that the following:

- Port performance is largely assessed based on the production theory and the use of inputs to produce certain outputs. Only a few studies have used elements of procedural efficiency as variables for their analysis.
- Several papers discuss the merits of decomposing performance into two different, although related components, namely, efficiency and effectiveness; the latter tends to be more customer-focused approach of assessing port performance.
- At large, the existence of swift and streamlined processes are recognized is a principal factor of efficiency but only from a terminal operations point of view; a more comprehensive approach has not been identified

This paper is part of a broader research effort to develop a BPM framework for the port sector using methodologies, approaches and tools used in other sectors. In this context, the key components, assumptions and constraints for developing such framework will be defined and a specific set of criteria will be developed to assess the appropriateness of process discovery, conformance and enhancement techniques in the port sector.

Notes

1. Search keywords for the first thematic area were: (process AND (port OR maritime)); for the second area: (port AND (efficiency OR effectiveness OR performance)) and for the third one: (port OR maritime) AND ((electronic "single window") OR (port community system) OR ("electronic data interchange") OR EDI)).
2. European Port Community Systems Association.
3. United Nations Centre for Trade Facilitation and Electronic Business.

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Appendix

Complete List of Databases

(1) Scopus (Elsevier)
(2) ProQuest SciTech Collection
(3) ProQuest Technology Collection
(4) ABI/INFORM Complete
(5) Business Premium Collection
(6) ABI/INFORM Global
(7) Social Sciences Citation Index (Web of Science)
(8) ProQuest Natural Science Collection
(9) OneFile (GALE)

(10) Informa – Taylor and Francis (CrossRef)
(11) ProQuest Science Journals
(12) ScienceDirect Journals (Elsevier)
(13) Science Citation Index Expanded (Web of Science)
(14) PAIS International
(15) ProQuest Pharma Collection
(16) ProQuest Environmental Science Collection
(17) ProQuest Research Library
(18) Taylor and Francis Online – Journals
(19) ProQuest Discovery
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