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A BPMN MODEL FOR RAIL PORT OPERATIONS TO EVALUATE POTENTIAL CAPACITY INCREASE

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Abstract

The rapid growth of container movements deriving from the advent of globalization has caused a relevant pressure on ports. In this context, the port efficiency performances requested by the market have been met by an increased adoption of railway transport. Despite its environmental and economic sustainability, this intermodal transport solution is characterized by a high degree of complexity given by the execution of different activities and the involvement of several stakeholders. As such, the need of deeply analyzing logistics business processes has led to the embracement of modeling techniques, which allow practitioners to identify possible criticalities along the chain. In this regard, the selection of the appropriate modeling method and notation definitely influences the results of the process examination. In the present paper, the train departure process in the Port of Trieste, Italy, has been investigated in terms of information flows: to that end, the Business Process Modeling Notation (BPMN) standard has been used. On one hand, this task has enabled to clarify the documentary procedure occurring in diverse operational scenarios and, on the other hand, it has allowed also to recognize the process bottlenecks which hinder an increase in the railway traffic volume. Furthermore, a quantitative analysis concerning the terminal and gateway capacity, before and after the implementation of a technological intervention, has demonstrated the possible growth of train flows by modifying the process only at the organizational level. These accomplishments have proved to port managers the usefulness of applying a theoretical graphical representation to a practical transport process.

Keywords: intermodal freight transport, rail operations, capacity, modelling standard, BPMN

1 Introduction

The phenomenon of globalization and the extensive adoption of containers occurred since the 1960s have substantially affected the change of the market environment which ports and shipping lines belong to [1]. Indeed, containerization has simplified freight transport and, at the same time, the size of containerships has significantly risen over the last decades to exploit the advantages of the economies of scale. The increase in freight standardization has allowed the implementation of intermodal transport systems, which permit the transfer of containerized materials by rail, truck or sea [2]. In order to sustain the growing freight demand, the effective management and execution of port operations has turned out to be fundamental as much as the presence of an adequate intermodal accessibility to roadways and railways [3]. A solution to drain the higher volumes of freight arriving to ports has consisted in a greater employment of trains, which has led to an enhancement of the competitiveness

of ports and, therefore, of their throughput [4]. In this regard, due to the expected raise in the railway share in the near future, capacity usage has become an even more central issue. Indeed, focusing on railway nodes, the identification of critical infrastructural elements in their configuration and the determination of effective measures to fully exploit their potential use constitute two common problems of railway engineering [5].
The need of conveniently managing intermodal systems can be analogized to the one of running industries, independently from the activity field, since in both circumstances an efficient organization of business processes represents a key feature for gaining competitiveness within the marketplace. A solution to assess possible productivity advancements can be provided by Business Process Management (BPM), which is defined as "a systematic, structured approach to analyze, improve, control and manage processes with the aim of improving the quality of products and services" [6]. The activity of representing the processes of a company is called Business Process Modeling (BPMo) and is usually carried out by business analysts and managers with the aim of analyzing the current situation ("as is") and planning an improved one ("to be") [7]. Numerous BPMo techniques, and their corresponding tools, have been developed to capture the various aspects of business processes but, as suggested in [8], the determination of process modeling goals should be the initial task to choose the appropriate BPMo method. In the present paper, the main objective of process modeling consists in analyzing the departure procedure of freight trains in the commercial port of Trieste, Italy, in order to identify possible bottlenecks that impede a capacity increase. To this end, rail operations have been modeled taking into account also the documentary flow which occurs among the numerous private and administrative actors involved in the examined process. More in detail, the BPMN standard has been used to represent the activities performed by the different stakeholders and the execution time of the principal tasks has been estimated in order to compare the capacity values before and after the potential implementation of a technological intervention.
The article is structured as follows. The second chapter reports a literature review on both the most used graphical standards, and the application of BPMN to freight intermodal transport case studies. The third chapter explains the methodological approach adopted for BPMo, while the fourth one illustrates the key features of the port of Trieste and of the rail operations included in the BPMN process diagram. The fifth chapter contains the capacity analysis results, which are discussed in the sixth one, along with the description of future developments in the use of BPMo for the analyzed problem. Finally, the last chapter draws conclusions on the usefulness of applying the theoretical methodology of process modeling to the practical context of intermodal goods transfer.

2 Literature review

In line with the increasingly common principle of organizing businesses according to value-adding processes rather than to functional hierarchies, the deployment of modeling techniques has diffused among practitioners and academics, facilitating also the development of supporting software [9]. Limiting the scope of the present study to the design stage of the business process life cycle, the focus of the literature review has been restricted to graphical standards. Among the various existing techniques, the following methods are the most widespread when modeling business processes in a graphical manner: Unified Modelling Language Activity Diagrams (UML AD), BPMN, Event-driven Process Chains (EPC), Role-Activity Diagrams (RADs) and flow charts. Actually, these latter three methods can be considered only as tools to graphically display the chronological implementation of activities, since a standardization process is missing. On the contrary, BPMN and UML AD are two proper standards used to model business processes which result to be very similar, as they supply analogous symbols and control flow patterns [10]. UML AD is one of the thirteen

diagrams which are provided by the Object Management Group (OMG) mainly for modeling object-oriented software. Despite its maturity in designing single processes, there are some difficulties in modeling sub-processes and resource-related or organizational aspects, like the interaction with the operational environment [10]. BPMN is a standard originally developed by the Business Process Management Initiative (BPMI), which then joined the Object Management Group (OMG) for developing a new BPMN Specification document [11]. BPMN rapidly became the de facto standard, since it offers a simple and expressive look to business analysts and provides the foundation for process implementation. It uses an expressive flowchart-based graphical representation to model the business process flow. In particular, the main graphical elements are activities, gateways, events, sequence flows, pools and lanes. Since each of graphical element is translated into an XML element, BPMN models are used to communicate and interchange the business requirements of a business process, as well as to execute them on enterprise engines.

The literature review concerning the application of BPMo techniques to the intermodal transport field has been limited to those using BPMN, especially for its capability of representing processes at different levels of granularity and for the opportunity of mapping BPMN models to execution code [10]. A few previous researchers have investigated the intermodal transport topic stressing the relevance of information exchanges between the actors engaged in the operations. For instance, in [12], the authors adopted BPMN to model business processes and data flows related to the incoming container traffic in the Port of Hamburg focusing on the elements standardization and integration, in order to identify the significant junctures of the transport chain where these two features would enable a more efficient utilization of the current infrastructure. In [13], a BPMN model is proposed to examine the Port Community System of Salerno, Italy, not only in terms of the organizational procedure of each involved actor, but also of the inter-organizational routines between them. To this end, the as-is, to-be and gap analysis regarding the administrative activities of an export process were carried out, proving the relevance of creating an integrated information and communication platform for intelligent logistics services. The case study reported in the present paper differs from the previous ones for two main reasons. The first one consists in the fact that the standardization and integration of information flows are given for granted in the Port of Trieste, as it has been undertaking a radical and innovative computerization process of data exchanges for years, definitely improving the communication among stakeholders. The second difference comes from the higher degree of complexity of the examined logistics context, which is given mostly by the engagement of a variety of actors. More specifically, the suggested BPMN model has been created with the intention of making explicit the documentary procedure of the rail operations related to an outgoing train. In this regard, a detailed status quo analysis of the selected business process has enabled the determination of its criticalities, which constitute hindering factors for an increase in the railway node capacity.

3 Method - BPMN

Following the framework for selecting BPMo methods proposed in [8], the objective of process modeling has consisted in the analysis of the current situation of rail operations in the Port of Trieste, which has permitted the identification of possible improvements in the involved activities. Consequently, the established objective has influenced the perspective of the modeling method and its features. On one hand, the activity perspective has been adopted, enabling the representation of both the performed actions and of the relationships between them. On the other hand, characteristics like scalability and enactability have been sought during the selection of the appropriate modeling method to ensure its capability of, respectively, dealing with large processes and offering automated tools for process simulation. In light of these three constructs, that are objective, perspective and characteristics,

the BPMN technique has been selected as the most appropriate modeling approach to address the appraisal of potential capacity increase in the Port of Trieste. To create the BPMN model of the problem considered in this study, much effort has been put to reach a good level of understandability, which depends mostly on graphical readership and pattern recognition. Attention has been paid in particular to the three categories of features, namely structure, layout and labeling, since, according to the investigation results reported in [14], they can frequently implicate some quality issues. Some recommendations concerning style and method suggested in [15] have been applied and, besides, the peculiar characteristics of the analyzed case study have been taken into account with the aim of building a context-sensitive model. Finally, in line with [16], stakeholder participation, information resources, and modeler's expertise have represented important factors to process modeling success. The relevance of engaging key actors in the evaluation of transport interventions has been corroborated in [17].

4 Case study

The Port of Trieste is located in the North-East of Italy, in a strategic position at the center of Europe, and represents the crossroads of different maritime routes and transport corridors. It constitutes an important international hub for the land-sea flows related to the marketplaces of Central and Eastern Europe, and more lately of Far East, also thanks to a great water depth. Besides, the Port of Trieste possesses an internal railway network, which is effectively integrated with the national and international ones. In this regard, it is the Italian port with the highest traffic volume of freight trains. The Port of Trieste is considered a Free Port, which means that customers can take advantage of special regulations with respect to customs procedures and the fiscal regime. In the recent past, the Port Authority has introduced a technological innovation consisting of an IT platform, named Sinfomar, in order to computerize the running process of port system operations. Through the creation of a section dedicated specifically to trains, Sinfomar enables not only the management of the incoming and outgoing railway flows in the Port of Trieste, but also the dematerialization of the document called CH30 and the interoperability with the information platforms of both railway and logistics third parties. CH30 is a digital customs document that contains detailed information on both the freight and the physical composition of trains and it certifies the arrival/departure of goods by train to/from the Port of Trieste, evolving through different statuses.
Bearing in mind the goal of identifying possible enhancements to increase the port railway capacity, in the present study it was decided to describe only the train outgoing process (Fig. 1) [18], since it allows to clearly visualize the potential criticalities limiting a growth of the traffic volume. The start event of the process consists in the reception by the customs of a provisional version of CH30, which is then athorized and verified also by the financial police if no mistakes are observed in the document and thus no modifications by the Multimodal Trasport Operator (MTO) are needed. Once the train is loaded, it is subjected to a pre-check by the competent railway company: in case of irregularities, cargo units have to be controlled, which can implicate their potential removal or addition and, consequently, a variation of CH30 by the MTO. If the outcome of the pre-check turns out to be positive, the MTO generates a definitive version of CH30, which is successively confirmed by the customs, and the train departure is validated. During the outgoing shunting, the train has to transit through a gateway which delimits the Free Port zone from the remaining port areas. In correspondence to this passage, the financial police perform a verification of both the wagons and loading units: if any irregularity is encountered, the execution of an additional shunting and a few modifications in the content and status of CH30 are necessary. In case of an affirmative result of this check, the financial police validate the final version of CH30 and the train is allowed to leave the port. Subsequently, after the detachment of the diesel locomotive used to perform

the exit shunting, the operation manager makes the train available to the railway company at the main port railway station, which is directly linked to the national network. Finally, prior to the opening of the departure signal by the national railway infrastructure manager, called Rete Ferroviaria Italiana (RFI), the railway company carries out a brake test on the train.

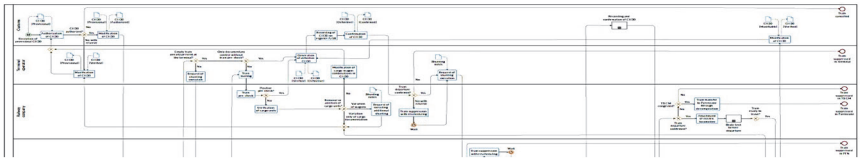

Figure 1 Part of the BPMN model of the examined railway process

5 Results

Using BPMN to model the train departure process, it was noticed that, at terminals, the loading procedure is followed by a train pre-check, which is currently performed manually by an operator of the railway company. According to the data provided by the Port Authority, that activity, along with the verification of cargo units, lasts about 35 minutes. This duration turns out to be quite substantial with respect to the one needed for loading operations, which are usually carried out in 3 hours. Considering that an additional hour elapses between two successive train loadings, the long duration of the pre-check primarily entails some traffic issues at terminals, rather than to the whole railway node. Indeed, taking into account a 22-hour daily operability and 288 working days for the terminals, the capacity of the three analyzed piers is limited to 9677 trains per year. The BPMN representation of the examined process has enabled the identification of another significant task for port capacity, i.e., the train check at the gateway separating the Free Port zones from the surrounding port areas. The detection of irregularities during that control implicates the addition of further 40 minutes to the normal execution time of the procedure. This delay is registered for 2 trains a day and entails the train stop right in correspondence of the gateway or, at times, on a buffer track in the proximity. The quite high frequency of check failures definitely has severe consequences on port railway traffic because, in that part of the infrastructure, a single track is present. In these circumstances, considering the time interval in which a departing train travels along the Free Port zone railway network until the gateway and the time necessary to exit its tail, the annual capacity on that specific infrastructure component equals to 11192 trains. Reasoning on the results of the "as-is" analysis, a procedural strategy to enhance the current operability has been developed and its impacts on the train flows have been estimated. The solution consists in improving the technique in which the train pre-check at terminals is carried out. As a matter of fact, the installation of optical reading portals able to automatically read the identification code of freights would certainly eliminate possible human mistakes. The spare of the time which is currently needed to perform the manual control, would allow an increase in the capacity of each terminal of 15 %, leading to an overall annual value of terminal capacity that is around 11088 trains. However, still considering a rate of 2 irregular trains per day, the growth of the total terminal capacity could potentially generate critical operational conditions, since it is near to the actual limit gateway capacity. Supposing that, thanks to the technological intervention at terminals, no irregularities are recorded during the control at the gateway, the annual capacity of this last infrastructure element would increase of 6.8 %, which means up to 11955 trains, obtaining a higher capacity margin.

6 Discussion

The evidences resulting from the BPMN modeling of a train departure process and from the quantitative capacity analysis have proved that the introduction of optical reading portals at terminals would not only enhance their capacity, but it would also have a beneficial impact on the control at the gateway, which represents the critical component of the port railway infrastructure. Indeed, the positive effects of the technological intervention proposed in the "to-be" scenario, i.e., the shorter duration of the execution time of the train pre-check and its greater quality reliability, would allow a growth in the annual port railway traffic of about 1000 trains. Thus, the suggested capacity increase would be accomplished just by modifying the current procedure at the organizational level, without realizing any additional track.
With respect to future advancements of the present study, going beyond the analyzed documentary flow, the departure process of a train within the Port of Trieste is planned to be investigated in depth also at the operational level, taking into account each specific shunting that is necessary to be performed. Besides, the interaction of different trains circulating in the port railway network is considered to be examined, in order to capture possible interference problems. Finally, the proposed static model is intended to be simulated using a tool called Business Process Simulation (BPSim), a standard by Workflow Management Coalition (WfMC) defining a specification for the parameterization and interchange of process analysis data, which is complementary also to BPMN. BPSim allows structural and capacity analysis of process models and supports both pre-execution and post-execution optimization of process models [19].

7 Conclusions

The remarkable increase in freight demand due to globalization and containerization has brought out the importance of an appropriate intermodal accessibility to inland transport modes and, consequently, the need of efficiently managing transfer processes at port facilities. To this end, business process modeling techniques have been adopted to deeply understand transport-related procedures at the organizational level, in order to identify potential criticalities of the current situation and to suggest an improved scenario. In the present study, the BPMN standard has been used to display the departure process of a train in the Port of Trieste, enabling to capture the bottlenecks that hinder a growth of the port rail capacity. The graphical representation of the examined process has constituted the basis for a quantitative analysis to compare the different time durations of the main involved activities before and after the implementation of some organizational interventions. This integrated evaluation has proved the possibility of a quite significant rise in the train traffic flows, respectively of 15 % at terminals and of 6.8 % at the critical gateway, without any modification to the existing railway infrastructure layout. Future developments of the research consist in representing via BPMN also the activities performed at operational level of the same railway procedure, considering the interactions among trains. Furthermore, the proposed model is intended to be animated by means of a simulation tool, in order to optimize the considered process. The accomplishments obtained in the present study confirm that BPM is a multi-disciplinary approach which demonstrates the usefulness of applying theoretical concepts to operational issues.

References

[1] Notteboom, T. E.: Container Shipping and Ports: An Overview, Review of Network Economics, 3 (2004), pp. 86-106

[2] Parola, F., Sciomachen, A.: Intermodal container flows in a port system network: Analysis of possible growths via simulation models, International Journal of Production Economics, 97 (2005), pp. 75-88

[3] Bassan, S.: Evaluating seaport operation and capacity analysis - preliminary methodology, Maritime Policy & Management, 34 (2017), pp. 3-19

[4] Caballini, C., Sacone, S., Siri, S.: The port as a system of systems: A System Dynamics simulation approach, 7th International Conference on System of Systems Engineering (SoSE), pp. 191-196, Genova, Italy, 16-19 July 2012.

[5] Malavasi, G., Molkovà, T., Ricci, S., Rotoli, F.: A synthetic approach to the evaluation of the carrying capacity of complex railway nodes, Journal of Rail Transport Planning & Management, 4 (2014), pp. 28-42

[6] Elzinga, D.J., Horak, T., Lee, C.Y., Bruner, C.: Business Process Management: Survey and Methodology, IEEE Transactions on Engineering Management, 42 (1995), pp. 119-128

[7] Chinosi, M., Trombetta, A.: BPMN: An introduction to the standard, Computer Standards & Interfaces, 34 (2012), pp. 124-134

[8] Luo, W., Tung, Y.A.: A framework for selecting business process modeling methods, Industrial Management & Data System, 99 (1999), pp. 312-319

[9] Aguilar-Savén, R.S.: Business process modelling: Review and framework, International Journal of Production Economics, 90 (2004), pp. 129-149

[10] Ko, R.K.L., Lee, S.S.G., Lee, E.W.: Business process management (BPM) standards: a survey, Business Process Management Journal, 15 (2009), pp. 744-791

[11] Object Management Group, https://www.omg.org/spec/BPMN/2.0, 16.11.2019.

[12] Elbert, R., Pontow, H.: Standardization and integration of information flow along the maritime transport chain, Darmstadt Technical University, Department of Business Administration, Economics and Law, Institute for Business Studies, 2013.

[13] Bisogno, M., Nota, G., Saccomanno, A., Tommasetti, A.: Improving the efficiency of Port Community Systems through integrated information flows of logistics processes, The International Journal of Digital Accounting Research, 15 (2015), pp. 1-31

[14] Leopold, H., Mendling, J., Guenther, O.: Learning from Quality Issues of BPMN Models from Industry, IEEE Software, 33 (2015), pp. 26-33

[15] Silver, B.: BPMN Method and Style, with BPMN Implementer's Guide, Cody-Cassidy press, Aptos, 2011.

[16] Bandara, W., Gable, G.G., Rosemann, M.: Factors and measures of business process modelling: model building through a multiple case study, European Journal of Information Systems, 14 (2005), pp. 347-360

[17] Caramuta, C., Giacomini, C., Longo, G., Padoano, E., Zornada, M.: Integrated evaluation methodology and its application to freight transport policies in the port of Trieste, Transportation Research Procedia, 30 (2018), pp. 119-126

[18] https://drive.google.com/drive/folders/1MqKO15xGi7OcwXd5muVzQjcXDqlT7rDi?usp=sharing