Integration of BPMN Modeling and Multi-actor AHP-aided Evaluation to Improve Port Rail Operations

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Abstract

Selecting the best scenario of intervention to improve the functioning of complex systems represents a troublesome task both for public and private decision makers, since it requires the deployment of appropriate analysis and evaluation tools. In the case of intermodal transport systems, complexity is given by the execution of different types of activities using various resources, and by the presence of several actors operating in the same environment with diverse goals. In this paper, an integrated approach to assess design alternatives regarding rail port operations is proposed by combining business process modeling and multi-actor multi-criteria evaluation. In fact, a railway process has been graphically represented by means of the standardized modeling language called Business Process Modeling and Notation (BPMN) at different levels of detail, i.e. taking into account not only the actual transport operations but also the necessary documentary procedures to perform the freight transfer services. In addition to the identification of possible bottlenecks, the analysis of the considered railway process has enabled the determination of its most significant features. These parameters have been subsequently used as some of the criteria according to which the performances of the examined scenarios of intervention have been evaluated, adopting the Analytic Hierarchy Process (AHP) technique. Furthermore, the appraisal has been enhanced by explicitly including the key stakeholders involved in the railway process at hand. The developed methodology has been applied to the case study of the Port of Trieste, Italy, in order to investigate possibilities for an increase in railway capacity.

Keywords: Intermodal transport systems; rail port operations; BPMN modeling; AHP evaluation.

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1. Introduction

The task of determining the best course of action to improve business processes, especially in complex contexts, definitely represents a challenge for decision makers who aim at enhancing the efficiency of the system they manage. The accomplishment of such selection procedure brings out the need of adopting adequate analysis and evaluation tools, whose combination enables to develop a robust approach for decision problem solving. Indeed, a thorough examination of the considered business process constitutes a fundamental initial step to capture its main features and possible criticalities. To this end, being central components of the discipline of Business Process Management according to Van der Aalst (2013), modelling languages are used to effectively display business processes. Referring to graphical standards, they permit to visualize the logic sequence of the activities to be performed and other essential characteristics of business processes like information flows, decision points and roles, as explained by Ko and al. (2009). Along with the understanding of the modelled business processes, Lodhi et al. (2014) consider the evaluation of their performances a primary stage to improve them. In this regard, many methods are present in literature, suggesting various measures to estimate the level of attainment of business processes against the identified goal. However, the main limitation of these measurement techniques consists in the fact that they usually reflect the perspective of only one of the stakeholder categories interested by the analyzed business process. The existence of such drawback in assessment procedures leads to the necessity of developing an appraisal framework able to encompass diverse aspects of business processes, in order to carry out a comprehensive evaluation of their performances. Indeed, the deployment of an assessment approach allowing to take into account multiple criteria turns out to be crucial to reach an aggregated evaluation result, which includes the various points of view of the actors engaged in the business process at hand.

Within the service field, the adoption of BPM principles is certainly suitable for designing possible advancements in the specific sector of freight transport and, more in particular, in the one providing intermodal solutions. In fact, modeling techniques have already proved to be capable of coping with the inherent complexity which characterizes the environment of a seaport, that is described by Caballini et al. (2012) as a "system of systems" due to the interaction among several factors, like regulatory and organizational ones. In such circumstances where different activities are executed by various actors to accomplish sometimes conflicting goals, as highlighted by Notteboom et al. (2003), the selection of the best design alternative to improve business processes undoubtedly requires the inclusion of many aspects in the performance evaluation procedure. To that purpose, resorting to participatory multi-criteria appraisal methods permits to cope with the socio-technical nature of the transport sector illustrated by Cascetta et al. (2015).

This paper proposes an integrated methodology which mixes the business process modelling and a multi-stakeholder multi-criteria assessment technique to rank a set of scenarios of intervention related to rail port operations. More in detail, the Business Process Modeling and Notation (BPMN) standard has been used to analyze the considered railway process, enabling the definition of some of the parameters that have been inserted in the appraisal framework developed according to the Analytic Hierarchy Process (AHP) method. The suggested methodology has been applied to the case study of the Port of Trieste, Italy, examining the freight trains departure process in order, to identify the best strategy for a possible railway capacity increase.

The paper is structured as follows. The second section reports a literature review of some frameworks used to estimate the performances of business processes, highlighting their main features, while the third one describes the proposed appraisal methodology for the selection of the best business process solution. In the fourth section the application of the suggested evaluation model to the considered case study is explained and the obtained results are discussed in the fifth section. Finally, conclusions are drawn on the effectiveness of the developed evaluation procedure, stressing out the importance of deploying an integrated assessment technique to formulate inclusive and shared recommendations on design alternatives in a multi-actor context.

2. Literature review

The importance of adopting a performance measurement system (PMS) in view of designing possible enhancements of business processes or organizations is well acknowledged among researchers and practitioners, and it is proved by the presence of many contributions in literature reviewing the techniques developed to face that issue.

In this regard, coherently with the goal of the present paper, attention has been drawn to studies concerning the elaboration of PMSs with two specific characteristics: on one hand, they are focused on evaluating the performances of business processes, and not of corporations or business units, and on the other hand, they take into account a wide range of assessment criteria. According to the framework positioning different measurement approaches proposed by Kueng (2000), such kind of appraisal methods constitute a so-called Process Performance Measurement System (PPMS). Regarding the first PPMS property, Milanović Glavan (2011) sustains that the adoption of a process-based PMS is essential for the continuous advancement of modern organizations, whose management has turned from being function-oriented to process-oriented. With reference to the second feature of a PPMS, Kueng (2000) stress that the PMS is required to encompass not only quantitative aspects, but also qualitative ones, in order to provide a holistic evaluation of the performances of the business process under examination. Indeed, as noticed by Neely et al. (2000), one of the main limitations encountered in the existing PMS consists in the fact that they usually consider a narrow set of measures or even an uni-dimensional focus, which is traditionally the financial one. This weakness is corroborated by Kueng et al. (2001), who highlight the necessity for an appropriate PMS of being able to track additional non-financial indicators. As reported by Leyer et al. (2015), the most used performance measures for business processes are quality, time, cost, and flexibility, which can be successively specified more in detail with further indicators. However, Kueng (2000) observes that process performance measurement should not be limited to these generic concepts, but they should be conceived so as to be stakeholder-driven, i.e. it should reflect the perspectives of the different actors interested by the business process at hand. The fulfilment of this requirement implicates carrying out a stakeholder analysis to determine the key personalities engaged in the business process improvement or affected by its impacts and, consequently, the identification of their respective objectives in relation to the considered business process.

In the following, some examples of PMS possessing the two main criteria abovementioned are reported. For instance, despite a partial reference to an organizational performance measurement model, Lynch et al. (1991) propose a hierarchical framework for business process measurement. In this latter, the various criteria are structured in a performance pyramid, with the main vision of the enterprise at the top, and they are distinguished among internal and external aspects of the business process. A PPMS with a similar configuration is proposed by Kueng (2000) and consists in a goal and performance tree, where the measures derive directly from the process high-level goals associated to the different process views and are then specified in sub-goals in a descendent way. Another attempt to provide a comprehensive method for business process performance measurement is illustrated in Van Looy et al. (2016). It delivers an extensive list of process-related performance indicators originated from a structured literature review, that have been categorized into 11 diverse performance perspectives with the aim of reaching a global view of the examined business process. The identified perspectives come from a refinement of the ones included in the widely used PMS called Balanced Scorecard, developed by Kaplan and Norton (1996), and are meant by the authors to be deployed as a checklist when defining the performance indicators for a certain business process. Notwithstanding the usefulness of PPMS in evaluating the effectiveness of business processes according to multiple dimensions, Kueng (2000) highlights that they do not show decision makers what initiatives should be taken to enhance business processes, because they limit to indicate whether corrective actions are needed on the basis of the weaknesses detected by analysing business process performances. In this regard, Yen (2009) remarks two main drawbacks of previous research concerning the evaluation of business processes: the difficulty in comparing different sets of multiple performance measures, due to the disaggregation of the assessment parameters, and the lack in considering stakeholders' preferences on the appraisal criteria. In order to overcome these limitations, he proposes an integrated model for business process measurement consisting in the adoption of the Analytic Hierarchy Process (AHP) technique. This method is a multi-criteria decision-making (MCDM) approach developed by Saaty (2004) and supporting decision makers in ranking diverse scenarios of intervention to select the best one. More in detail, according to the AHP principles, he created a hierarchical evaluation diagram composed by three diverse levels which, moving from the top to the bottom of the framework, correspond to the goal of the assessment, the selected appraisal criteria and, finally, the identified business process alternatives. The criteria included in the model encompass both quantitative and qualitative aspects and reflect the perspectives of the various stakeholders interested by the business process. With the aim of effectively managing both types of criteria regardless their different nature, Yen transforms any performance measurements into a common ordinal scale in terms of level of satisfaction, which is expressed through a five-point Likert scale defined by stakeholders. This

conversion facilitates the determination of a single overall measure. The described approach is applied to a patient clinical service process, that is intended as a proper business process.

In line with the aforementioned characteristics of a PPMS defined in literature, this paper presents an evaluation methodology focused on a specific business process and considering multiple performance measures, which have been partially derived from the analysis of the examined business process model. The selected performance measures have been then combined by means of a multi-stakeholder assessment technique to determine the best overall improvement solution to the examined business process. Finally, the application of the integrated methodology to a complex case study regarding the intermodal transport sector is illustrated, with the purpose to show how to practically operationalize it in a real context.

3. Methodology

Agreeing with Glykas (2011) on the relevance of integrating performance measurement indicators and tools, the methodology presented in this paper combines business process analysis using BPMN modeling to identify performance measures, and multi-stakeholder multi-criteria evaluation by means of the AHP technique to aggregate the decisional components. Indeed, the business process considered in this paper has been examined following its visualization carried out through the BPMN standard, whose Specification document is provided by the Object Management Group (2014). The deployment of such standard is widely spread among business analysts since it offers the possibility of easily modelling business processes based on a specific notation, whose main graphical elements are tasks, gateways, events, sequence flows, pools, and lanes. Besides, the displayed elements are then translated into corresponding XML elements, that enables the execution of the modelled business processes. The expressiveness of the created BPMN flowchart has permitted to capture the main features and criticalities of the investigated business process, revealing different possible performance measures. In this regard, in their systematic review of studies having measurements for the advancement of business process quality as the principal subject, Sánchez González et al. (2010) observe that the prevalence of the examined initiatives focusing on business process model measures, rather than on execution ones, highlights their usefulness in detecting process weaknesses and, thus, in eliminating potential errors in early stages of business process lifecycle, i.e. in the design phase.

The performance measures identified thanks to the BPMN model analysis represent the connecting elements with the other technique considered in the proposed methodology, namely the AHP method. In fact, some of them have been used as assessment criteria, along with further variables, to perform a multi-stakeholder multi-criteria appraisal aimed at determining the best scenario of intervention to improve the business process at hand. The AHP technique is an evaluation method consisting in the decomposition of complex decision problems into a multi-level hierarchical structure made of simpler elements, among which both quantitative and qualitative criteria can be included. Given the significant influence of the engagement of stakeholders when carrying out decision-making procedures, similarly to other evaluation approaches, also the AHP method has been further developed to integrate in the evaluation process the perspectives of different actors. According to the results of the review on the approaches to define AHP criteria elaborated by de F. S. M. Russo et al. (2015), it turns out that, in the majority of the analyzed contributions, criteria are selected from literature or on the basis of the relevance they are attributed to by a specific organization. Only a marginal share of the examined research studies resorted to the support of external experts for the definition of criteria. In the suggested methodology, in addition to deriving assessment criteria from the analysis of the developed BPMN representation of the business process, they have been chosen partially adopting the latter strategy. In this regard, in analogy with the observations of Kueng (2000) concerning the elicitation of performance indicators, starting from scratch to determine criteria proves to be more promising than selecting the right ones from an existing generic list. Indeed, in this way, the appropriate level of detail of criteria and their adaptation to the examined business process can be arbitrarily defined. In any case, the reference to the process goal represents the key principle when defining measurement criteria. As illustrated by Ho (2008), in the AHP method the creation of the decision-making framework is followed by a phase in which pair-wise comparisons are performed between the elements composing the hierarchical structure, in order to estimate their priorities. Judgements on the comparative attractiveness of two attributes belonging to the same level are expressed according to Saaty's 1-9 rating scale, against one element inserted in the upper level; subsequently, the inconsistency of judgements is checked with respect to an established benchmark value. Finally, the synthesis of the judgements

attributed to the relative importance of the elements enables to define the ranking of the considered alternatives and, thus, the formulation of an aggregated decision recommendation for the problem at hand.

4. Case study

The suggested methodology has been applied to the case study of the train departure process in the Port of Trieste, Italy, whose graphical representation and detailed explanation is reported in Campagna et al. (2020). The Port of Trieste represents a relevant international hub for land-sea flows benefitting from its strategic position in the center of Europe, at the crossroad of different maritime routes and transport corridors. The freight traffic related to the Port of Trieste mainly serves the marketplaces of Central and Eastern Europe, but more recently also the one of Far East, thanks to the port great water depth and to its advantageous regime of Free Port. This latter unconventional favorable legislation guarantees to customers the exemption from duty payment and concerns both the import, export and transit operations. Furthermore, the Port of Trieste has an internal railway network, integrated with the national and international ones, which has enabled a significant development of intermodal transport in the last years. Indeed, according to national statistics, it is currently the Italian port with the annual largest number of freight train flows. The areas and buildings of the Port of Trieste are given in concession by the public entity managing the port (called Port Network Authority of the Eastern Adriatic Sea) to various private terminal operators, who handle the movements of diverse product categories, such as containers, and solid and liquid bulks. Given its role of important European intermodal transport facility, the railway network of the Port of Trieste is foreseen to be interested by an increasing traffic volume in the next future, but the inadequacy of the current railway infrastructure and the limited residual capacity could hinder a growth in train flows. Therefore, the application of a comprehensive evaluation procedure proves to be essential to identify the most valuable initiative leading to an advancement in the management of railway processes.

The analysis of the developed BPMN model representing the train departure process in the Port of Trieste made evident various performance measures concerning different aspects of the process, which range from financial to managerial and technical parameters. Indeed, regarding the economic field, operational and investment costs certainly represent two variables to estimate the expenditures required for the execution of railway port activities. Organizational features of the considered process have been captured by further measures like process duration, the number of completed processes, operations management, the technological innovation level, and the administrative procedures smoothness. Some of them have been included in the AHP assessment framework, together with other criteria related to the transport process.

The integrated model created for the AHP-aided evaluation is reported in Fig. 1 and consists of four principal levels; a similar assessment approach has been adopted in Caramuta et al. (2018). At the top of the hierarchy there is the main goal of the decision problem, which is the increase in railway port capacity, expressed as the number of trains generated by the Port of Trieste per year. The second level of the decision framework contains the key stakeholders involved in the business process under study, namely the Port Authority, the terminal operators, the railway companies, and the shunting operations manager. The Port Authority is the public entity managing the port, while terminal operators are those who actually perform freight movements, providing intermodal logistics services. The railway companies are charged of transferring freight along rail corridors until their destination port, whereas the shunting operations manager is responsible for carrying out the shunting activities inside the Port of Trieste, to the service of railway companies and terminals. The third level of the hierarchy includes the macro-criteria that have been identified to describe different features of the process alternatives to be analyzed; these macro-criteria have been in turn specified by defining some criteria, making the appraisal procedure more articulated. More in detail, the macro-criterion concerning costs, i.e. the financial expenditures necessary to perform freight railway transfers in the Port of Trieste, has been split into the operational costs needed to practically carry out railway services, deploying physical and human resources, and the investment costs required to realize different initiatives, whether infrastructural or organizational ones. The macro-criterion related to process efficiency, which encompasses the aspects that determine the quality of the executed railway operations, has been distinguished into the following facets: the administrative procedure smoothness, which concerns the exchange of documents needed to manage train flows in the Port of Trieste; the technological innovation level, i.e. the degree of IT solutions adoption to check the compliance of both freight transfer units and rolling stock with train document indications; and the operations

management, intended as the efficiency in deploying port resources, both tracks and shunting locomotives, in order to avoid idle time for those operational elements. The macro-criterion related to transport improvement, which includes the achievements that can be accomplished at port level with respect to the transport field, has been categorized into port competitiveness, meant as the capability of the Port of Trieste of accommodating the freight train demand originated by the reference logistics marketplace; the increase of interoperability, intended as a better cooperation among the stakeholders involved in the analyzed business process; and the impact on modal shift, corresponding to the effect on modal share that can be obtained on the basis of the adopted process management approach. Lastly, the macro-criterion related to the environment and social impact comprises the criteria that consider the reduction of emissions, which can lead to an improvement of the process environmental sustainability; the reduction of noise, caused by some port activities, and the level of employment, which is expected to possibly vary on the basis of the intervention to be implemented. The final level of the hierarchical appraisal structure consists of the business process design alternatives that are assessed by key stakeholders against the diverse aspects captured in the described macro-criteria and criteria. The three following scenarios have been taken into account: the status quo, which means the current configuration of the train departure process; the one entailing organizational and technological initiatives, thanks to the introduction of IT innovations, (e.g. by installing optical reading portals at terminals to automatically read the identification code of freight transfer units); and the one considering also infrastructural interventions in addition to organizational and technological arrangements, in terms of creating further tracks to the existing railway port network and advancing the traffic control system to manage infrastructural elements.

For the application under study, direct judgements on the relative importance of the elements included in the proposed hierarchical framework have been expressed by a group of experts during a technical meeting, taking into account the different perspectives of key stakeholders engaged in the railway process at hand. Such task required efforts to the group of experts for the attribution of realistic values to capture the actual priority of the evaluated elements, since the administration of structured interviews to perform pair-wise comparisons directly to the involved actors was not possible.
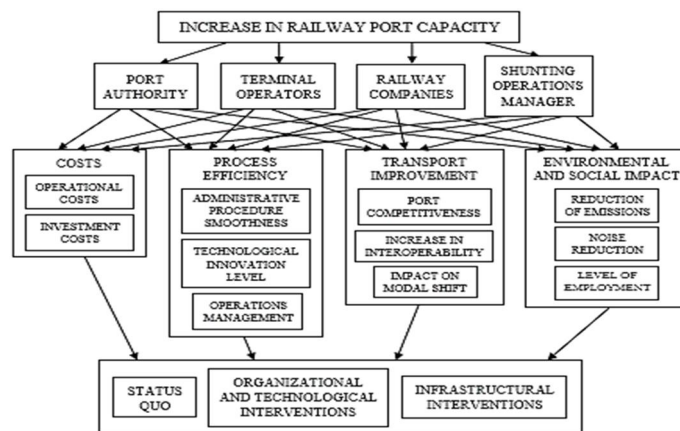

Fig. 1. Hierarchical evaluation framework.

5. Results and discussion

The preferences considered by the group of experts to reflect the various stakeholders' points of view have been then implemented in the model, according to Saaty's AHP method, in order to determine the level of influence of such actors with respect to the attainment of the main goal, the priorities of the attributes and the ranking of the alternatives. As it can be noticed in Fig. 2, it turned out that the Port Authority is the most influential stakeholder to increase the railway port capacity, followed by the shunting operations manager and the terminal operators; on the contrary, railway companies prove to play a very marginal role for the accomplishment of the considered objective. This result underlines the importance of the managerial activities carried out by the Port Authority.
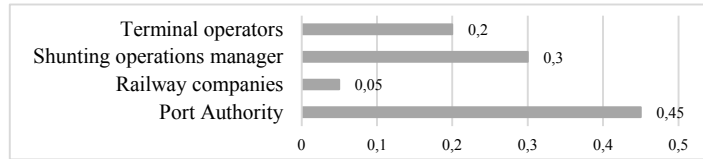
Fig. 2. Level of influence of the considered key stakeholders.

Regarding macro-criteria, Fig. 3 reveals that process efficiency proves to be the most relevant macro-criterion, even though also the great significance of costs is shared by all the considered actors. Besides, evaluation outcomes suggest that transport improvement is definitely associated to a remarkable priority, while the importance of the environmental and social impact is quite limited. Furthermore, within each relative macro-criterion, the criteria related to operational costs, the administrative procedure smoothness, port competitiveness, and the level of employment result to be associated to the highest priority.
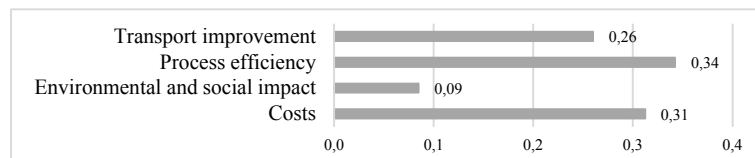

Fig. 3. Priorities of macro-criteria.

Finally, as reported in Fig. 4, the overall ranking of the examined initiatives was determined on the basis of the level of influence of the involved stakeholders and on the priorities of macro-criteria and criteria, to define the most valuable intervention in a multi-actor context. The order showed that the most effective alternative to increase railway port capacity corresponds to the one considering the implementation of infrastructural interventions, since the global effect deriving from the combination of both arrangements on the railway network and of organizational and technological initiatives exceeds the one generated only by the realization of these latter activities. However, the actualization of the second-best scenario would certainly entail an advancement in terms of a growth in train flows with respect to the status quo, but in a more modest extent compared to the one entailed by the preferred solution.
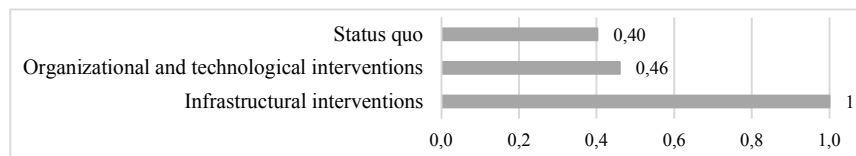

Fig. 4. Ranking of the alternatives.

6. Conclusions

In light of designing possible improvement initiatives of business processes, the evaluation of their performances through a comprehensive measurement system represents a fundamental task which requires to consider the various aspects characterizing business processes and, thus, to reflect the perspectives of the different involved actors. To this end, the paper proposes an integrated methodology that combines the analysis of business processes and a multi-stakeholder multi-criteria appraisal technique, enabling to select the best course of action to advance the business process under study. More in detail, some performance measures have been suggested by the examination of the business process model created by using the BPMN standard, which helped to identify process features and criticalities thanks to the development of an expressive graphical representation. Such indicators have partially corresponded to the criteria which have been inserted in the hierarchical assessment framework obtained by

adopting the AHP method. This latter structure has been refined introducing further transport-related criteria defined by a group of experts and explicitly including a few key stakeholders engaged in the analyzed business process. The proposed methodology has been applied to the train departure process in an Italian port, in order to select the best alternative to improve port operations and, consequently, to increase railway port capacity. Based on the judgements expressed by the experts to capture the different perspective of the considered stakeholders, the Port Authority turned out to be the most influential actor for the achievement of the main goal, while process efficiency has proved to be the macro-criterion with the greatest significance. Finally, the ranking of the alternatives revealed that the most effective course of action to increase railway port capacity consists in the implementation of both infrastructural initiatives and organizational and technological interventions, since the actualization only of these latter would entail a quite modest growth in train flows. Future advancements of the present research are twofold. On one hand, they consist in the administration of structured interviews to the involved stakeholders in order to gather their preferences concerning the priorities of the elements included in the model with respect to pair-wise comparisons. On the other hand, a further potential development of the proposed methodology is represented by the optimization of the considered business process, based on the performance criteria included in the AHP evaluation and inherently taking into account the diverse stakeholders' points of view, with the aim of capturing the socio-technical complexity of the intermodal system at hand.

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