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INVITED PAPER

Modeling inter-organizational business process governance in the age of collaborative networks

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Abstract
Collaborative networks require inter-organizational business process governance (IO-BPG) mechanisms to define ownership over shared resources and activities, accountability over operations, inter-organizational roles and responsibilities, and strategic partner alignment. We developed an IO-BPG modeling approach aiming to incorporate (1) IT governance activities (e.g., IT performance measurement), (2) data governance activities (e.g., data strategy management), and (3) "shadow" parallel governance-related operations. Resulting from a design science research project, our contributions include the building blocks (domain attributes, ontology, and requirements) of a novel BPMN extension, its demonstration in logistics operations, its evaluation, and design principles to guide IO-BPG modeling. Suggestions for the development and evaluation of future BPMN extensions are also highlighted based on the lessons learned in this project. For practitioners, our contribution can improve accountability reports over data assets and operations, identify dataset ownership, assist in the coordination of governance activities in networked businesses, and comply with regulations and strategic partnership agreements.

Keywords Inter-organizational business process governance · Inter-organizational data governance · BPMN extension · Design science research · Collaborative networks

JEL Classification L86 · M15 · O32 · C63

Introduction

Digital transformation (DT) has put pressure on businesses to develop integrative capabilities (Vial, 2021). The structural, procedural, and relational mechanisms proposed by the most prominent frameworks for process governance (e.g., (Kirchmer, 2017)), IT governance (e.g., COBIT), and data governance (e.g., (Data Management Association, 2017)) were designed to be applied to a single organization (Abraham et al., 2019; ISACA, 2018). However, the focus has shifted from internal operations to inter-organizational business processes (Abid et al., 2022; Bouchbout & Alimazighi, 2011; Norta et al., 2014), with an emphasis on networked businesses that enable companies to exploit digital products developed, implemented, and managed by multiple partners (Priyono et al., 2020). This requires robust IT support (Aulkemeier et al., 2019) and changes the dynamics of how organizations enact processes and how participants interact with each other (Buchinger et al., 2022). As a result, new mechanisms are required to govern business processes in collaborative networks (Kirchmer, 2021b).

Business process governance (BPG) aims to establish and ensure "end-to-end" business process performance while promoting alignment with the organizational goals (Kirchmer, 2021b). It covers process identification and prioritization, business process ownership definition, roles and responsibilities assignment, and process performance measurement (Kirchmer, 2017, 2021b). BPG shares its roots and foundational procedural (e.g., governance processes performance measurement), structural (e.g., defining

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responsibilities), and relational (e.g., informal relationships between departments) mechanisms with the tenets of IT and data governance, which needs to be reflected in the overall organizational governance approach (Kirchmer, 2021a).

Contemporary business processes are getting increasingly agile and distributed across organizations that are involved in collaborative networks, becoming more difficult to model using standard languages, such as Business Process Modeling and Notation (BPMN) (Amdah & Anwar, 2020; Legner & Wende, 2007; Liu et al., 2011). Modeling techniques can contribute to designing and optimizing inter-organizational business processes (Buchinger et al., 2022) by describing the relationships and flow of activities and decisions between multiple organizations (Semar-Bitah & Boukhalfa, 2019). However, the current modeling notations cannot fully represent the scope of inter-organizational business process governance. As an example, BPMN does not include the elements to represent details on data exchange between several partners (Amdah & Anwar, 2020), does not capture the behavior of resources distributed among the partners (Kunchala et al., 2020), nor the formal specification of business process interfaces (Legner & Wende, 2007). Moreover, it lacks the semantics to describe the dependencies of the global control flow (Bouchbout & Alimazighi, 2011) and is not able to represent the exchange and the ownership of process resources (Henkel et al., 2019). Lastly, the BPMN standard does not allow the modeling of shared data assets (Haarmann & Weske, 2020). All these elements are required for organizations to align business process logic and semantics between multiple partners (Legner & Wende, 2007). Therefore, our research objective (RO) was to "develop an inter-organizational business process governance modeling approach."

We set up a design science research (DSR) project that evolved in two cycles. The first cycle involved a leading telecommunications service provider that develops hardware and software solutions (e.g., network management platforms, fiber optics hardware) that integrate state-of-the-art technologies (e.g., artificial intelligence, data analytics, Internet-of-Things, and cloud infrastructures). The second cycle was performed in cooperation with a major European port management company operating in a highly regulated sector, providing a unique set of characteristics for an IO-BPG study. This company operates in an inter-organizational environment involving shipping companies, logistics agents, ship operators, technology suppliers, marine engineering consultants, and telecommunication companies, among many other public and private stakeholders, collaborating in port management processes and operations. Recently, the European Union approved new regulations for greenhouse gas emissions in logistics and transportation (European Council, 2022), which are responsible for about a quarter of the world's greenhouse gas emissions (CarbonCare, 2023). Also, in 2023, they approved a €59 million digital transformation project involving 35 organizations, including our University, to develop a data-driven and sustainable smart port ecosystem. The port will integrate state-of-the-art technologies, including solutions that combine advanced data analytics, cloud operations, artificial intelligence (AI) systems, machine learning (ML) models, Internet-of-Things (IoT) integration, and blockchain. A key challenge is how to model the governance of the inter-organizational business processes across multiple stakeholders, considering the IT resources and data assets that play a key role in their outcome. This collaborative context seemed well suited for our DSR project.

The remainder of the article is organized as follows, based on the structure proposed by Gregor and Hevner (2013) for DSR reporting. First, the literature review section presents the input knowledge for DSR, including IT governance, business process governance, data governance, BPMN and its extension mechanism, and related work on inter-organizational governance modeling scenarios. Then, the method section explains how DSR was adopted in this research. The subsequent section describes the developed artifacts: the inter-organizational process governance attributes, the domain ontology, the modeling requirements, and the graphical representation of the BPMN extension concepts. Next, the evaluation is presented, followed by a discussion of the results. Finally, the paper closes with the main conclusions, implications for theory, implications for practice, project limitations, and avenues for future research.

Literature review

From IT governance to business process governance

IT governance aims at the "strategic alignment of IT with the business such that maximum business value is achieved through the development and maintenance of effective IT control and accountability, performance management, and risk management" (Webb et al., 2006). To ensure the effectiveness of IT governance programs, organizations should define mechanisms to monitor compliance and performance with the agreed-on objectives (ISACA, 2018). Multiple factors influence the IT governance strategy, including the organizational culture, regulations, company mission and values, and business objectives and strategic intentions (Levstek et al., 2018).

COBIT (Control Objectives for Information and Related Technologies) (ISACA, 2018) is one of the most recognized industry frameworks for IT governance (Mangalaraj et al., 2014). Its governance domains include (1) value delivery, (2) resource management, (3) business-IT alignment, (4) performance management, and (5) risk management (ISACA, 2018). These dimensions are supported by relational, procedural, and structural mechanisms (ISACA, 2018). Relational can promote cross-functional IT-business training, IT-business co-location, the shared understanding of IT-business objectives, the interaction between the principal stakeholders, and the partnership rewards (Haes & Grembergen, 2015). For procedural mechanisms, organizations can define processes for strategic information systems planning, IT service management, and IT portfolio management (Haes & Grembergen, 2015). Lastly, structural mechanisms can include appointing an IT strategy committee, the IT steering committee, or the CTO (Chief Technology Officer) (Haes & Grembergen, 2015).

IT governance executes corporate governance toward managing key technological resources and operations (Ross & Weill, 2004), being a critical element of an organization's governance structure (Mäntymäki et al., 2022). When following a process approach, BPG focuses on the procedures and decisions to specify actions, verify performance, control the results, and grant power to business process management (BPM)-related activities (Kirchmer, 2017). It enables the "effective management of the process life cycle" toward achieving the organization's business and strategic objectives (Kirchmer, 2017). Therefore, BPG is considered a fundamental pillar in increasing BPM maturity (Rosemann & Brocke, 2015). Table 1 describes the BPG scope of activities in the organizational context (Kirchmer, 2017, 2021b).

On the one hand, BPG drives organizational transformation, leading the design and redesign of business processes to capitalize on the opportunities afforded by new technologies (Jurczuk, 2021; Kirchmer, 2021b). On the other hand, BPG aims to ensure that the BPM strategy is consistently executed and satisfies the stakeholders' expectations while keeping the organization competitive (Jurczuk, 2021; Kirchmer, 2017). To achieve these objectives, there is the need to develop a high-level enterprise process model, define the goals and management plans (e.g., business goals, organizational strategy, the enterprise architecture), and implement an organizational structure that coordinates the people involved in the BPM activities (Kirchmer, 2017).

There are similarities between the factors affecting IT and process governance. For example, the organizational strategy and culture, technological development, compliance requirements, industry trends, and financial constraints (Kirchmer, 2017). Moreover, governing processes increasingly supported by IT suggest the existence of synergies between both (Kirchmer, 2021b). As an example, the research of Rahimi et al. (2014) highlights the need for mutual adjustments between IT governance and the governance of business processes regarding the "*accountability for business-IT strategic alignment, process and IT requirements specification, and IT-enabled business value realization*" (Rahimi et al., 2014).

Business process models are essential to document business processes (Baiyere et al., 2020). They describe behavioral aspects of a system with the graphical representation of process flow, tasks, activities, data, and events. These models are often used to promote process reorganization, certification, activity-based costing, or human resource planning (Becker et al., 2000). Business process modeling is the basis of process-centric systems implementations, especially in the case of Enterprise Resource Planning systems (Barjis, 2008), on the key elements of the BPM culture, enabling the monitorization and logging of business processes (van der Aalst, 2013) and in the creation and implementation of BPM Systems (Weske, 2007).

However, the dynamic and rapid changes that characterize DT make it more challenging to model the ever-changing business processes (Baiyere et al., 2020). It becomes even more complex when multiple organizations share digital resources to conduct business.

Data in business process governance

An information system "emerges from the usage and adaptation of the IT and the formal and informal processes by all of its users" (Paul, 2007). Moreover, the information

Table 1 Business process governance scope of activities based on Kirchmer (2017, 2021b)

Activity	Description
Process identification	Identify the organization's cross-functional and critical business processes
Goals alignment	Clarify the high-level business and strategic goals and the corresponding key performance indicators (KPIs)
Business process ownership	Define accountability and ownership for the organization's business processes
Performance measurement	Define the measurement mechanisms that guarantee the transparency of the activities and enable agile decision-making
Process improvement	Settle the priorities for business process improvement
Reward and recognition	Define reward and recognition mechanisms regarding process-related activities

technologies used to support business processes produce a significant amount of data (e.g., process performance data) that is valuable for organizations (Fosso Wamba & Mishra, 2017). Process governance capitalizes on these data assets to improve the organization's process performance (Kirchmer, 2021a). This leads to a close interaction between the *context*, *IT*, *people*, *process*, and *data* that needs to be reflected in the governance approach (Kirchmer, 2021a). However, data assets require particular governance mechanisms (Khatri & Brown, 2010). Therefore, data governance should be addressed separately from IT governance, regarding the need to separate information assets (e.g., data sources, datasets, metadata, data storage technologies) from the IT assets (e.g., computers, servers) (Khatri & Brown, 2010; Mäntymäki et al., 2022) and processes (Kirchmer, 2021a).

Data governance handles data as a strategic corporate asset to develop innovative data-based solutions, manage data-related risks, comply with data-related regulations, deal with decentralized data assets, and improve data quality mechanisms (Abraham et al., 2019). Furthermore, it defines the organizational structures and the policies, processes, standards, and procedures that guide all the data-related activities of the organization (Abraham et al., 2019).

The data governance mechanisms are divided into three main categories (1) procedural mechanisms, (2) structural mechanisms, and (3) relational mechanisms, based on the proposal of Abraham et al. (2019) following the logic of Information Technology Governance (ITG) (Van Grembergen & De Haes, 2009). These mechanisms "*comprise formal structures connecting business, IT, and data management functions, formal processes and procedures for decision-making and monitoring, and practices supporting the active participation of and collaboration among stakeholders*" (Abraham et al., 2019).

For procedural data governance, organizations should define mechanisms to address data accuracy, correctness, security, and efficiency (Borgman et al., 2016). These include defining a data strategy, data policies, data standards, data processes, data procedures, contractual agreements, performance measurement mechanisms, compliance monitoring, and issue management (Abraham et al., 2019). The data strategy represents a comprehensive approach based on business goals (Medeiros et al., 2020), while data policies provide general guidelines and rules related to data creation, collection, storage, security, quality, and acceptable use (Alhassan et al., 2019). Data standards and procedures are deployed to guarantee that data representation and execution of data-related activities are consistently normalized across the enterprise (Data Management Association, 2017) to enable interoperability across the organizations and even externally (Costabile et al., 2022). Contractual agreements (e.g., service-level agreements (SLAs)) can be required to establish the data provisioning and sharing settings between involved internal departments or external organizations (Abraham et al., 2019) and is also necessary to assess the effectiveness of data governance by measuring goal achievement (Weber et al., 2009). Compliance monitoring is intended to track and enforce legal requirements and compliance with company policies, standards, and SLAs (ISACA, 2018), which can include the supervision of data professionals and projects, internal audits, and preventive/corrective measures (Data Management Association, 2017). The last type of procedural mechanism, issue management, refers to identifying, managing, and resolving data-related problems, which can include the standardization and categorization of data issues and issues resolution and the definition of a specific department to address these issues (Data Management Association, 2017).

The structural governance mechanisms are concerned with the definition of governance entities, accountability of actions, and reporting entities, focusing on setting roles (e.g., governance leader, data owners) and responsibilities as well as the allocation of decision-making (Abraham et al., 2019; Borgman et al., 2016).

The relational mechanisms deal with the definition of measures to promote the collaboration between the various internal (e.g., departments, team members) and external stakeholders (e.g., collaborating organizations), including communication (e.g., awareness for data governance, communication channels), training (e.g., promote new knowledge), and the coordination of decisions (e.g., hierarchy) (Abraham et al., 2019; Borgman et al., 2016).

Inter-organizational business process governance

The establishment of collaborative networks between organizations in vertical and horizontal integration paradigms (Camarinha-Matos et al., 2019) can offer opportunities at the "*strategic level, as well as significant challenges at tactical level, in order to properly combine flexible and effective inter-organization collaborations with traditional internally managed processes*" (Bocciarelli et al., 2017b).

Inter-organizational business processes (IO-BP) are interconnected sequences of activities shared and performed by two or more partner entities to reach a business outcome valuable to the organizations (Bala & Venkatesh, 2007). The partners rely on message and data exchange to perform business transactions (Abid et al., 2022). Implementing and executing IO-BP requires establishing trust mechanisms between the business partners, such as in the case of legal contracts. However, compliance and real-time control requirements are challenging in decentralized decision-making (Giaglis et al., 1996). Table 2 describes the main challenges in defining and implementing IO-BP.

Digital transformation increases the complexity of the challenges reported in Table 2, requiring the development

Table 2 Inter-organizational business processes challenges

Element	Description
Process interdependencies	Business process interdependencies must be managed and coordinated between the partners (e.g., shared IT resources and coordinated touchpoints) (Legner & Wende, 2007)
Roles and responsibilities	Roles and responsibilities must be defined for each business partner at the several steps of the business process (Kirchmer, 2017, 2021b)
Semantic gaps	Existing inter-organizational semantic gaps must be handled, considering that each business partner may have a distinct business process language (Legner & Wende, 2007)
Process traceability	Inter-organizational policies to control and trace the process tasks performed across several partners must be defined, including monitoring metrics at specific points (Breu et al., 2013)
Process integration	Strategies must be defined to make the IO-BP definition more agile, reducing adaptation efforts from partners and fostering process alignment across multiple organizations (Bala & Venkatesh, 2007)
Distinct geographical locations	Mechanisms to deal with the distributed activities and events are necessary between the several trading partners, which can be subject to distinct regulations (Schoenthaler et al., 2015)
Organizational autonomy	Individual organizations' autonomy and shared outcomes must be balanced to allow each to implement its strategy at an adequate pace (Markus & Jacobson, 2010)
Data exchange	IO-BP data must be retrieved in a transparent process across several partners while complying with the existing regulations (e.g., GDPR (European Parliament, 2016)) and confidentiality restrictions (Abid et al., 2022)

of new governance mechanisms (Baiyere et al., 2020). Inter-organizational business process governance (IO-BPG) is a solution to align and ensure the interoperability of distributed business processes (Santana et al., 2011), but there are difficulties. For example, hierarchical decision schemes should accommodate the distinct organization's culture, economic power, and process dependencies (Huiskonen & Pirttilä, 2002; Markus & Jacobson, 2010). Moreover, the inter-organizational scenarios require the combination of lateral relations with vertical authority to deal with the autonomy of each organization (e.g., partially or fully autonomous of each other) (Markus & Jacobson, 2015). Additionally, organizations integrating partnerships must deal with the increasing data volumes from different sources, ensure data privacy and accessibility (Lis & Otto, 2020), handle the distinct regulations for different geographical locations (Abraham et al., 2019), clarify data ownership (Lis & Otto, 2020), and foster inter-organizational collaboration on the sharing and use of data (Nielsen et al., 2019).

Personal and impersonal mechanisms can contribute toward IO-BPG (Markus & Jacobson, 2015). The personal mechanisms include the culture of collaboration (Markus & Jacobson, 2015), the co-location of trading entities, and the definition of inter-organizational committees/coordination units (e.g., responsible for the business process monitoring, issue management, interdependencies management) (Huiskonen & Pirttilä, 2002). Moreover, these mechanisms may include the creation of liaison roles replicated through the involved entities or even be a requirement of the third parties enacted in the process (Danese et al., 2004). On the other hand, impersonal governance mechanisms focus on the formal activities and policies that guide the partnership (Markus & Jacobson, 2015). For example, legal agreements and practice guidelines according to industry standards and regulations (Danese et al., 2004). Moreover, they can include information systems that provide an overview and the exchange of information across the partners (Cartwright et al., 2005) and the definition of process and data standards across all business partners to streamline the inter-organizational communications, data exchange, transactions, and process operations (Markus et al., 2006; Rasouli et al., 2016).

Inter-organizational data governance mechanisms will impact organizations in a collaborative network, raising the need for mechanisms that handle the loss of control over data and data-related operations (Jagals & Karger, 2021; Rasouli et al., 2016). Furthermore, different mechanisms have to be deployed to allow inter-organizational data accessibility (Lis & Otto, 2020), clarify data ownership (Lee et al., 2019), and monitor the use and management of data across the partners (Lis & Otto, 2021; Otto & Jarke, 2019).

Business process models can support reengineering and improvement through BP analysis and simulation, the development of process support technologies, enhance and standardize internal communication, and support business process decision-making and control (Alotaibi, 2016). There are influential notations to model business processes (Aguilar-Savén, 2004), such as BPMN and the Unified Modeling Language (UML). However, no solution specifically addresses the modeling of IO-BPG scenarios. The following sub-section highlights aspects concerned with the theoretical underpinnings of business process modeling notations and how to expand them.

BPMN and IO-BPG modeling foundations

Process modeling languages focus on the formal graphical representation of an organization's activities, flow, decisions, and events, allowing the "*orchestration, monitoring,* *and improvement of an organization's workflow*" (Pillat et al., 2015). BPMN, an ISO standard (ISO, 2013), provides a notation and metamodel for business process modeling (Pillat et al., 2015). It includes a graphical representation of procedural elements, thus facilitating human interpretation (Pillat et al., 2015). Additionally, the BPMN metamodel facilitates model exchangeability and tool integration (Braun & Schlieter, 2014). Despite its apparent simplicity, BPMN can represent very complex cases, for example, in manufacturing production scenarios (Erasmus et al., 2020).

A set of elements characterizes the BPMN process models: (1) flow objects (e.g., gateways, activities, events), (2) connecting objects (e.g., sequence flows, message flows), (3) swim lanes (e.g., pools and lanes), (4) data (e.g., data objects), and (5) artifacts (e.g., groups, annotations) (Lucidchart, 2019; Von Rosing et al., 2014).

The BPMN 2.0 version features a built-in extensibility mechanism (Pillat et al., 2015) that enables the addition of domain-specific concepts and attributes (Stroppi et al., 2011) while complying with the standard (Rogowski & Swoboda, 2020) and improving the BPMN's flexibility by design (Milanović et al., 2011). Extending the base BPMN with domain-specific concepts is expected to be less costly than developing an entirely new modeling language from scratch (Braun et al., 2014). Moreover, the extension mechanisms afford model interchangeability and validity (OMG, 2011). Therefore, BPMN extensions have been used as a solution to model healthcare scenarios (Braun et al., 2014), ubiquitous business processes (Yousfi et al., 2016), or cyber-physical production systems (Bocciarelli et al., 2017a). Table 3 describes the four elements involved in extending the notation (OMG, 2011).

The base BPMN includes some elements useful to model inter-organizational workflows, such as (1) the pools to represent network participants (e.g., a manufacturing company) and (2) the message flows to represent the exchange of information between the network's participants (Pillat et al., 2015). However, the standard does not allow the complete representation of decentralized data governance regarding the need to define the ownership of data assets (Lee et al., 2019), the accountability over data-related operations (De Prieelle et al., 2022), and the network participant's roles (Jagals & Karger, 2021). In its basic form, BPMN does not allow capturing "the global aspects of a system of business processes" (e.g., goals, reasons, compliance, relations with other processes) (Řepa, 2023)—such as the case of IO-BPG setups. Therefore, the BPMN extension mechanism is a promising solution to address these modeling challenges (Zarour et al., 2019).

Some authors have previously proposed BPMN extensions to model IO-BP scenarios. Fedorowicz et al. (2005) introduced one of the pioneering contributions using messages, pools, and lanes. An overview of IO-BP is provided by Bouchbout et al. (2010), identifying the existing challenges in decentralized scenarios and proposing a framework for their design, modeling, and deployment. A BPMN extension for collaborative business processes (Amdah & Anwar, 2020) presents concepts for task execution status, activity disclosure, and process monitoring. Ribeiro et al. (2021) proposes a BPMN extension to model IO-BP in the paradigm of Industry 4.0 (I4.0), including concepts to model manufacturing stages, the exchange of goods between network's participants, partner's decisions, machines, tools, and compliance requirements. The authors in Ribeiro et al. (2022) propose integrating risk categories in inter-organizational business process models. Bocciarelli et al. (2017b) propose a BPMN extension inspired by the High-Level Architecture object model to introduce the specifics of collaborative business processes, such as procedural data exchange and distributed simulation approaches. However, these contributions do not include approaches for specific inter-organizational business process governance aspects.

Method

DSR follows a rigorous process to solve existing problems, demonstrate the artifacts, evaluate the solutions, and communicate the observed results to the targeted audiences (Peffers et al., 2007). DSR can be used to create innovative artifacts to solve specific problems in organizational settings (Peffers et al., 2007). Possible DSR artifacts include

Table 3 BPMN extension mechanism elements based on Rogowski and Swoboda (2020) and Martinho et al. (2015)

Extension element	Description
Extension	Makes the extension elements available to the standard BPMN elements by binding the ExtensionDefinition and its attributes to a BPMN model definition
ExtensionDefinition	Groups and defines the additional ExtensionAttributeDefinition (e.g., the name and type) that can be added to the standard BPMN elements
ExtensionAttributeDefinition	Defines the attributes that can be integrated into the standard BPMN elements
ExtensionAttributeValue	Describes the extension attribute value (e.g., an integer, a Boolean)

constructs, methods, models, and instantiations, depending on the nature of the problem and context (March & Smith, 1995). Additionally, modeling languages, such as the case of BPMN extensions, can be conceived as artifacts in the form of methods that require both static (syntax and semantics) and procedural components (a modeling procedure) (Braun et al., 2016). Further, DSR provides solid guidelines for evaluating artifacts, combining rigor and relevance (Hevner et al., 2004). Therefore, DSR is recognized as a suitable approach to develop BPMN extensions (Polančič, 2020; Recker, 2010). For example, Polančič (2020) used DSR to create a BPMN extension for modeling process landscapes. DSR is thus suitable for developing an approach to support organizations in modeling their IO-BPG setups.

DSR follows a six-step iterative process (Peffers et al., 2007) consisting of (1) "problem identification and motivation," (2) "definition of the objectives for a solution," (3) "design and development," (4) "demonstration," (5) "evaluation," and (6) "communication." March and Smith (1995) and Venable et al. (2016) consider "design and development" and "evaluation" to be the DSR's key activities. The artifact development should draw from existing theories and knowledge to conceive a solution to an identified problem and should be effectively communicated to the audiences (Hevner et al., 2004; Peffers et al., 2007). Its outcomes should be relevant to an existing problem (Hevner et al., 2004; Peffers et al., 2007). DSR evaluation is "crucial" to demonstrate the developed artifact's quality, utility, and efficiency (Hevner et al., 2004). Therefore, the developed artifact must be rigorously evaluated by applying well-defined methods (Hevner et al., 2004) to assess the artifact's performance and use, as well as the reasoning for alterations caused to systems and people (Vaishnavi et al., 2004). Lastly, the "Evaluation" can also provide feedback for the artifact's further development and "assures the rigor of the research" (Venable et al., 2016).

Our work so far is summarized in Fig. 1, adapted from Peffers et al. (2007).

Our DSR project evolved in two cycles, as depicted by the black lines (first DSR cycle of the upper part of Fig. 1) and blue lines (second DSR cycle of the upper part of Fig. 1). The first DSR cycle involved the participation of a leading European telecommunications service provider (TSP), integrated into a highly regulated sector and a multinational environment. The TSP is involved in a collaborative network that aims to develop innovative products and services based on state-of-the-art AI systems and ML models, providing the context to conduct the modeling of concrete cases of IO-BPG. For the second DSR cycle, we contacted a major European port management company. Shipping a container from East Asia to Europe can involve nearly 30 stakeholders, exchanging information at about 200 distinct moments

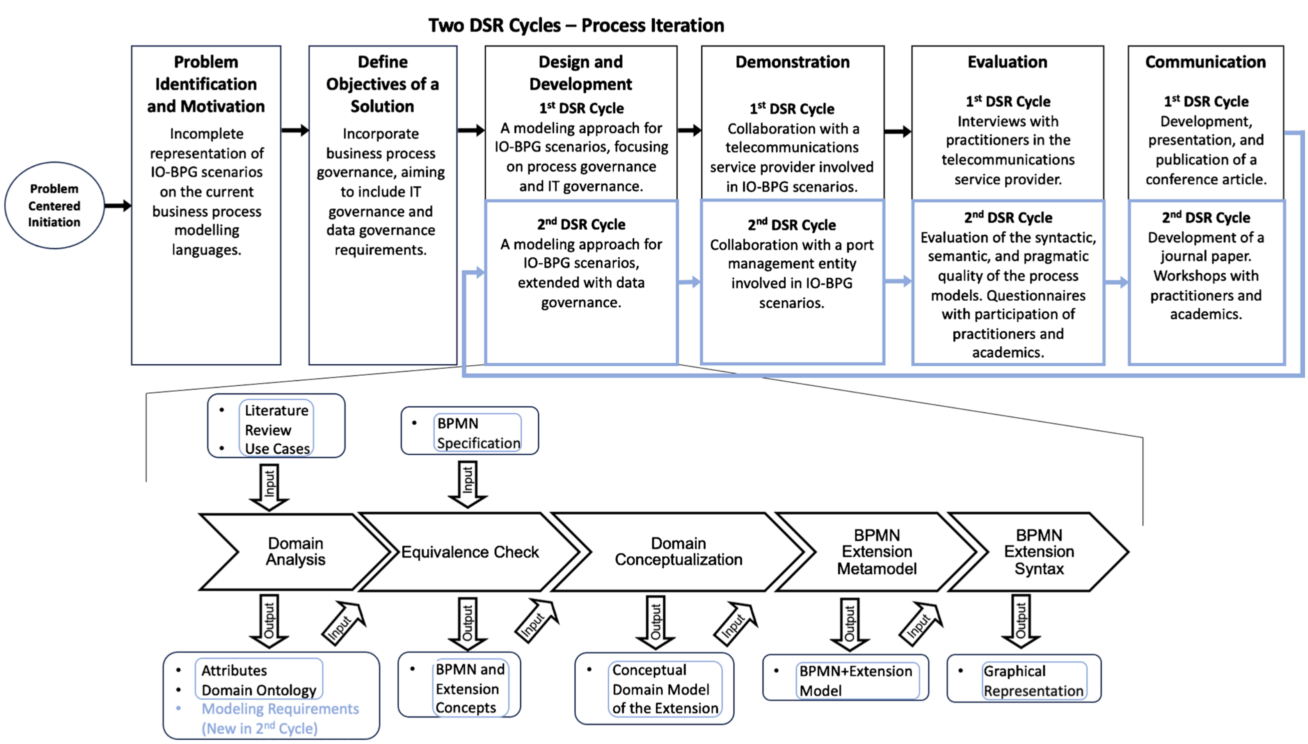


Fig. 1 DSR project (two cycles) for inter-organizational business process governance based on Peffers et al. (2007), Stroppi et al. (2011), and Braun and Schlieter (2014)

(Petersen et al., 2018). The port management company is responsible for the full range of seaport operations, including ship facilitation, container placement, navigation assistance, temporary cargo storage, environmental and security control, and the control of the traffic flow entering and leaving the port. They use applications that can support the seaport in managing the available ship slots, providing them with suggestions on how to organize the routes of the arriving and departing vessels. These applications require that data are constantly retrieved from arriving ships, the ship slots, the departing ships, and other ports. The port operations provide a setup in which the involved partners are assigned with distinct roles, requiring the clarification of their responsibilities regarding the accountability over the actions in the partnership.

Our DSR project had a problem-centered initiation that included a literature review and the establishment of contacts with experts in the field of BPG governance. A literature review was performed using three relevant sources (Harzing & Alakangas, 2016): (1) Scopus, (2) Web of Science (WoS), and (3) Google Scholar. The goal was to obtain input knowledge for the "Design and Development." Search expressions included a combination of relevant terms, namely ("BP governance" OR "BPM governance" OR "business process management governance" OR "process governance" OR "business process governance" OR "data governance" OR "IT governance") + ("modeling" OR "modelling") + ("interorganizational" OR "ecosystem" OR decentral*). This yielded 12,500 results in Google Scholar, excluding citations and patents. For WoS we obtained four results, while Scopus returned 1563 matches, using a search in all fields in both cases. In the face of these numbers, we made a more specific search to identify related work, focusing on the extension artifact: ("BP governance" OR "BPM governance" OR "business process management governance" OR "process governance" OR "business process governance" OR "data governance" OR "IT governance") + ("BPMN Extension"). This returned 51 results in Google Scholar, excluding patents and citations, 22 matches in Scopus, and none in WoS. Among these, we could not identify any research that presented approaches for modeling IO-BPG scenarios. This emphasizes the opportunity to contribute to the IO-BPG modeling area.

As objectives for our solution, we defined the development of a modeling approach that included a BPMN extension for the IO-BPG scenarios covering IT governance (in the first DSR cycle) and data governance (in the second DSR cycle), supported by a set of design principles for its application and use (in the second DSR cycle). Table 4 describes the IO-BPG modeling approach components and structure.

The modeling approach includes a BPMN extension to model IO-BPG scenarios and design principles to guide the artifact's development, use, and evaluation. Extensions can provide the means for enriching process models with additional information that is required for organizations to perform simulations (Rosenthal et al., 2021). Furthermore, users have demonstrated to make fewer errors and better understand models when performing modeling activities in specific domains (e.g., enterprise communication) while using BPMN extensions (Polančič & Orban, 2022). Additionally, BPMN extensions can be integrated and executed in business process engines (e.g., process modeling, process monitoring, process simulation) (Braun & Schlieter, 2014). We propose two categories of design principles for IO-BPG. The first category of design principles describes several steps to apply the BPMN extension in modeling IO-BPG setups. The second category of design principles focuses on the BPMN extensions's evaluation.

During our design and development phase (refer to the bottom of Fig. 1), we sought inspiration from Stroppi et al.'s (2011) proposal for creating BPMN extensions based on model-driven architecture. This proposal suggests a model-transformation-based process for developing BPMN extensions using UML profiles (Braun, 2015). Later, Braun and Schlieter (2014) extended this approach by introducing a requirements analysis at the beginning of the extension's development. This development approach was used in both DSR cycles. In the first DSR cycle, we performed a domain analysis, with a literature review on BPG, IO-BPG, IT governance, and data governance. Moreover, we contacted experts from the TSP to develop a set of use cases. As a result of this step, we identified a set of attributes and

Table 4 IO-BPG modeling approach components and structure

Inter-organizational business process governance modeling approach	
IO-BPG BPMN extension	IO-BPG design principles
• A BPMN extension that integrates a set of extension elements that extend the standard notation. It also includes: ° Attributes for the IO-BPG ° A domain ontology for IO-BPG ° Modeling requirements for IO-BPG ° Graphical representation for extension elements	• Design principles for applying the BPMN extension to model IO-BPG scenarios • Design principles to evaluate BPMN extensions

developed a domain ontology for IO-BPG. Next, we performed an equivalence check by comparing the identified attributes, domain concepts, and modeling requirements with the standard BPMN specification to identify the missing IO-BPG domain concepts. At this stage, we identified the (1) BPMN concepts and (2) extension concepts. Then we conceptualized the IO-BPG domain by creating the conceptual domain model of the extension (CDME) based on equivalence check results. The following step was to transform the CDME into a valid BPMN extension meta-model (BPMN + X) using UML stereotypes and a set of transformation rules, resulting in the extension of the standard BPMN metamodel. To conclude the design and development phase, we produced a graphical representation of the extension elements.

For the second DSR cycle, we aimed at incorporating data as a key element in business process governance, considering the need to model the ownership of shared data assets, modeling data flow across business partners, identifying the roles and responsibilities for data-governance-related activities, and disclosing the openness of process data assets. The research team collected new information (e.g., use cases, models, documents) for developing the second iteration of the IO-BPG modeling approach, based on the port management company's setups and challenges (Braun & Schlieter, 2014; Stroppi et al., 2011). At this stage, we revisited the IO-BPG domain attributes and the ontology from the first DSR cycle (as marked by the rounded rectangles in Fig. 1), considering the incorporation of data concepts. Moreover, we identified a set of modeling requirements for the IO-BPG domain and derived the new extension elements by conducting a comparison with the standard BPMN. Afterward, we revised the CDME and the BPMN + X meta-model. Next, we developed the graphical representation for the new BPMN extension elements.

A demonstration was conducted at both case companies, where we applied the IO-BPG modeling approach to address several operation scenarios and test our solution. Moreover, we used both standard BPMN and the IO-BPG modeling approach to model the companies's scenarios and conduct a comparison of both.

We performed two evaluation episodes, one for each DSR cycle. For the first DSR cycle, we followed a quick and simple single-evaluation episode, as proposed by Venable et al. (2016), during which we conducted several interviews with experts from the TSP company. On the one hand, the first iteration of the notation covered IT governance activities (e.g., resource management, risk management, strategic alignment) and roles (e.g., operations, business, Chief Information Officer), the traceability of tasks (e.g., private task, traceable task), and partner's collaboration (e.g., collaborative task, partner decision gateway). On the other hand, the IO-BPG modeling approach lacked details on data governance specifics, considering the data exchanged between the partners, the existing regulations, and the data-based operations conducted by the partners. At the end of the first cycle, we concluded that there was a need to incorporate additional elements in the notation, such as data assets that are used and managed in business process governance (e.g., defining data ownership), allowing a comprehensive evaluation of DSR. For the second DSR cycle, we used the systematic framework proposed by Lindland et al. (1994) to evaluate the quality of the IO-BPG modeling approach. This framework considers both the model itself and the process used to develop it. It has a strong theoretical foundation and has been validated through empirical research (Maes & Poels, 2007). According to Lindland et al. (1994), modeling is about making statements using a specific language (Maes & Poels, 2007). The framework is composed of the following elements (Lindland et al., 1994):

- Domain: a collection of statements that describe the domain's problem.
- Language: statements that are possible to do with the modeling language according to the defined syntax. This syntax covers the alphabet and the grammar. The alphabet "contains a set of modeling constructs, each of which has a unique notation." The grammar defines the rules on how it is possible to combine modeling constructs.
- Model: statements that are made using the language—a script.
- Audience interpretation: statements that the users (or stakeholders) perceive in the script.

Additionally, this framework depicts three script quality dimensions considering the correspondence between distinct statements (Maes & Poels, 2007):

- Syntactic quality (the correspondence between language and model) describes the model's adherence to the grammar's rules. Our IO-BPG BPMN extension evaluation focused on the notation's compliance with the abstract syntax (e.g., attributes, concepts, and relationships).
- Pragmatic quality (the correspondence between Language and Model) describes how well the users understand the model. Our evaluation addressed the interpretation of the models in terms of comprehension and the fulfillment of users' needs.
- Semantic quality (the correspondence between Domain and Model) covers how well the model captures what is being represented. For the case of our IO-BPG BPMN extension, it refers to the concept's and relationship's interpretation that is presented in the new notation's syntax.

To evaluate the mentioned dimensions, we identified and assessed a set of quality criteria, based on a questionnaire and the analysis of process models obtained using the IO-BPG modeling approach.

Regarding "communication," we produced scientific articles and conducted workshop discussions with specialists in IO-BPG modeling. In the first DSR cycle, we wrote a conference article [REF – Remover for paper review purposes] reporting the preliminary results of the initial cycle. In the second DSR cycle, we developed a journal paper (this contribution) providing the full account of our proposal, iterated, refined, and validated across the entire DSR project.

Throughout the project we have considered six guidelines to handle DSR limitations, which include (1) "identify and clearly state limitations," (2) "separate limitations and future work," (3) "avoid trying to create infallible artifacts," (4) "reflect on limitations during the DSR Lifecycle," (5) "use delimitations as the first step for framing DSR limitations," and (6) "acknowledge the centrality of the artifact to the DSR and limitations" Barata et al. (2023).

Artifact description

This section details the design, development, and demonstration of the IO-BPG modeling approach. It starts with the identification of domain attributes, followed by the creation of a domain ontology, and definition of modeling requirements. The graphical elements are subsequently explained and illustrated with a real scenario of IO-BPG. The port management setting selected for the second iteration in our DSR is used as a reference because it uses the final versions of the artifacts.

Domain attributes

We started the modeling approach design and development by identifying 12 attributes for the IO-BPG domain using a literature review. These were compared and complemented with the case companies' attributes by analyzing available process documentation and the use cases for IO-BPG scenarios. For example, the port access request use cases involve the participation of the port management and shipping companies exchanging data. Table 5 introduces the IO-BPG attributes.

The attributes in Table 5 capture the specificities of IO-BPG scenarios, such as the need to track business process executions across several models (Breu et al., 2013), managing shared process-related data (Abid et al., 2022; Bouchbout & Alimazighi, 2011), performing collaborative tasks (Amdah & Anwar, 2020), and specifying a set of roles for data governance (Abraham et al., 2019).

Domain ontology

In the domain analysis step, we created an ontology for the IO-BPG domain to contextualize the several data-interdependent organizations' domains, attributes, relationships, and concepts. An ontology is a suitable means to explicate domain knowledge (Happel & Seedorf, 2006) and its key elements (Van Heijst et al., 1997). Its development was based on the literature review, as Braun and Schlieter (2014) suggested, and complemented with insights from the case companies' context and involvement in IO-BPG scenarios. Figure 2 presents the domain ontology for IO-BPG.

The gray elements in Fig. 2 represent the main components of IO-BPG, with the activities performed by actors according to a process flow, the participation of a set of partners, the resources involved, and the events that may influence or trigger the activities. The participating organizations operate according to formal agreements that are established (e.g., data sharing agreements, data use agreements, infrastructure use agreements) (Abraham et al., 2019; Danese et al., 2004) (see top center-left). The partners can have distinct roles in the collaborative network (e.g., leader, participant). The regulatory space (e.g., standards, contracts, industry procedures, privacy regulations) varies according to geographical location and industry field (Abraham et al., 2019; Kirchmer, 2017) (see center-left). IO-BPG operations require continuous monitoring (e.g., data, messages, documents, logs) and the exchange of resources between the partners (Kirchmer, 2017; Markus & Jacobson, 2015) (see top right). In the bottom right of Fig. 2, several IO-BPG governance activities must be shared considering two domains: (1) IT (e.g., risk management, resource management, performance management, strategic alignment, value delivery) (ISACA, 2018) and (2) data (e.g., data strategy, policy management, compliance monitoring, issue management, performance measurement, contractual agreements management) (Abraham et al., 2019; Data Management Association, 2017). These activities promote ecosystem innovation and ensure the strategic alignment between technology and the network's business goals (ISACA, 2018). Distinct data types can be used and exchanged between the network's members (e.g., personal data, non-personal data). The IO-BPG governance activities can be performed by specific governance actors (e.g., C-level officers, data scientists, business, operations, and external data stakeholders). The inter-organizational process flow can evolve in sequence or parallel in each process participant, as illustrated in the center-left of Fig. 2. Moreover, we must consider the data flow between the process participants, who can exchange data assets through predefined channels (Lee et al., 2019). Involved in business partnerships, organizations need to manage decentralized resources (e.g., human, IT, financial), as seen on the right

Table 5 Inter-organizational business process governance attributes

Attribute	Description	Port management company example	Source
Accountability	Organizations should define mechanisms for accountable decisions, activities, and data operations	The port management entity must define accountability for the cargo manifest	Abraham et al. (2019), Kirchmer (2021b)
Autonomy	Organizations should identify autonomous decisions and tasks (e.g., one organization can innovate (part of) the process)	The vessel is not autonomous in defining the docking slot	Iden et al. (2021), Markus and Jacobson (2010), Van Den Broek and Van Veenstra (2015)
Conformance	Organizations should define audit mechanisms to monitor compliance with the network's policies, standards, rules, and processes	The vessel must comply with the port's rules on where it will dock	Markus and Jacobson (2015), Rasouli et al. (2016)
Regulatory environment	Organizations may need to deal with several regulations according to their geographical location and industry context	The European ports are required to comply with a set of specific regulations	Abid et al. (2022), Kirchmer (2017), Legner and Wende (2007)
Traceability	The network partners should ensure traceability throughout the IO-BPG lifecycle, activities, resources, and decisions	The vessel needs to track the several containers that it carries	Breu et al. (2013), De Prieelle et al. (2022)
Collaboration	The network partners can perform operations in collaboration	The vessel defines a docking plan with the port management company	Amdah and Anwar (2020)
Data accessibility	The organizations may have restrictions in sharing internal data, considering regulations and industrial and/or business secrecy data	The vessel is unwilling to share route optimization data with the port company	Abid et al. (2022), Bouchbout and Alimazighi (2011)
Authority	The partners should describe the distinct decision-making rights of local and global actors in diverse scenarios	The port management company defines and enforces the vessel's allocation of a docking place	Legner and Wende (2007)
IT governance operations	IT governance relies on five sub-types of activities: value delivery, resources management, risk management, performance management, and strategic alignment. The partners use and share several technological devices and systems to execute their activities and govern the processes	The port management company performs risk assessment of the several partners	ISACA (2018)
IT governance roles	Each partner's members perform several IT governance activities and decisions	The C-level officers of the port management company are responsible for defining the IT strategy	ISACA (2018)
Data governance operations	Data governance operations include multiple dimensions, such as data compliance monitoring, contractual agreements, policy management, data strategy, data issue management, and data performance measurement	The port management company performs a data quality assessment of the data sent by the vessel	Abraham et al. (2019), Data Management Association (2017)
Data governance roles	Each organization's members perform several types of data governance activities and decisions. It includes the C-level officers, data managers, data stewards, and data scientists	Data managers define the ownership of shared data with the partners	Abraham et al. (2019), Jagals and Karger (2021)

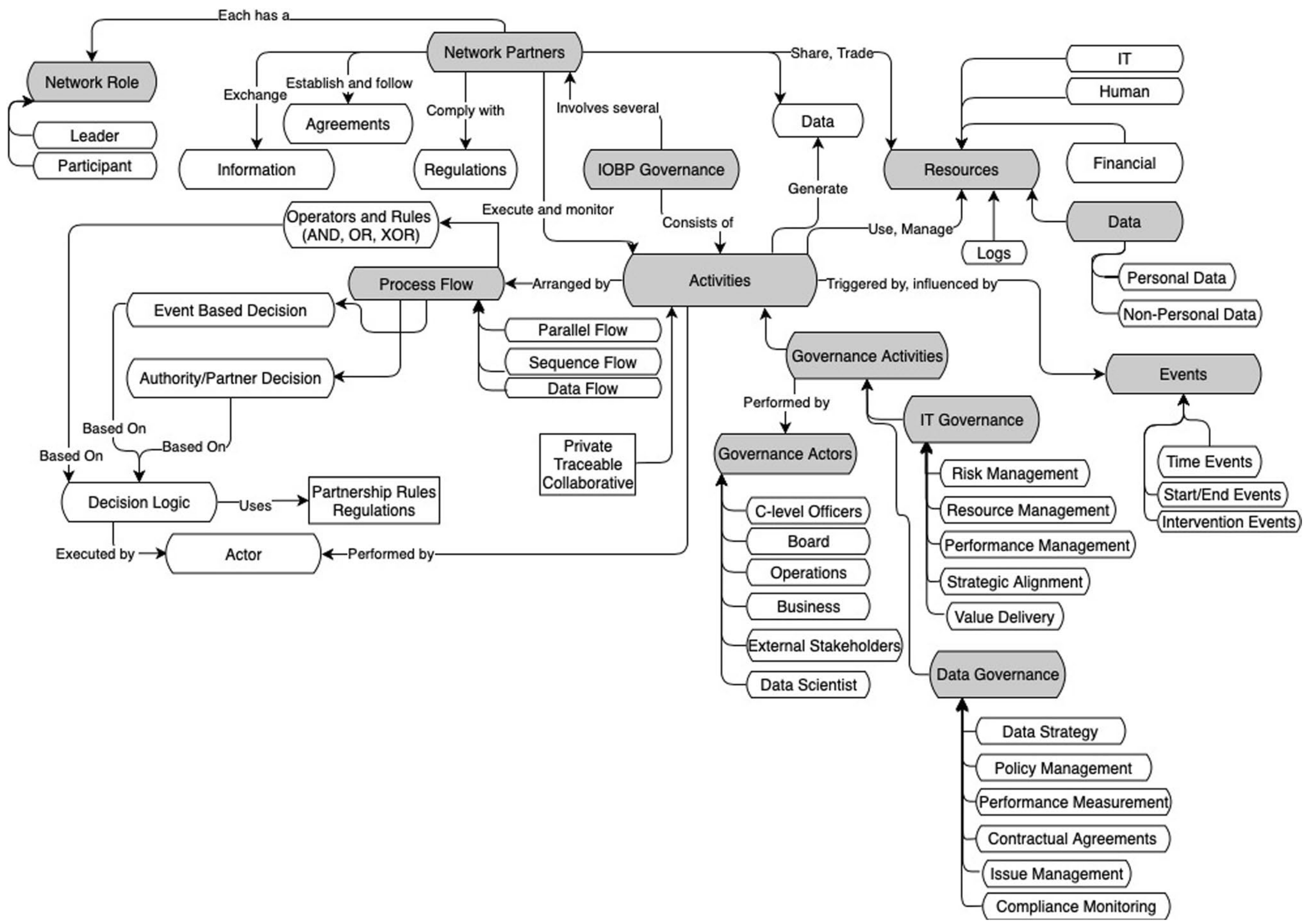


Fig. 2 Domain ontology for IO-BPG

of Fig. 2. Decisions are made (e.g., partner decision, event-based, flow gateway) about the path to follow (e.g., next activity to perform, send a message, terminate the process) according to a predefined decision logic (e.g., partnership agreements, regulations) (Bouchbout & Alimazighi, 2011), as shown on the left of Fig. 2.

Modeling requirements

We conducted a Domain Requirements Analysis as proposed by Braun and Schlieter (2014). Modeling requirements can be defined as "the explication of domain concepts and configurations that need to be covered by the language (functional requirements) and also as additional constraints such as language extensibility" and can be identified through literature reviews and/or modeling use case scenarios (Braun & Schlieter, 2014). In our case, we derived and consolidated a set of modeling requirements for the IO-BPG domain based on the results of the literature review, the created domain ontology, the experts' insights, and the use case scenarios (e.g., standard BPMN models, process descriptions). Table 6 presents the modeling requirements. It consists of three columns: requirement IDs, descriptions, and rationales based on BPMN limitations for the purpose at hand.

We found the three artifacts—the attributes, domain ontology, and modeling requirements—helpful in understanding the most critical aspects that must be explicitly included in the IO-BPG models. We combined the results and performed an equivalence check to verify the domain concepts that were already included in the standard BPMN. We created a conceptual domain model of the extension to derive the new extension elements from the standard BPMN for the concepts that were covered yet. Finally, we created the concrete syntax for the IO-BPG BPMN extension, which is shown in the following section.

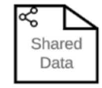
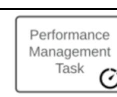
BPMN extension graphical elements

Based on the results provided by the conceptual domain model of the extension, we classified the IO-BPG concepts as (1) BPMN elements and (2) extension elements. We created the specific syntax with a new graphical representation for the latter. Table 7 describes the proposed BPMN extension elements for IO-BPG.

Table 6 Modeling requirements for IO-BPG

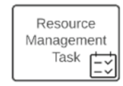
Requirement	Description	Rationale
R1	A language for the IO-BPG domain should provide concepts for data governance-related operations (e.g., the port management company to perform data-related risk management analysis of new partners)	BPMN does not allow the representation of the IO-BPG domain-specific data governance sub-tasks (e.g., data policy management)
R2	A language for the IO-BPG domain should provide concepts for IT governance-related operations (e.g., measure the performance of the AI system for slot allocation) and resources (e.g., AI systems to optimize slot allocation in the port)	BPMN does not include elements to model IT governance-specific sub-tasks (e.g., resource management) and IT resources (e.g., AI systems)
R3	A language for the IO-BPG domain should provide concepts for distinct governance actors involved in the operations and taking decisions (e.g., C-level officers of the port management company)	BPMN does not include the sub-types of actors responsible for conducting governance activities (e.g., C-level officers, business units, data scientists)
R4	A language for the IO-BPG domain should provide concepts for explicitly exchanging data resources between the partners (e.g., the vessel transmits data to the port management company)	BPMN does not allow to represent the exchange and transmission of data resources between business partners
R5	A language for the IO-BPG domain should provide concepts for data categories (e.g., route data is non-personal data, personal data of vessel crew) and disclosure characterization (e.g., route data is not shared with the port management company)	BPMN data objects do not provide details on the disclosure (e.g., shared data assets) and the category of data they cover (e.g., personal and non-personal data)
R6	A language for the IO-BPG domain should provide concepts for network participants (e.g., the port management company) and corresponding roles (e.g., the port management company leads and owns the business process)	BPMN allows representing multiple organizations and partners (e.g., the port management company and the vessel) by using pools and lanes. However, it does not allow for modeling the role of each partner (e.g., leaders and participants) and its decision-making at points of the business or governance process
R7	A language for the IO-BPG domain should provide concepts for the flow of activities across the several business partners and their decision-making	BPMN allows the modeling of the process flow of activities across the several partners involved in IO-BPG
R8	A language for the IO-BPG domain should provide concepts for the traceability of activities and data resources across several partners (e.g., the vessel's position in proximity to the port is sent to the port management company)	BPMN does not include concepts to represent traceable activities and data resources
R9	A language for the IO-BPG domain should provide concepts for the agreements, regulations, and rules with which the several partners must comply (e.g., the vessel must comply with the port's regulations)	BPMN does not include concepts to model agreements, regulations, and rules with which the several business partners must comply
R10	A language for the IO-BPG domain should provide concepts for governance activities associated with the corresponding business process tasks (e.g., while defining the docking plan, the contractual requirements are verified by the port management company)	BPMN does not allow the parallel representation of the business process and "shadow" governance activities executed by other departments or organizations

Table 7 BPMN extension elements for IO-BPG

Attribute	Element	Description	Graphic
Data Accessibility	Shared Data	The term "shared data object" refers to a data object (or one of its children) that other business partners can access.	
Autonomy Accountability Authority	Partner Decision Gateway	The partner gateway is a point in the flow when a specific partner determines the "route" of the actions carried out in the subsequent phases (e.g., allowing the use of data for a particular purpose).	
Autonomy Accountability Authority	Partner Intervention Event	The partner intermediate event denotes the participation in an activity initiated by an authorized partner.	
Collaboration	Collaborative Task	The collaborative task concerns governance activities performed in collaboration between the partners.	
Regulations	Private Data	The term "private data object" refers to a data object (or one of its offspring) kept secret, meaning no information about it is shared with the partners.	
Regulatory Environment	Regulations	The regulations describe the laws, contracts, and standards that a particular business partner must follow and the norms that must be adhered to (e.g., ISO 9001).	
Traceability	Traceable Task	The traceable task designates it as traceable, implying that a set of metrics is obtained and logged to execute it.	
Traceability	Private Task	The private task means no information about it is shared with the partners.	
Data Governance Operations	Data Flow	The data flow represents the flow of data between the network partners.	
IT Governance Operations	Virtual Inter-Organizational Governance Pool	The governance pool represents the activities and resources involved in IT and data governance activities.	
IT Governance Operations	IT Value Delivery Task	The value delivery tasks focus on the activities that ensure optimal business value obtained from IT.	
IT Governance Operations	IT Risk Management Task	The risk management tasks are concerned with monitoring and mitigating several types of risks.	
IT/Data Governance Operations	IT/Data Performance Management Task	The performance measurements focus on measuring the organization's strategic objectives.	

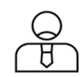
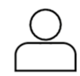
The IO-BPG BPMN extension is comprised of 33 elements, adapting some from the domain of collaborative business processes (e.g., traceable/private tasks, private/shared data) (Amdah & Anwar, 2020) and extending previous work on inter-organizational business processes for Industry 4.0 (e.g., collaborative task, partner intervention event, partner decision gateway) Ribeiro et al. (2021). The DSR team ensured that each new element was distinctive while remaining consistent with those currently in the standard. Additionally, some elements are concerned with the roles (e.g., data science unit, board of administrators). The graphical representations were created with Lucidchart (Lucidchart, 2023)

Table 7 (continued)

Attribute	Element	Description	Graphic
IT Governance Operations	IT Strategic Alignment Task	The strategic alignment task aims to promote the alignment between the organization's strategy and IT resources.	
IT Governance Operations	IT Resource Management Task	The resource management tasks focus on managing the organization's assets and ensuring that the IT capabilities and resources are enough to meet its goals.	
Data Governance Operations	Data Strategy Task	The data strategy management task focuses on defining the ecosystem business cases and data requirements, the partnership goals, and the high-level guidelines of the network.	
Data Governance Operations	Data Policy Management Task	The data policy management task includes defining, implementing, monitoring, and reviewing the organization's policies.	
Data Governance Operations	Data Contractual Agreements Management Task	The contractual agreements management aims to ensure compliance with settled data-related contracts. Moreover, it can deal with establishing new data-related agreements (e.g., data-sharing agreements and data-use agreements).	
Data Governance Operations	Data Compliance Monitoring	The compliance monitoring task aims to track and enforce compliance with existing external (e.g., GDPR) and internal regulations (e.g., data policies, data procedures, and data standards).	
Data Governance Operations	Data Issue Management	The data issue management task focuses on identifying, monitoring, and solving data-related issues.	
Data Governance Role	Data Management Unit	The data management unit is responsible for performing all the activities focused on governance and management, such as supervising operations, ownership of data assets, and guiding several departments.	
Data Governance Role	Data Science Unit	The data science unit explores the organization's data assets to develop new data-based solutions.	
IT/Data Governance Role	External Stakeholder	External stakeholders (e.g., regulators and financial entities) can participate in data governance activities.	
IT/Data Governance Role	Board of Administrators	The Board of Administrators (e.g., Chief Technology Office, Chief Information Officer) is responsible for the meaningful decisions and strategies of the organization.	
IT/Data Governance Role	Operations	Operations roles are responsible for performing IT resource management activities.	

and the IconFinder database (Iconfinder, 2023). As extension elements, we targeted the specificities of IO-BPG (e.g., risk management task, issue management task), the need to explicitly include privacy for data assets and activities (e.g., shared data, private data, private task, traceable task), the complexity of shared gateways (e.g., partner decision gateway), and more representative governance-related roles (e.g., board of administrators, external stakeholder, data science unit). Moreover, we have included the representation of the data flow across several partners (e.g., a partner sending a dataset to another) and the role of each partner in the network (e.g., participant, leader).

Table 7 (continued)

Attribute	Element	Description	Graphic
IT/Data Governance Role	Business	Business roles are responsible for business model implementation and strategy activities.	
IT/Data Governance Resources	Cloud	Cloud infrastructures may host digital services and data assets the organizations involved in the partnerships use.	
IT/Data Governance Resources	On-premise	Server infrastructures can be deployed and managed by the organizations involved in the collaborative network.	
IT/Data Governance Resources	AI/ML Models	AI and ML models can be used to conduct data-based operations and obtain relevant insights (e.g., simulations).	
IT/Data Governance Role	Leader	The partnership manager is mainly responsible for the execution, monitoring, and management of the IO-BP.	
IT/Data Governance Role	Participant	The partnership participant is responsible for executing activities and reporting the agreed information to the manager.	
Data Governance Operations	Personal Data	Personal data covers the data person's identifiable data. This category is typically subject to privacy regulations (e.g., GDPR).	
Data Governance Operations	Non-Personal Data	Non-personal data cover non-identifiable data.	

IO-BPG modeling approach demonstration

Of the various cases to which we applied our artifacts, for demonstration, we selected the critical berth operations at the seaport involving the port management company and its partners. These require careful daily planning to choose the best available slots to place incoming ships, considering the duration of stay, any cargo loading or unloading, and the need to carry out maintenance. In this process, the first step is obtaining the ship's geographical location for optimizing berth operations. If all the slots are occupied, the vessel crew can reduce the cruise speed to save fuel and delay its arrival. Considering the complexity of the tasks, the case company is developing a smart berth planning solution using AI. Figure 3 uses standard BPMN to model the part of allocating an arrival slot to an incoming ship, focusing on determining the ship's location.

The business process starts when a ship's docking request is authorized for a place in the seaport. The ship managers prepare the necessary information by activating the docking position sensor. The ship's data (e.g., current position) is transmitted to the port management company. The port management company receives the vessel's position data, verifies its content, and stores it in its data storage infrastructures.

The ship's geographical location determination business process using the standard BPMN model does not incorporate the parallel governance activities associated with each process task (e.g., risk management, performance measurement) and shared data assets (e.g., data quality control), as well as the roles and responsibilities of each partner toward governance (e.g., data units). Moreover, it does not incorporate traceability of tasks by the partners across the process flow (e.g., tracing data transmission), the regulations and contractual agreements impacting the business process, and the type of data used across several activities (e.g., non-personal data, personal data). Figure 4 models this case's inter-organizational process management governance using our proposed IO-BPG BPMN extension.

A new virtual governance pool (the dashed box at the bottom of Fig. 4) incorporating lanes for each partner (e.g., transport company, port management company) represents the process governance structure. This dashed pool allows the modeling of the governance-specific tasks for each business partner (e.g., the data quality assessment is performed by the data science unit in the port management company, and the transmission channel is set up by the data management unit in the transport company). Moreover, the governance-related activities are categorized according to IT (e.g., risk assessment is a risk management task, system metrics, and logs is a performance management task) and data (e.g., integrating results in structures is a data strategy management task) governance categories.

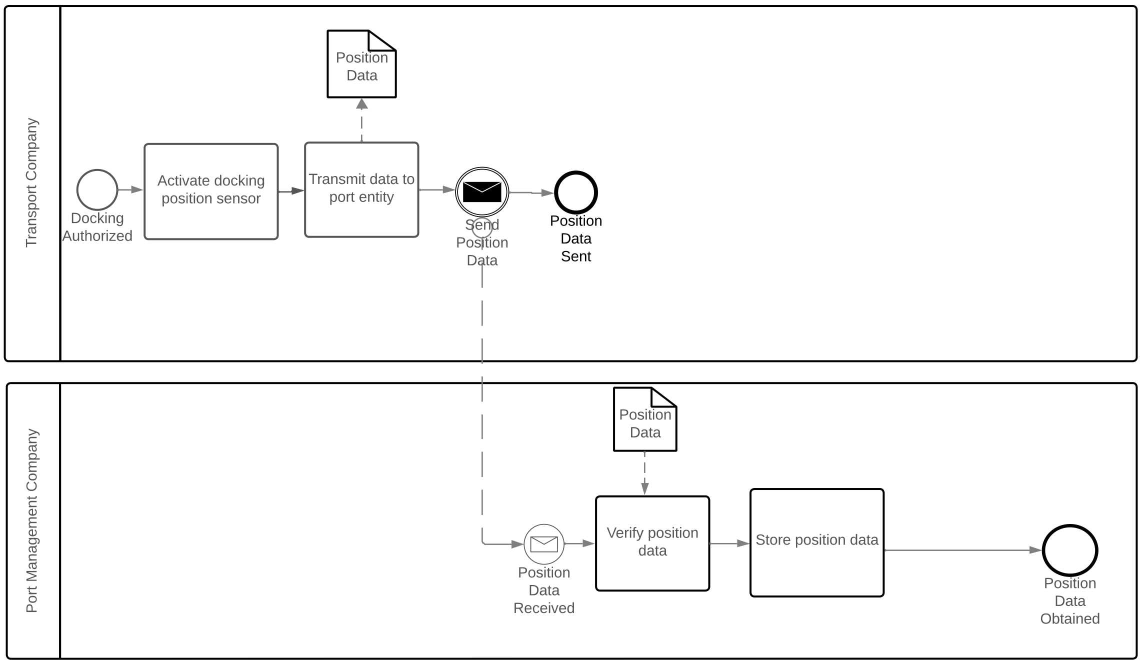


Fig. 3 A ship's geographical location determination business process using standard BPMN

Our proposal enriches the standard notation elements by integrating the disclosure of process tasks and governance-related activities for the partnership members. Tasks can be classified as private (e.g., integrating data in structures is a private task) or traceable (e.g., running a data quality assessment is a traceable task).

Furthermore, the BPMN extension describes the disclosure of data objects (e.g., the position data is a shared document) and tasks (e.g., activating the docking position sensor is a private task) across the participants. The data flow across the business partners is represented by the double dashed line across the pools (e.g., the vessel transmits data to the case company's port). Additionally, the extended notation includes the representation of IT resources used in governance and process-related tasks (e.g., private cloud).

Evaluation

To evaluate the IO-BPG BPMN extension, we defined specific quality criteria to assess the syntactic, pragmatic, and semantic quality (Lindland et al., 1994; Maes & Poels, 2007), as described in Table 8.

To support our assessment, we developed a questionnaire based on the System Usability Scale (SUS) (Brooke, 2013) and open-ended questions, which are aligned with the work of Ramos-Merino et al. (2018).

Questionnaire development

The IO-BPG BPMN extension evaluation questionnaire includes five sections.

- The first section describes the research context and the questionnaire's structure.
- The second section presents an example of IO-BPG operational scenarios. This included a process description, tasks-related governance activities, a table containing the new elements of the BPMN extension notation, and process models using both standard BPMN (as seen in Fig. 3) and the IO-BPG BPMN extension (as depicted in Fig. 4).
- The third section aims to retrieve the respondent's personal information (e.g., age), professional experience (e.g., career years), and current roles.
- The fourth section presents an adapted version of the SUS performed by Ramos-Merino et al. (2018). This scale uses a ten-item questionnaire based on a Likert scale (e.g., 1—strongly disagree, 5—strongly agree) to conduct a subjective assessment of the usability of a system (Brooke, 2013). Moreover, the quality of a notation can be evaluated based on its score (Bangor et al., 2008). A score of above 70 is considered acceptable, while a score between 50 and 70 is classified as marginal. A score below 50 is not acceptable.

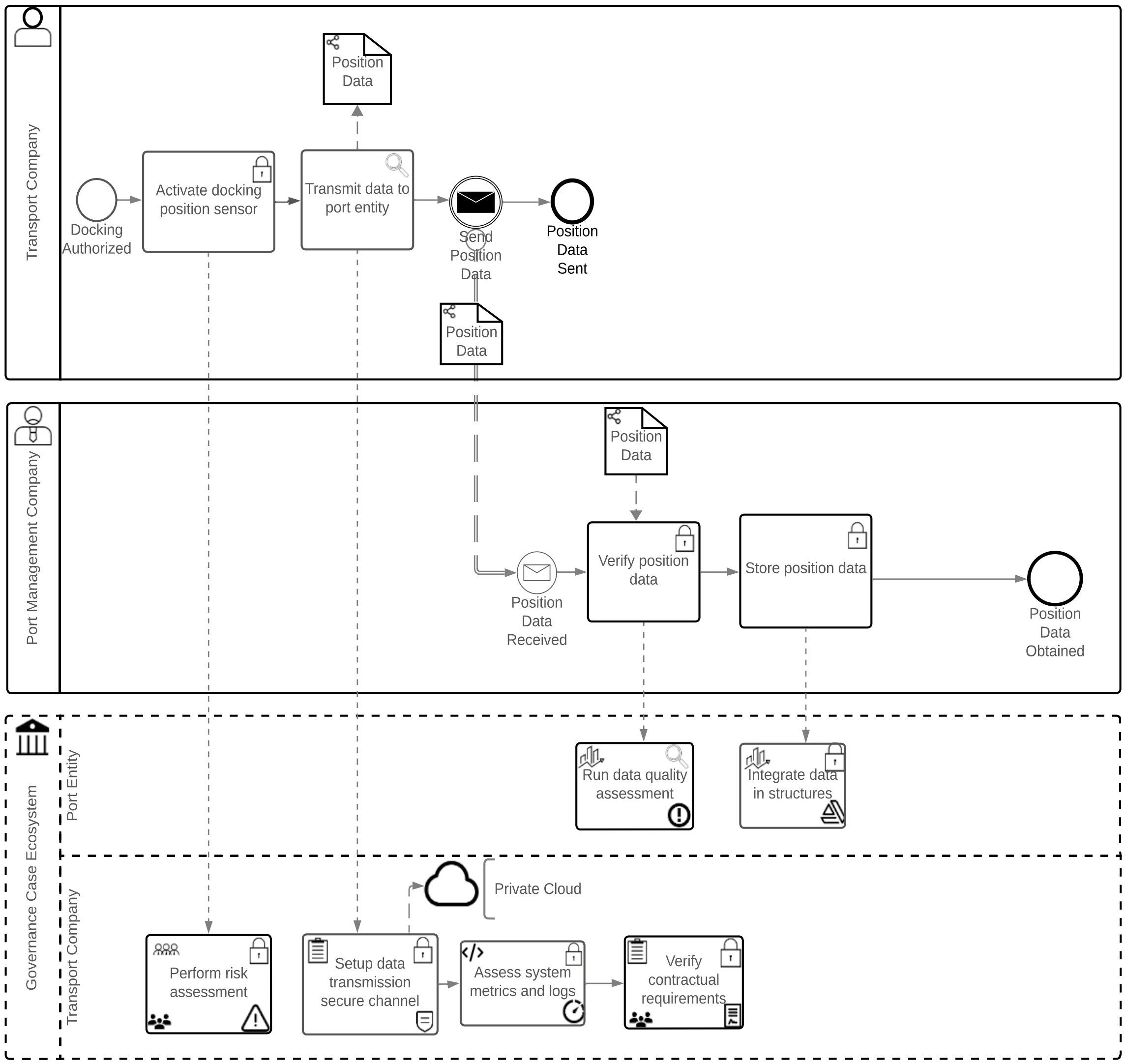


Fig. 4 A ship's geographical location determination business process using the IO-BPG BPMN extension

Table 8 Evaluation quality criteria for IO-BPG BPMN extension

Dimension	Criteria	Description
Syntactic quality	Syntactic correctness	Syntactic correctness aims to evaluate the way the notation's elements are compliant with its syntax (Rittgen, 2010)
Pragmatic quality	Relevance	Relevance aims to understand if the notation's elements are relevant to address the existing problem (Rittgen, 2010)
Semantic quality	Completeness	Completeness aims to assess if the concepts used in the process model possess the properties that are necessary to represent and describe them (Bork & Fill, 2014)
	Easiness to understand	This criteria aims to assess how well the users understand the model's semantics and notation—the graphical elements used to represent the metamodel (Huber et al., 2019)

- Finally, the fifth section introduces open-ended questions to gather additional insights into the advantages, disadvantages, and impacts of using the IO-BPG BPMN extension (full version in Appendix A, Tables 9 and 10).

Respondents identification

Following Schwiderowski et al. (2023), we identified the questionnaire's respondents using a two-stage procedure. First, we contacted industry practitioners and academics following suggestions provided by an expert working in the case company (Schwiderowski et al., 2023). Second, we used a snowball sampling technique to find more respondents (Schwiderowski et al., 2023). The goal was to reduce possible bias in the evaluation and to obtain additional perspectives on our modeling approach. The two groups of modeling experts are:

- Group 1 "practitioners": business process modeling practitioners. For this group, we focused on the results of the SUS questionnaire to evaluate the artifacts' utility, which is central to DSR evaluations.
- Group 2 "academics": scholars with expertise in business process modeling, business process management, and governance. This group was essential to obtain more fine-grained insights about the theoretical implications of our new notation. Therefore, we carefully analyzed their open-ended answers to explore opportunities for future research.

A total of 21 responses were obtained between December 2023 and February 2024 (cf. Appendix B, Table 11), which follows the sample size suggested by Brooke (2013).

Syntactic quality analysis

For the syntactic quality, we have considered the syntactic correctness criteria. BPMN is a standard modeling language with a well-defined syntax and standardized rules for each of the elements and their interactions (OMG, 2011). We validated the syntactic correctness of the IO-BPG BPMN extension process models against OMG's BPMN specification—which includes mechanisms for BPMN extension creation (OMG, 2011). For the extension development, we followed the methodology proposed by Stroppi et al. (2011) and extended by Braun and Schlieter (2014), which is compliant with the BPMN standard's specifications (Zarour et al., 2019). The answers to the questionnaire support our results since no respondent reported inconsistencies in the notation (see Q6). Therefore, the IO-BPG BPMN extension is syntactically correct.

Semantic quality analysis

In this dimension, we have considered the notation's completeness and ease of understanding. For completeness, we ensured adherence to the literature review findings and validated our results with real use cases. The questionnaire's respondents did not report missing elements. As for the notation's understanding, BPMN is recognized for its ease of interpretation and expressiveness, reducing the possibilities of incorrect knowledge transfer (OMG, 2011). The SUS questionnaire results offered the foundational assessment: for odd questions (e.g., Q1, Q3), values above 3 are expected—to agree and strongly agree; for even questions (e.g., Q2, Q4), values below 3 are expected—to disagree and strongly disagree.

The SUS questionnaire's results show that most respondents consider the extension elements to be well-integrated (Q5) and that the IO-BPG BPMN extension is easy to understand (Q3). Moreover, the majority of the respondents reported that they felt confident using the IO-BPG BPMN extension (Q9), that they would not need the help of technical support to use it (Q4), and that most people would understand it quickly (Q7). Lastly, the respondents noted that the was not complicated (Q8) and that the models developed using the IO-BPG BPMN extension were consistent (Q6). On the other hand, the respondents were divided in their answers about the need to learn background concepts to use the IO-BPG BPMN extension (Q10), the frequent use of the extension for modeling activities (Q1), and its increased complexity (Q2).

The final results returned a mean SUS value of 63, which corresponds to a "marginal high" rank according to the defined scale (Brooke, 2013).

Pragmatic quality analysis

According to the respondents, the IO-BPG BPMN extension offers new information layers, namely for representing the shadow governance activities (P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P14, P17) and clarifying stakeholders' roles and responsibilities (P1, P3, P14, P17). For example, P14 stated it "Clearly delineates roles, responsibilities, and power dynamics among business partners, leading to smoother collaboration and process management." Further, respondents pointed to its ability to disclose data governance activities that address data objects (P1, P5, P9, P11, P13, P14). For example, P1 stated, "(The IO-BPG BPMN extension) gives more information about the data, the tasks and their performers than the standard one while maintaining the same complexity," and P14 mentioned, "Addresses data ownership, quality validation (…) integrates secure data transmission channels." Moreover, respondents found that the IO-BPG BPMN extension enables the representation of shared resources (e.g., data assets) and operations that involve their use while clarifying responsibilities and accountability for each partner regarding these assets (P14, P17). For example, P14 stated that it "Facilitates tracking of shared resources and tasks, improving accountability and operational transparency among partners"). Additionally, P10 and P17 state that the IO-BPG process models allow the parallel representation of business processes and their governance in a single process model. For example, P10 stated, "It's much more descriptive and allows the inclusion of processes that are usually not reflected, as shown in the diagram. Usually, that would result in a separate diagram or some other description of the flows of governance, and this makes it easier to have every piece of info related to the process in one place." The respondents P1, P6, P13, and P14 highlight that the proposal contributes toward the alignment of governance and operations. For example, P1 mentioned, "we can design governance together with operations." One of the respondents stated that the single model can contribute to identifying and assessing possible risks associated with specific process activities and shared resources (P14). According to P1, P3, P11, and P14, the BPMN extension improves communication between stakeholders involved in IO-BPG scenarios by representing their contribution to governance. For example, P13 stated, "[models] are critical to have a clear idea of governance-related activities, share those activities with all the shareholders and stakeholders and communicate effectively with the general public," and P14 mentioned the "enhanced communication and collaboration." Respondents P2, P3, and P13 mentioned that the proposal provides a common language for business process stakeholders. For example, P13 classified the IO-BPG BPMN extension as "a standard language to communicate with all the people involved is of major importance." Lastly, P2 and P3 stated that the new process models improve process documentation.

The respondents also pointed out some negative aspects. According to P2, P3, P7, and P8, the IO-BPG BPMN extension is more complex due to the inclusion of additional information layers that may raise some difficulties in interpreting the models. P5 and P10 mentioned the difficulties in interpreting some of the new extension graphical elements. For example, P5 said that "some of the images/logos (e.g., data Science Unit) could be more intuitive." One of the respondents (P9) also stated that "BPMN is a standard, known and used by many people and organizations, and frameworks must be added with this new notation," considering the need to develop artifacts that support the notation's use.

In sum, most respondents declared that they would prefer to migrate to the IO-BPG BPMN extension when modeling inter-organizational setups.

Discussion

The main benefit of using the IO-BPG modeling approach is the ability to handle inter-organizational process governance-related concepts. Thanks to the addition of new layers of information to the process models, the BPG activities become explicit while remaining compliant with the original process representation and the intended use of the standard BPMN elements. Furthermore, new symbols add more specific details regarding the domain's compliance requirements, shared IT and data resources, and process performance data. Moreover, the new process models can be used to identify and assess the risks associated with specific inter-organizational operations and shared resources (e.g., data assets).

The new modeling approach improves process readability by extricating the governance-related tasks from the operational process model and representing them in a separate virtual pool. As such, while IT resources and data objects pertaining to the traditional business process representation are placed in the standard pools, the capabilities, relational mechanisms, governance structures, and governance processes are represented in the partnership's virtual governance pool. We chose the term "virtual" because (1) unlike the standard pools that represent an organization, the governance pool aggregates different process participants from multiple organizations, (2) it represents a shadow process governance operation that is sometimes invisible to other process stakeholders, and (3) it has scalability advantages. For example, we can continuously improve the same virtual governance pool (and reuse it when applicable), including more inter-organizational business processes in the overall model of the partnership. The new process models can be integrated into business process management systems and engines, allowing them to model, incorporate, and track operations, obtaining additional insights into IO-BPG activities and decisions across several partners, thus contributing to the improvement of the process and governance.

The IO-BPG modeling approach highlights the governance of the processes' data assets. The process models include details on data ownership, pointing to the origin of data and its flow across the business partners. Moreover, the notation enables the identification of the type of data (e.g., personal and non-personal data) and the regulations that apply to the data assets (e.g., General Data Protection Regulation (GDPR)). Lastly, data governance-specific activities can be represented in the process models using the virtual pool.

The IO-BPG models can be used as a standard communication tool between the partner organizations (e.g., to coordinate innovation activities) while clarifying the accountability and responsibility for performing governance operations. The new modeling approach allows the documenting of the governance activities embedded in business process activities and the sharing of this documentation among several partners. The process models are also helpful for audit purposes, guiding the assessment of the organization's business process execution, data assets, IT resources, compliance requirements, and the "shadow" BPG-related tasks of the digital business that have now become explicit.

The drawbacks of our approach also need to be carefully analyzed. Several respondents referred to the complexity of the new business process models since the information displayed may only be relevant to part of the organization. As noted by P5, these models are attractive for specific organizational teams. Therefore, when developing the process models using the IO-BPG modeling approach, we suggest identifying the teams and processes to which the topic is more relevant. Another possibility, as pointed out by some respondents, is to develop specific process model views suitable for the distinct departments and partners (e.g., a focused data governance view presented to the legal department or data science teams). Additionally, the IO-BPG modeling approach may not be relevant to all organizational processes—some have more data governance requirements than others.

The completion of our DSR project allowed us to devise the following design principles (DP) for the modeling approach application to represent IO-BPG scenarios:

- DP1: identify the regions of interest (e.g., departments, projects, teams, assets) and their inter-organizational processes. Specify data exchange and decision-making shared by multiple partners, touchpoints (e.g., process phases), and shared resources.
- DP2: identify the governance requirements for data, IT, and procedures for the inter-organizational processes in each region of interest. Collect the internal and external regulations, the responsibility and accountability of each partner for the several stages and resources, aiming to identify the governance mechanisms required for each stage of the process and the involved resources.
- DP3: identify the stakeholders (e.g., data science unit, data security unit) responsible for implementing the identified governance requirements and involve them in developing the new process models using the IO-BPG BPMN extension. The aim is to integrate the governance operations and corresponding partners that will be responsible for executing them.

The reflection made by the design team during the DSR cycles and the insights provided by practitioners and academics also allowed us to propose design principles for future BPMN extension studies:

- DP4: BPMN extensions traceability. Researchers should identify the source and the rationale for each extension element (e.g., using a literature review and use cases), as well as their utility and correction, aiming to justify the need and validity of each item in the new notation.
- DP5: BPMN extension gap analysis. Demonstrate the extension by modeling a real case scenario and comparing (1) the process model with standard BPMN and (2) the model using the new notation to identify the main differences, advantages, and disadvantages of using the extension-based models.
- DP6: BPMN extension focus. The extension should be evaluated by potential users (pragmatic quality) and experts in the syntax and semantics of conceptual modeling languages, for example, by applying a SUS questionnaire to assess the notation's utility and open-ended questions to obtain more subtle insights on the notation's syntactic and semantic correction, and the corresponding theoretical implications.
- DP7: BPMN extension scope. The extension may be more relevant to specific contexts, such as parts of the organization or specific teams. Researchers must identify the scope of using the extension and guidelines suitable to that context.

Conclusion

We described how we used DSR to develop a modeling approach to model inter-organizational business process governance (IO-BPG) scenarios. The results include (1) the identification of a set of attributes for the IO-BPG domain, (2) the creation of a domain ontology for IO-BPG, (3) the definition of modeling requirements for the IO-BPG domain, (4) the definition of a graphical representation of the IO-BPG BPMN extension elements, and (5) an evaluation of the proposed notation.

Theoretical implications

Our work extends the literature on BPG with a modeling approach demonstrated and evaluated in highly regulated and dynamic sectors of the economy. We extend the work of Machado Ribeiro et al. (2022) and included the representation of data assets and data governance-specific activities (e.g., data strategy management task, data issue management task, compliance monitoring task, data contractual agreements management) and roles (e.g., data science unit). Moreover, we add to the work of Amdah and Anwar (2020) by including the types of data (e.g., personal data and non-personal data) that the partners can use and produce. Our work also includes the explicit representation of the data exchange (the data flux extension element) between organizations. Furthermore, we can represent additional governance activities contributing to risk mitigation, extending Ribeiro et al.'s (2022) and Cardoso et al.'s (2021) contributions.

Using a virtual governance pool, our proposal enhances the business process representation with the "shadow" process governance activities carried out at specific points by each involved party. These activities can be targeted mainly toward the IT resources and data assets supporting the processes. Seven design principles to apply the IO-BPG modeling approach and conduct future work on BPMN extensions are proposed.

Since the IO-BPG BPMN extension allows the simultaneous representation of governance activities related to the tasks of specific business processes, it contributes to the logic of modeling details of a system of interacting processes (Řepa, 2023). Our work thus contributes to the "conceptualization of data governance as repertoires of mechanisms that form configurations that contribute to the achievement of organizational outcomes" (Davidson et al., 2023). By modeling IO-BPG, we can represent interactions between the partners at specific points, including the manipulation, use, and sharing of data assets. It is possible to depict a data governance profile of the partner organizations (e.g., the shared assets, the private data, the data infrastructures) that can use the models to improve the deployed mechanisms. Moreover, the models can promote the alignment between the partners and foster collaborative operations between the organizations.

Our work also offers a script and an example of a systematic approach for evaluating BPMN extensions. This addresses Zarour et al.'s (2019) concern that only 29% of the BPMN extensions produced were formally evaluated, and the call for an approach for evaluating BPMN extensions.

Practical implications

Our work provides a blueprint for establishing governance activities at the process level (e.g., value delivery, performance measurements), data assets disclosure (e.g., shared dataset, private dataset), data transmission mechanisms (e.g., data transmission flow), and regulations (e.g., GDPR (European Parliament, 2016), HIPPA (Act, 1996)). Moreover, the IO-BPG models using the proposed modeling approach can highlight partners' accountability over governance-related operations and data assets, the confidentiality of private datasets, the compliance with existing regulations, the autonomy of each member to perform their routine activities, the authority of the network's managers over the remaining partners, the traceability of data assets and data-related activities, and the collaboration and interactions between the network's members. Attaching the IO-BPG models to contractual agreements in networked businesses is a possible use. The IO-BPG process models can also be used to support process change analysis, as the models may reveal the impacts of specific changes in process compliance requirements. The IO-BPG modeling approach can be helpful for standards-certified organizations adopting a process management approach (e.g., ISO 38505–1 (ISO/IEC 38505–1, 2017)) to disclose their processes and third-party collaborations, with a more complete and concise representation of the several interactions and activities.

The IO-BPG modeling approach contributes toward documenting governance in business process models using a single process model—the integrated representation of governance and operations. The new approach can be a means to achieve interoperability within IO-BPG by exposing the several touchpoints between the partner's processes and systems, fostering the implementation of alignment mechanisms that facilitate the interaction and collaboration between the involved stakeholders at these points (e.g., defining data exchange standards, data formats).

Many organizations already use business process models regarding the requirements of several process-related certifications (e.g., ISO 9001 (International Organization for Standardization, 2015)). Using the IO-BPG modeling approach, it is possible to reuse the already existing business process models (e.g., BPMN) and extend them with the corresponding governance specifics. Therefore, our approach does not require the development of new models from scratch, which would be too onerous in terms of time and cost.

Limitations

We must acknowledge some limitations of our study besides those mentioned in our artifact's demonstration and discussion. Research limitations were managed based on "(1) input knowledge and technology, (2) research process, (3) resulting artifact, and (4) design knowledge" limitations (Barata et al., 2023).

First ("input knowledge and technology"), we used specific databases and keywords for the systematic literature review research and process documentation analysis from experts to identify IO-BPG domain attributes, concepts, and ontology. Conducting further industry surveys in the future may reveal more information layers or IO-BPG BPMN extension elements that should be added.

Second ("research process"), the research evolved in two case companies with particular priorities in inter-organizational business process governance (e.g., finances, manufacturing, software development). Therefore, the subsequent DSR cycles need to include different organizations participating in IO-BPG scenarios, aiming to improve the study's transferability. Our design also followed specific guidelines for BPMN extension design (Braun & Schlieter, 2014; Stroppi et al., 2011), but others can be tested. Moreover, our focus in the two cycles was the extension development, missing the insights that a longitudinal study on model use can provide.

Third ("resulting artifact"), the increased complexity of the models suggests a selective approach to IO-BPG modeling. Compared with the standard BPMN business processes, the additional information makes the models harder to understand, and redundancies may occur in the extension elements when modeling multiple business processes. The virtual pool needs continuous improvements to ensure consistency as more partners or processes appear. This problem also exists in standard BPMN elements (e.g., data objects), requiring consistency validation.

Lastly ("design knowledge"), our business process models are "static" at this stage since we cannot yet represent the changes in the IO-BPG mechanisms when specific events occur (e.g., cyber-attack, external audit, internal audit), which is crucial to make the modeling proactive. The creation of IO-BPG archetypes can contribute to addressing this challenge.

Future work

We have identified several future research avenues. First, research can be conducted to assess the possibility of using the IO-BPG models for GDPR (European Parliament, 2016) or security certification audits (e.g., ISO 27001 (ISO, 2022)). Second, creating IO-BPG governance archetypes (e.g., external audit, innovation, security intrusion) will be relevant to tailor governance based on the organization's context and business objectives. The work of Schmidt and Kolbe (2011) introduces the proposal of three governance archetypes for green IT governance, including "centralized, decentralized, and federal" scenarios. The MIT-CISR proposed five distinct governance archetypes: (1) "business monarchy," (2) "IT monarchy," (3) "feudal," (4) "federal," and (5) "anarchy" (Weill & Woodham, 2005). However, both propose a "static" view of the organization. We suggest that the digital transformation requires adaptative IO-BPG governance archetypes that can handle the constant environmental changes (e.g., new data-related regulations, innovative data science technologies, and market shifts). Third, inspired by the work of del-Río-Ortega et al. (2019), we suggest integrating new BPMN extension elements that enable the representation of key performance indicators (KPIs). Fourth, developing a BPMN-inspired modeling tool that includes the IO-BPG BPMN extension notation elements. This tool could include features to develop and deploy new BPMN extensions to other domains (e.g., finances, healthcare, and the manufacturing industry). Fifth, inspired by the proposal of Ribeiro et al. (2021), defining IO-BPG maturity levels for each dimension (e.g., data, process, technology). These could be represented by a number (e.g., maturity stage ranging from 1-Initial to 5-Optimized) in each element of the IO-BPG BPMN extension. Lastly, inspired by the enterprise architecture paradigm (The Open Group, 2018), developing multiple business process views (e.g., data view, maturity status view) adapted to each stakeholder's needs and expertise area.

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