Organizational Interoperability: A Systematic Mapping Study

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ABSTRACT

Context: Organizational interoperability enables collaboration amomg organizations with different structures and processes, promoting efficiency and integration in sectors such as public administration, health, and education. **Problem**: Implementing organizational interoperability presents significant challenges, including the lack of commonly accepted processes, difficulties interpreting administrative procedures and legislation, and the absence of conceptual models to define inter-organizational relationships. There are few studies that report organizational interoperability, and there is no consensus on several concepts and structures. **Solution**: The study maps existing approaches, including models for assessing organizational interoperability maturity, and a conceptual model based on Systems of Information Systems (SoIS) to help create interoperability connections between organizations. **Information systems theory**: Organizational interoperability research is associated with organizational information processing theory. **Method**: A systematic literature mapping was conducted in databases such as IEEE Xplore, ACM Digital Library, ScienceDirect, and Scopus. **Summary of Results**: Ten main studies were identified. In general, organizational interoperability has been treated as the ability of organizations to align business processes and expectations for effective information exchange. Challenges include the need for standardized processes, difficulties with regulations, and the absence of conceptual models. Solutions involve process-oriented approaches, but adoption still needs to be improved. **Contributions and Impact in the area of information systems**: The study contributes by providing a comprehensive view of organizational interoperability, identifying gaps, challenges, and possible solutions. It reinforces the importance of interoperability for inter-organizational collaboration to promote a more efficient and collaborative environment.

CCS CONCEPTS

• **Information systems** → **Data management systems**; • **Data management systems** → **Information Integration**; • **Information Integration** → **Data Integration**.

KEYWORDS

Organizational Interoperability, Interoperability, Process and Business Process alignment

1 INTRODUCTION

Interoperability is a fundamental concept in various areas of society and is perceived as the ability of different systems, devices, or components to work together effectively and efficiently, sharing information and functionalities, regardless of their origins, standards, protocols, or platforms [3, 4, 24]. To achieve interoperability, those involved should agree on how it will occur.

Interoperability at a system level is often associated with four main dimensions such as *technical*, *syntactic*, *semantic*, and *pragmatic* dimensions [21, 24, 27]. *Technical* interoperability allows systems and components of different technologies to communicate and exchange information efficiently through technical interfaces, tools, and protocols. With *syntactic* interoperability, different systems exchange data in a common format but do not guarantee that they understand the meaning of the data. *Semantic* interoperability dimension interprets and understands the meaning of data exchanged consistently and accurately. The *pragmatic* interoperability dimension ensures that data exchanged between distinct systems, organizations, or entities leads to meaningful and intended actions.

In multi-organization scenarios, *technical*, *syntactic*, *semantic*, and *pragmatic* interoperability may not address business processes, policies, and procedures of different organizations to achieve a desired outcome, specifically the alignment of business processes. According to some of the framework initiatives for interoperability, such as the e-Government Interoperability Framework (e-GIF) [19], Electronic Government Interoperability Standards (e-PING) [17], and the European Interoperability Framework (EIF) [4], it is important to consider other dimensions, such as ***organizational*** interoperability, to address the concerns related to business process alignment.

Organizational interoperability usually addresses interoperation issues among several organizations with different structures, aligning distinct business processes to achieve agreed-upon objectives for efficient, integrated, and transparent inter-organizational collaboration services [4]. ***Organizational*** interoperability has been tackled by addressing problems like the absence of commonly agreed-upon processes, challenges in interpreting administrative procedures and legislation, and lack of conceptual models to define cross-organizational relationships [6, 13, 16]. It's a crucial concept

in modern management, but it is often considered overlooked or undervalued [5, 29].

There are various types and dimensions of interoperability aimed at overcoming barriers that hinder collaboration on business processes across different organizations. Addressing interoperability challenges requires a shared understanding of the issues, a conceptual organization of types, and standardized terminology to achieve effective solutions [15, 24]. Ambiguity and misunderstandings regarding these concepts pose a significant obstacle to ***organizational*** interoperability, potentially impacting Systems of Systems (SoS) [6, 21]. Moreover, ***organizational*** interoperability is a crucial challenge for achieving *full* interoperability [14], as it requires alignment not only of systems but also of organizational structures, workflows, and governance models across institutions. This alignment is especially important in the context of Systems of Information Systems (SoIS) [8].

Collaboration between organizations requires that the people involved understand business models, regulatory requirements, and institutional policies to ensure efficient alignment. The absence of clear governance, misaligned process models, and heterogeneous systems create barriers to collaboration between organizations and can generate inconsistencies in the exchange of information and coordination of business processes between them, thus influencing ***organizational*** interoperability.

Therefore, this paper aims to analyze the state of the art of ***organizational*** interoperability through a systematic mapping of literature [2, 10, 11]. The main objective is to investigate and analyze ***organizational*** interoperability to answer the following research questions: (i) How has ***organizational*** interoperability been defined? (ii) What issues ***organizational*** interoperability attempting to address? (iii) How has ***organizational*** interoperability been implemented? and (iv) In which contexts/domains was ***organizational*** interoperability addressed?

We conducted an initial search in 2023, where 1,180 studies were analyzed, resulting in a total of 10 studies for full reading. Since the number of studies removed in the first analysis was considerably high, we conducted a new search in 2024, where 355 studies were analyzed, resulting in a total of 11 studies for full reading. After reading the studies in both reviews (21 studies) and applying the inclusion/exclusion criteria a total of 10 studies were considered to answer the research questions.

Results highlight that despite the frequent mention of ***organizational*** interoperability, this remains an area that has not been sufficiently addressed in depth. In contrast, the development of solutions is a significant concern for government and health domains.

The remainder of this paper is organized as follows: **section** 2 describes some concepts related to interoperability; **section** 3 describes some relevant related work on ***organizational*** interoperability; **section** 4 presents the methodology established for conducting systematic mapping; **section** 5 describes collected data analysis results, survey questions answered, and discusses some of our results; **section** 6 analyzes some threats of validity; **section** 7 presents our conclusions and future works.

2 BACKGROUND

According to the authors of [26], interoperability is the ability of two or more systems or components of systems to exchange information between them and use it. However, the concept of interoperability is multidimensional and can be analyzed from different perspectives and approached from various domains.

The concepts of interoperability and integration are often used as synonyms in the field of Information and Commnications Technology (ICT); however, these concepts are complementary. Integration refers to the process of connecting two or more systems, creating a technological dependency between them. Interoperability concerns the process of communication between two or more systems without generating a technological dependency between them [24].

For interoperability to occur, everyone must agree on how this interoperability will take place. Therefore, the standards used in interoperability mechanisms must be well known, so that less effort is required in creating interoperating interfaces and communication happens more quickly and efficiently [3].

Technical interoperability is the most basic dimension of interoperability and concerns the capacity of systems to communicate through standardized network protocols and hardware interfaces. *Syntactic* interoperability dimension refers to the ability of systems to support the structure and formatting of exchanged data. This includes accurately defining data formats, to ensure information is interpreted correctly by target systems. *Semantic* interoperability dimension goes beyond syntax and involves ensuring that systems share a common understanding of the meanings of the data exchanged. This requires the standardization of vocabularies, ontologies, and metadata so that systems can interpret data coherently. ***Organizational*** interoperability dimension refers to the capacity of organizations and entities, including government agencies, to effectively collaborate in service delivery and information sharing. This involves the harmonization of processes, policies, and organizational structures to facilitate cooperation [4, 21, 24]. Other interoperability types, out of this study scope, are emerging, such as *cloud* interoperability, *blockchain* interoperability and *legal* interoperability [15].

3 RELATED WORK

The current literature presents a few studies concerning ***organizational*** interoperability and related topics.

During the mapping, we found three secondary studies [18, 20, 28] and one tertiary study [24] that are directly related to ***organizational*** interoperability.

The authors of [28] discuss *governance* interoperability, which involves coordinating and managing processes and decisions for effective interoperability between organizations. It is defined as a set of rules, structures, and processes that support collaboration, ensuring strategic alignment, compliance with standards, and resource management. ***Organizational*** interoperability is closely related, focusing on aligning business processes, responsibilities, and expectations to achieve common goals. In contrast, *governance* interoperability focuses on creating policies, guidelines, and structures to ensure that organizational interactions follow shared principles and objectives.

The study presented in [20] discusses the importance of ***organizational*** interoperability in government information systems, highlighting that the ability of different government entities to exchange information and cooperate is essential to improve efficiency, reduce costs, and provide better services to citizens. The review identifies several challenges governments face in implementing interoperable systems, such as problems with integrating legacy systems, the need for alignment between different departments, and challenges related to compliance with privacy and security regulations.

The authors of [24] conduct a tertiary analysis of interoperability classifications, structuring a comprehensive classification based on secondary studies and systematic reviews. This analysis identifies patterns and variations in classifications over time and across contexts. The study highlights that ***organizational*** interoperability involves business rules, policies, process alignment, and actions that enable collaboration. It also addresses how systems align their processes, responsibilities, and expectations to achieve shared goals.

Finally, the study presented in [18] conducts a comparative analysis of methods and approaches for assessing interoperability in the context of Industry 4.0. The study examines the main techniques used to measure and improve interoperability in highly connected industrial environments, where cyber-physical systems, the Internet of Things (IoT), and automation play a central role. ***Organizational*** interoperability is the ability of the company to cooperate with partners to achieve common goals in the business process dimension, sharing data securely and efficiently within the company or its partners.

According to these works, the literature highlights the diverse applications of ***organizational*** interoperability, illustrating its role in aligning business processes, responsibilities, and expectations to facilitate effective collaboration between systems and organizations. As detailed in [28], *governance* interoperability supports this alignment by establishing policies and frameworks that guide inter-organizational exchanges. As discussed in [20], government applications highlight the efficiency and service improvements achieved through interoperable systems, although challenges with legacy systems and regulatory compliance remain. The analysis in [24] further categorizes the types of interoperability, emphasizing the reliance of ***organizational*** interoperability on shared business rules and process alignment for collaborative goals. Finally, in the context of Industry 4.0, the authors of [18] point to the growing need for ***organizational*** interoperability to enable secure and seamless data exchange between partners, reinforcing its importance in increasingly interconnected industrial environments.

In contrast to existing studies, our research addresses gaps that are only partially explored or not covered in related works. While previous studies discuss various specific aspects of ***organizational*** interoperability—such as governance structures to facilitate collaboration [28], domain-specific challenges like legacy system integration in government [20], industrial data-sharing methods [18], they do not establish a unified view of its core definition or a comprehensive analysis of its application across multiple domains. Our research seeks to bridge these gaps, aiming to provide a cohesive understanding that integrates these elements and offers a broader perspective on the alignment required for successful ***organizational*** interoperability across sectors.

4 SYSTEMATIC MAPPING METHODOLOGY

The Systematic Mapping Study reported in this paper follows the guidelines presented by [12] and comprises three steps: (i) plan, (ii) conduct, and (iii) report. The planning stage will support researchers in defining the scope of the study, the research questions, the research strategy, the inclusion and exclusion criteria, and the data extraction method. In the conduction stage, the defined plan will be executed, with studies being researched and evaluated and selected and relevant information extracted to answer the research questions. Finally, in the reporting phase, the review results will be released.

4.1 Planning

This review aims to map the state of the art in ***organizational*** interoperability and answer the following Main Research Question (MRQ): *How has **organizational** interoperability solutions addressed business processes dimension between companies?* To assist in answering this MRQ we defined four additional questions:

- RQ1 - How has ***organizational*** interoperability been defined? - With this question, we aim to analyze if there is a community consensus on ***organizational*** interoperability.
- RQ2 - What issues ***organizational*** interoperability attempting to address? - With this question, we want to identify the problems the community has encountered when implementing ***organizational*** interoperability.
- RQ3 - How has ***organizational*** interoperability been implemented? - With this question, we want to investigate frameworks, languages, models, and standards that deal with ***organizational*** interoperability.
- RQ4 - In which contexts/domains was ***organizational*** interoperability addressed? - With this question, we aim to map which domains still have solutions/solved the ***organizational*** interoperability.

To perform the review, we initially considered four important research databases in Software Engineering: IEEEXplorer, ACM Digital Library, Science Direct, and Scopus.

We refined the studies selected from the automatic search manually according to the following inclusion criteria (IC) and exclusion criteria (EC):

- IC1 - Study in the English language
- IC2 - Study that addresses problems of ***organizational*** interoperability or its synonyms
- IC3 - Study with full text available
- IC4 - Study with examples of ***organizational*** interoperability, tools and frameworks, or other solutions that implement ***organizational*** interoperability
- EC1 - Study in a language other than English
- EC2 - Study that does not address problems of ***organizational*** interoperability or its synonyms
- EC3 - Study without full text available
- EC4 - Study similar to another that reports the same results, where the most recent one is the basis for analysis
- EC4 - Study that deals with other types of interoperability that are not ***organizational***.

4.2 Conducting

We conducted the first replication of our search in 2023 in the IEEE Xplore, ACM Digital Library, and ScienceDirect databases, where we selected works using the following search string:

> *("organizational" OR "process" OR "enterprise" OR "business process") AND interoperability.*

This string was formulated based on the findings of [15], which pointed out that these types of interoperability are related to collaboration among organizations. Likewise, this search string was applied to the title, abstract, and keywords, considering studies published between 2018 and 2023. IEEE Xplore returned 697 studies, ACM Digital Library 249, and Science Direct 309, totaling 1255. We found and removed seventy-five duplicate studies, resulting in a total of 1.180 for analysis. The 1.180 studies had their titles and abstracts analyzed. At the end of this analysis, 1.128 studies were excluded, leaving 52 studies with their introductions and conclusions analyzed. After this second analysis, we excluded 42 studies, resulting in 10 studies for complete reading.

The number of papers removed in the first analysis (title and abstract) was considerably high. This occurred because the terms "organizational" and "interoperability" have their meanings when they are not used together. For example, "organizational" can refer to an organization's environment and "interoperability" can be a global concept or associated with other types of interoperability. All the steps of the mapping can be seen in **Figure 1**:

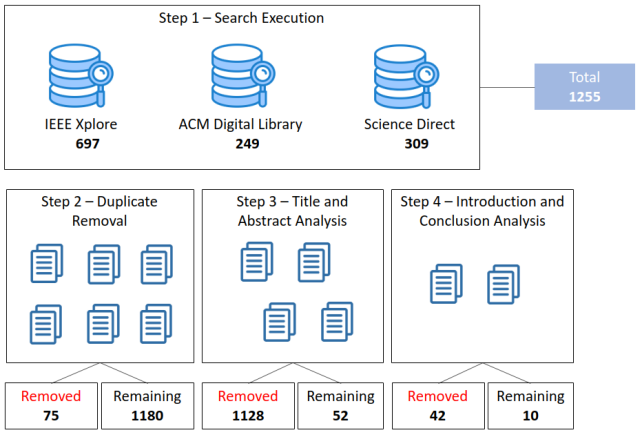

Figure 1: First Systematic Mapping Phase

Due to the high number of papers removed compared to the initially obtained quantity, we decided to refine the search string. So, in 2024, the search was conducted in the IEEE Xplore, ACM Digital Library, ScienceDirect, and Scopus databases using an improved search string:

> *"Organizational Interoperability" OR "Process Interoperability" OR "Enterprise Interoperability" OR "Business Process Interoperability".*

We applied this search string to the title, abstract, and keywords, considering studies published between 2014 and 2024. The search returned 59 studies from IEEE XPlorer, 112 from ACM Digital Library, 150 from Science Direct, and 59 from Scopus, totaling 380 studies. From there, we removed 25 duplicated studies, resulting in 355 studies for analysis.

The 355 studies had their titles and abstracts analyzed. At the end of this analysis, we excluded 303 studies, leaving 52 studies with their introductions and conclusions analyzed. After this second analysis, we excluded 41 studies, resulting in 11 studies for complete reading along with the 10 found in the first review, totaling 21 studies for complete reading. After reading the 21 studies of both mapping phases and applying the inclusion/exclusion criteria, 10 primary studies were considered to answer the research questions. It is possible to observe that the total number of papers removed in this review remained high. Many removals occurred because the studies cited the term "***organizational*** interoperability" (or its synonyms) but did not specifically address our research questions of "***organizational*** interoperability" (or its synonyms). Additionally, ***organizational*** interoperability encompasses several related terms, such as *enterprise*, *business*, and *process* interoperability, which are more akin to sublevels of ***organizational*** interoperability. These terms are used inconsistently, making understanding more difficult and, consequently, hindering the development of ***organizational*** interoperability solutions. All the steps of the seconding mapping phase can be seen in **Figure 2**.

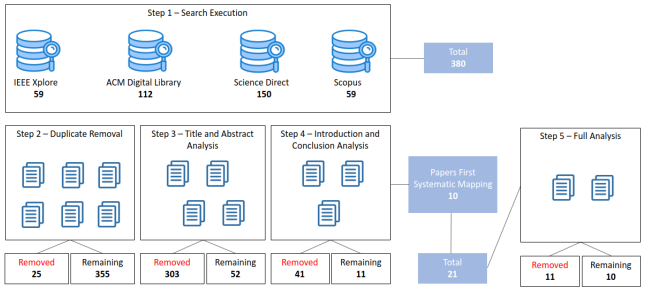

Figure 2: Second Systematic Mapping Phase

5 RESULTS

This section initially presents an overview of the studies and then answers these research questions.

5.1 Overview of Studies

The ten primary studies [1] selected to answer the research questions are listed in (**Table 1**).

5.2 RQ1 - Organizational Interoperability Definitions

Regarding RQ1 *How has* ***organizational*** *interoperability been defined?*, as presented in **Table 2**, most of the studies adopt the terminology ***organizational*** interoperability, only three studies (S2, S9, and S10) reference it using synonyms.

[1]The list of studies and extracted data is available in https://abrir.link/oEmlw

Table 1: Primary Studies

ID	Title	Years	Reference
S1	Collaboration Mechanisms for IoT Platform Federations Fostering Organizational Interoperability	2018	[29]
S2	The Interoperability of Things: Interoperable solutions as an enabler for IoT and Web 3.0	2018	[9]
S3	Development of Interoperability Problem-Oriented Model for University E-Learning System (by the Case of Nosov Magnitogorsk State Technical University)	2019	[22]
S4	Assessment of organizational interoperability in e-Government: a new model and tool for assessing organizational interoperability maturity of public service in practice	2020	[16]
S5	Innovative Ways to Ensure the Interoperability of a Complete Group of Processes in the Lifecycle of an Integrated Management System Based on their Synchronization	2020	[13]
S6	An Approach Based on Conceptual Modeling to Understand Factors that Influence Interoperability in Systems-of-Information Systems	2021	[6]
S7	Do data security measures, privacy regulations, and communication standards impact the interoperability of patient health information? A cross-country investigation	2021	[25]
S8	The role of interoperability dimensions in building information modeling	2021	[5]
S9	Base Frame of Algerian E-Health System: How to Ensure Data Consistency Exchanged With Laboratory Management System Using BPM and IHE Profiles?	2021	[1]
S10	Towards a Reference Enterprise Architecture to Enforce Digital Sovereignty in International Data Spaces	2022	[7]

Table 2: Organizational Interoperability Definitions

ID	Definition	Terms
S1	Organizations can communicate and transfer meaningful information effectively, even though they may use various information systems on widely different systems.	Organizational Interoperability
S2	It is the integration and orchestration of services across domains through common semantics and programming interfaces.	Organizational Interoperability
S3	It is interaction at the dimension of business processes within and between different systems.	Organizational Interoperability
S4	It is the interoperation between organizations with different organizational structures and different management processes to carry out efficient, integrated, and transparent inter-organizational services.	Organizational Interoperability
S5	It is the process-oriented integration that provides a complex interaction of heterogeneous functional systems with different dimensions of technological implementation within a cross-cutting process.	Process Interoperability
S6	It is how organizations align their business processes, responsibilities, and expectations to achieve agreed objectives.	Organizational Interoperability
S7	It is a predefined set of agreed rules and processes that facilitate the standardization of services across different issues or multiple units within an organization.	Organizational Interoperability
S8	It is the collaboration of administrators who wish to exchange information and may have different structures, business objectives, and internal processes.	Organizational Interoperability
S9	It is the data exchange between information systems from different organizations, based on process management, to ensure better integration between them.	Business Interoperability
S10	Organizations can interact with each other to achieve shared objectives through the sharing of information and the integration of business processes.	Enterprise Interoperability

Of the ten studies analyzed, eight consider the use of business processes to define ***organizational*** interoperability. Only two (S1 and S2) define ***organizational*** interoperability only at the system dimension. Therefore, there is a common understanding of the importance of business processes for implementing ***organizational*** interoperability.

Organizational interoperability (S1, S2, S3, S4, S6, S7, S8) concept emphasizes the ability of organizations to communicate and exchange meaningful information effectively, regardless of diverse systems, structures, and management processes. ***Organizational*** interoperability involves aligning business processes, responsibilities, and expectations to achieve common objectives across organizations. It also includes setting shared rules and processes to facilitate standardized services, enabling integrated and transparent

inter-organizational services, as highlighted in definitions like S1, S4, and S6.

Process interoperability (S5) focuses on integrating processes at a functional level to enable complex interactions across systems with varying technological implementations. Unlike ***organizational*** interoperability, which emphasizes the alignment and collaboration of entire organizations, *process* interoperability focuses more on managing cross-functional, process-specific interactions within a technical framework.

Business interoperability (S9) concerns data exchange between information systems from different organizations, mainly through process management. While ***organizational*** interoperability includes broader considerations, such as aligning goals, processes, and expectations at an organizational dimension, *business* interoperability primarily ensures data flows smoothly across systems, emphasizing technical data exchange rather than broader organizational alignment.

Enterprise interoperability (S10) involves the capacity for organizations to interact to achieve shared goals by sharing information and integrating business processes. While similar to ***organizational*** interoperability, *enterprise* interoperability often focuses on aligning systems and processes to achieve business outcomes at an enterprise dimension. In contrast, ***organizational*** interoperability goes beyond just systems and processes by addressing organizational structures, governance, and cross-functional responsibilities to foster effective collaboration.

Furthermore, ***organizational*** interoperability across organizations can be structured into multiple dimensions, which are more akin to sublevels of ***organizational*** interoperability, each addressing specific aspects of integration and collaboration. At the highest dimension, ***organizational*** interoperability, followed by *enterprise*, *business* and finally *process*. At the highest dimension, **Organizational* Interoperability* focuses on aligning structures, processes, and objectives to enable meaningful communication and cooperation between entities. **Enterprise* Interoperability* supports this broad alignment, which centers on achieving shared business goals by integrating processes and information across organizations. Beneath this, **Business* Interoperability* ensures the technical compatibility of systems and data exchanges, facilitating smooth interactions between systems. Finally, at the most detailed dimension, **Process* Interoperability* manages the integration of individual processes across diverse technological environments, enabling detailed workflow connections essential for seamless collaboration. Together, these dimensions build toward a comprehensive framework that allows organizations to cooperate effectively across both strategic and technical dimensions.

Based on the studies found, we can define ***organizational*** interoperability as a combination of the concepts of the different terms discussed. Thus, we can say that ***organizational*** interoperability *enable the communication, integration, and interaction between organizations with different organizational structures that align their heterogeneous business processes to achieve agreed objectives of collaboration among efficient, integrated, and transparent inter-organizational services.*

5.3 RQ2 - Organizational Interoperability Issues

Achieving ***organizational*** interoperability involves addressing various critical issues across conceptual, procedural, security, and technical domains.

Regarding RQ2 *What issues* ***organizational*** *interoperability attempting to address?*, the studies analyzed addressed the following problems: the lack of commonly agreed-upon processes, difficulties in interpreting administrative procedures and legislation, and the absence of conceptual models to define inter-organizational relationships. Additionally, the increasing complexity of integrated systems heightens the difficulty of ensuring their interoperability due to the heterogeneity of the systems involved in the composition, which are developed with different technologies and belong to different organizations. All problems addressed in each paper can be seen in **Table 3**

First, the lack of commonly agreed-upon processes, as identified in S4, S3, S7, S1, S2, and S9, emphasizes the necessity of standardized procedures to support organizational alignment. This gap complicates cross-organization cooperation, as each entity operates under different guidelines and expectations. These standardized processes are necessary for achieving seamless ***organizational*** interoperability.

Second, S4, S8, and S10 highlight issues related to interpreting administrative procedures and legislation. Organizations often need help with varying legal and administrative frameworks, which can hinder effective collaboration and data exchange between entities. This regulatory variability requires more adaptable and universal frameworks to support consistent understanding and application.

Third, S6 underscores the absence of conceptual models to define inter-organizational relationships, which points out a significant gap in providing managers with frameworks to recognize existing connections and identify new opportunities for services. A lack of structured models limits the ability to build effective interoperability strategies.

Lastly, S5 addresses the inherent difficulty of integrating heterogeneous systems developed with varying technologies and maintained by distinct organizations. This system diversity adds another layer of complexity, as interoperability efforts must bridge differences in technical standards, architectures, and operational requirements.

In summary, achieving ***organizational*** interoperability requires a unified approach that includes standardized processes, adaptable regulatory interpretations, well-defined conceptual models, and solutions for managing system heterogeneity. These factors contribute to building a more cohesive and operationally aligned organizational environment, which is essential for achieving seamless interoperability across diverse domains.

5.4 RQ3 - Solutions for Organizational Interoperability

Regarding RQ3 *How has* ***organizational*** *interoperability been implemented?*, the studies analyzed describe the development of various approaches and models to improve ***organizational*** interoperability in multiple areas. These initiatives include the creation of a new model/tool to assess the dimension of ***organizational*** interoperability maturity, the definition of a SoIS-based conceptual model to

Table 3: Organizational Interoperability Issues Addressed

ID	Addressed Problems
S1	The lack of commonly agreed processes, difficulties interpreting administrative procedures and legislation, and difficulties defining authorities and responsibilities.
S2	The non-existence of a specific conceptual model that defines inter-organizational relationships prevents managers from recognizing the existence of these relationships and envisioning new services and business possibilities.
S3	The lack of a quality management system that guarantees and manages organizational interoperability.
S4	The need for security measures in organizational interoperability.
S5	Addresses the lack of shared understanding among stakeholders and the limited number of studies dealing with organizational interoperability.
S6	The complexity of integrated management systems increases the problem of ensuring their interoperability due to combining a wide range of heterogeneous functional systems in their composition.
S7	The fact that although syntactic and semantic interoperability has already been widely addressed, organizational interoperability, which enables direct, business-oriented interactions, has not been in focus.
S8	The difficulty that companies may have in interpreting business rules and architectural guidelines when they need to share data in a business ecosystem can lead to implementations with interoperability problems.
S9	The need for standards that allow horizontal (technical, syntactic, and semantic) and vertical (organizational) communication, operation, and programming between devices and platforms, regardless of the model or manufacturer.
S10	The need to adopt a process management approach to improve the quality of companies' products and services and consistently satisfy their customers' requirements.

help create interoperability links between organizations, and the application of process-oriented approaches to achieve interoperability in healthcare systems, Internet of Things (IoT), education and enterprise architecture. Each proposal aims to improve interoperability in different contexts and dimensions, addressing *technical*, *organizational*, *semantic*, and *legal* factors. All solutions proposed in each paper are in **Table 4**.

The analysis of proposed solutions for ***organizational*** interoperability reveals a diversity of approaches tailored to specific contexts, showing that no universal solution exists. Each model or tool examined seeks to address unique issues associated with its respective domain, reflecting the particular requirements and challenges of healthcare, education, and IoT systems. For instance, while process-oriented models effectively promote interoperability in healthcare environments—where secure data exchange and regulatory compliance are essential—more flexible frameworks are required for IoT environments, where device and protocol diversity demands an adaptable approach.

The increasing use of maturity models to assess ***organizational*** interoperability is notable. These models allow organizations to diagnose their levels of alignment and interoperability, facilitating the identification of gaps and the creation of improvement strategies. However, these models still lack standardization and broad applicability, limiting their use across different sectors and inter-organizational contexts.

Another significant point is conceptual models based on Systems of Information Systems (SoIS), which provide a structure for connecting organizations but still face adoption and implementation challenges, mainly due to the need to adapt existing processes and organizational structures. While these solutions offer substantial progress, barriers impede *full* interoperability between organizations. Integrating legacy systems, the need for common standards, and the technological heterogeneity used by different organizations remain significant obstacles. Furthermore, future research must develop more integrated approaches holistically considering the technical, semantic, and organizational dimensions.

This diversity of solutions demonstrates that achieving effective ***organizational*** interoperability requires a multidimensional approach. This approach enables models and frameworks to adapt to the specific realities of each domain while also advancing toward standardization and the creation of shared protocols.

5.5 RQ4 - Organizational Interoperability - Contexts/Domains

Regarding RQ4 *In which contexts/domains was* ***organizational*** *interoperability addressed?*, the studies analyzed map ***organizational*** interoperability in different contexts, emphasizing areas such as public administration, health, education, and the Internet of Things (IoT). Many proposed solutions are domain-independent, i.e., they can be applied to any domain.

The lack of standardized processes in public administration hinders collaboration between government agencies, making interoperability more complex. Public organizations need help interpreting and applying regulations and policies that vary across departments and jurisdictions. Interoperability Maturity Models allow public entities to assess their dimension of ***organizational*** interoperability, identify gaps, and develop alignment strategies. In addition, creating specific policies and guidelines facilitates aligning processes and procedures, ensuring that all public agencies work towards common goals.

In healthcare, legacy and specialized systems make integration difficult, especially between clinics, hospitals, and laboratories that use different technologies. Interoperability needs to be improved by complying with stringent privacy and security regulations. A model that integrates systems utilizing a business process management approach enables healthcare systems to share data securely and efficiently. In addition, defining common protocols and standards for data sharing, emphasizing security and privacy, facilitates interoperability while maintaining regulatory compliance.

Institutions often face difficulties exchanging information in an integrated and standardized way with other educational and government systems. Institutions may use different technologies and educational systems, making information exchange and collaboration difficult. A specific interoperability model for e-learning

Table 4: Organizational Interoperability - Solutions and Domains

ID	Solutions
S1	Proposes an interoperability framework where the system components can cooperate and offer continuous operation. This end-to-end interoperation project allows the interaction of several complex service composition configurations and system management through standards.
S2	Investigates how adopting security measures, privacy regulations, and communication standards impacts information interoperability at the technical, semantic, and organizational dimensions.
S3	Proposes applying a process-oriented approach to systems integration that expands the list of processes considered in the systems life cycle based on organizational data, organizational resources, and technical-technological processes.
S4	Proposes developing a new model/tool for assessing the maturity level of organizational interoperability, providing a more complete and reliable method for diagnosing the current situation and planning future improvements.
S5	Proposes a mechanism to reconcile data sovereignty and enterprise interoperability requirements in a reference enterprise architecture.
S6	Proposes a conceptual model based on SoIS to assist managers and researchers in designing interoperability links between organizations.
S7	Proposes a mechanism for defining and monitoring Service Level Agreements (SLA) and an exchange solution to guide the sharing process between platforms, which need to be orchestrated by mechanisms that guarantee the fair use of shared resources.
S8	Proposes a methodology to integrate a health laboratory system based on a Business Process Management approach.
S9	Discusses the problem but does not propose any solution.
S10	Proposes a problem-oriented interoperability model as an evolution of the interoperability reference model, which contains an expanded set of interoperability dimensions due to the detailing of the upper dimensions of the reference model.

platforms allows data exchange between institutions and facilitates collaboration on inter-institutional projects.

In the IoT environment, devices often use different protocols and standards, which makes interoperability difficult. The need to share and control data between platforms and devices from other vendors can be challenging to ensure interoperability. Developing a framework that standardizes communication and management between devices allows IoT systems from different manufacturers to work together. In addition, adopting Service Level Agreements (SLAs) that define clear rules for sharing and using resources between devices ensures secure and efficient collaboration in the IoT environment.

These solutions reflect domain-specific approaches focused on overcoming barriers and improving ***organizational*** interoperability by facilitating collaboration and alignment between systems and processes across organizations.

6 DISCUSSION

Organizational interoperability enable the coordinated alignment of heterogeneous business processes, organizational structures, and management practices to enable effective communication and meaningful information exchange between organizations. This interoperability type supports collaborative, efficient, and transparent inter-organizational services by establishing common goals, shared processes, and standardized rules that facilitate integration across disparate systems.

Figure 3 shows a summary of the findings of this study, with the proposed definition for ***organizational*** interoperability, the types of interoperability related to ***organizational*** interoperability, the problems addressed by the analyzed studies, the proposed solutions and the domains where these solutions have been applied.

Despite being frequently cited, ***organizational*** interoperability is rarely explored in depth in the literature. Our mapping identified limited studies addressing our core research questions regarding its definition, challenges, and solutions. Key findings indicate that (1) standardization of business processes and shared rules are critical but inconsistently addressed across studies, (2) challenges such as heterogeneous system integration and lack of shared conceptual models persist, and (3) solutions often focus narrowly on technical integration without fully considering organizational alignment.

Systems of Systems (SoS) and Systems of Information Systems (SoIS) require solutions that enable them to dynamically identify participants and evolve processes as collaboration requirements change. Although intra-organizational process management and alignment solutions exist, only some focus on inter-organizational process alignment, and those that do are rarely adopted in commercial environments. While applicable in some contexts, existing service choreography and orchestration solutions need to be revised to deal with the complexity inherent in SoS.

Future research should focus on frameworks that connect *technical* and *organizational* dimensions across domains. Dynamic governance models and emerging technologies, like blockchain, can enhance ***organizational*** interoperability, enabling decentralized, secure data exchange ideal for SoIS and SoS. Blockchain-based smart contracts can automate compliance, while machine learning identifies misalignments and suggests improvements. AI can dynamically reroute processes, supporting adaptability, coordination, and effective decision-making in complex SoS environments.

Cloud platforms offer scalable infrastructure for inter-organizational collaboration, providing shared services and APIs that standardize data formats and protocols. These systems enable real-time process orchestration, connecting and coordinating services quickly—essential for agile SoIS and SoS. Digital twin technology allows organizations to create virtual replicas of processes or systems, enabling them to simulate scenarios, optimize interoperability before deployment, and adapt processes dynamically, helping SoS manage complexity.

These technologies offer promising approaches for operationalizing ***organizational*** interoperability, enabling SoS and SoIS to

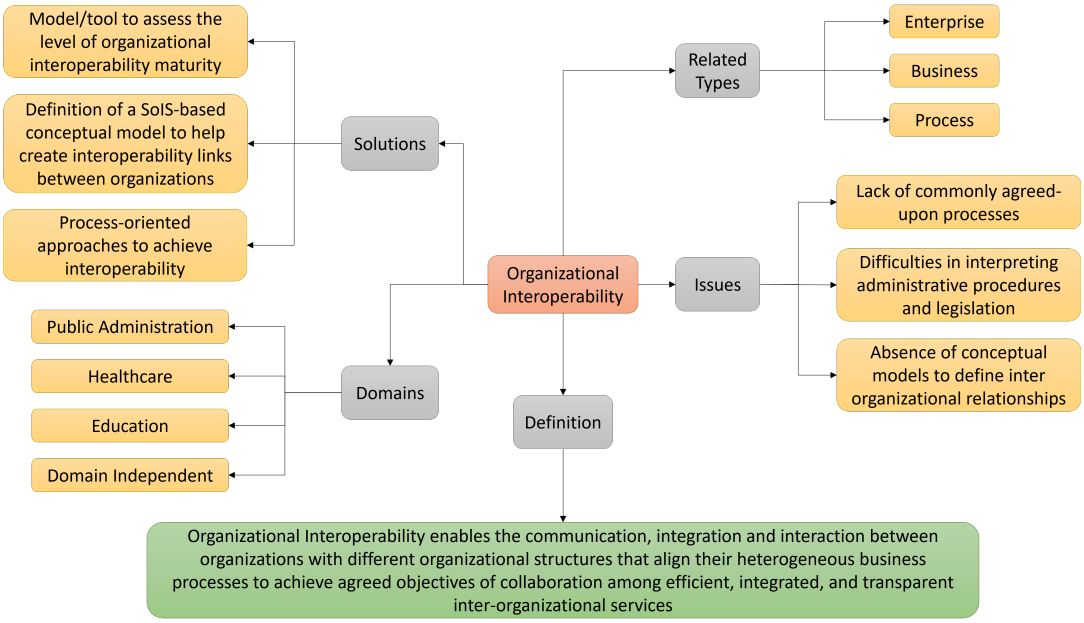

Figure 3: Organizational Interoperability Elements

dynamically adapt, connect, and collaborate in complex, multi-organizational environments.

6.1 Threats of validity

Considering construction validity, to decrease bias in paper selection and extraction, we established a protocol for how the reviews should be conducted following the guidelines of [12] for systematic literature mapping, ensuring transparency in the selection of studies.

Regarding internal validity, to ensure consistency in the search process, the initially defined string was reviewed and reapplied in a second revision. Moreover, to reduce the risk of reviewers' judgment, the first author led the search and extraction process and was assisted by the second author. The last author resolved any discrepancies. The research was conducted in well-established databases (IEEE Xplore, ACM Digital Library, ScienceDirect, and Scopus), and the search strategy was refined to increase the relevance of the included studies.

Concerning external validity, to achieve greater representation in the selected works, we considered papers written in English and published in four major research databases, which contain the main publications in the interoperability domain.

To ensure the conclusion validity, it is crucial to emphasize the connection between solutions and domains, which can impact the generalization of our conclusions.

7 CONCLUSION AND FUTURE WORKS

This systematic mapping study on ***organizational*** interoperability provides a comprehensive overview of the state of the art, highlighting the main definitions, challenges, and solutions found in the literature. ***Organizational*** interoperability is essential to enable effective collaboration between organizations with distinct structures and processes, contributing to efficiency and integration in diverse domains, such as public administration, health, and education. However, the results indicate there are still limitations, mainly in the lack of standardized processes and conceptual models that would facilitate inter-organizational collaboration more broadly[23]. Although there are advances, the literature still shows a lack of consensus on definitions and practical approaches that fully address the challenges posed by ***organizational*** interoperability.

The main distinction of our study is in the structured definition of ***organizational*** interoperability, improving ***organizational*** interoperability solutions. Our study maps challenges such as lack of standardization and difficulties in interpreting regulations and suggests that open standards and clear regulations improve communication between organizations, proposing solutions such as the use of BPM and SoIS-based models.

Our study argues that ***organizational*** interoperability should be analyzed alongside other forms of interoperability. It highlights that *technical*, *semantic*, and *pragmatic* interoperability are insufficient to ensure effective collaboration between organizations. ***Organizational*** interoperability is seen as a strategic dimension that depends on these other forms to be effectively implemented.

Regarding the challenges of GranDSI-BR, our study highlights that ***organizational*** interoperability lacks unified models, unlike *technical* and *semantic* interoperability. Additionally, it points out that ***organizational*** interoperability is a socio-technical issue, as it involves multiple actors, policies, and distinct organizational contexts.

To advance research in the area of ***organizational*** interoperability, future work could focus on creating conceptual models that

facilitate the definition and alignment of processes between organizations that can help reduce interoperability problems and promote more effective collaboration, and on creating assessment methods that allow measuring the level of maturity of ***organizational*** interoperability in different contexts and sectors, providing a more accurate diagnosis of the needs of each organization. These approaches will strengthen the field and help address interoperability challenges between organizations, promoting a collaborative and efficient environment.

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