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Literature Review on Interoperability Approaches: Taxonomy and Challenges

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***Abstract*— Real-world systems scarcely keep data limited to the small spaces where they were first acquired. Interoperability has been deemed highly valuable in many cases. In this new era, it is difficult to harmonize the data in an environment during its transfer and identify the processes that result in more democratic data while stopping the flow of insufficient data at the beginning of the transfer to obtain one golden copy of the authentic interoperable data. This article conducted a detailed survey discussing a detailed taxonomy, advantages and challenges of interoperability and cutting-edge methods for promoting interoperability among various current approaches. So, we will extend the research to collect issues of the available interoperability models and frameworks adopted in industry concerning to the Internet of Things (IoT), physical and industry 4.0, cloud, health care, public health care, context -ware, Systems-of-Systems (SoS), Systems of Information Systems (SoIS), large scale systems. Finally, the paper presents the most common issues and potential future deployments in the scope.**

Index Terms*— Integration, Interoperability, Logistics of Interoperability

I. INTRODUCTION

THANKS to data science and advanced analytics, we now live in an era of technology where most of our daily activities are saved as data. As a result, there is a vast amount of data in several types, including urban, Internet of Things, social media, financial, business, healthcare, mobile, security, and multimedia. Data could exist as structured, semi-structured, or unstructured, and it grows in real time [1].

Because of data analytics' widespread and growing importance in computer science, its challenges have become research areas that many people want to examine and address theoretically and practically. These problems can be classified and treated in a variety of ways, but the majority of them lack accurate solutions [2]. Interoperability is regarded as one of the most critical data analytics issues.

Interoperability is stated as "the ability to cooperate and exchange data in spite of variations in languages, interfaces and execution platforms" [3]. Organizations and countries can reap benefits from sharing data for research, statistics, and health purposes. This requires unified logistics (standards, protocols, interfaces, codes, frameworks, etc.) to share data of various types and make certain validity at any level or dimension of interoperability.

Obtaining interoperability in an open and dynamic environment such as the Web is a challenging and intricate process that demands a high level of application alignment. Expertise in industry has demonstrated that the interoperable systems result in several advantages [4]:

i. *Getting more precise data:* relates to the capacity of the interoperable systems or components for information exchange and utilization.
ii. *Accomplishing functionalities that systems cannot achieve on their own*: concerns with how well certain products, systems, or business procedures can cooperate to complete a common function.
iii. *Reduce the cost of each transaction:* if interface standardization is available, information sharing can encourage application integration and data exchange.
iv. *Growth of operating efficiency:* Due to the capability of interoperability of systems to be shared throughout numerous systems, they often culminate in a decrease in the number of devices. As a result, the system's overall cost is reduced.
v. *Better quality service levels and more predictable response:* Interoperability makes it easier for various participants to communicate information on the condition of their components and systems.
vi. *Data creation and information integration:* Interoperability makes it possible to define new data or to integrate information that was previously dispersed.

Since the popularization of distributed systems and heterogeneity in different systems, interoperability is still a prevailing issue because of the levels of complexity and openness that modern systems reach about SoS, SoIS, IoT, etc [5]. This study attempts to highlight the most important key figures for these issues:

i. A more detailed taxonomy for interoperability.
ii. An in-depth explanation of related work, including existing researches based on the presented taxonomies for interoperability.

iii. A deep comparison among existing approaches for interoperability pursuant to extensive related works.

iv. Exhaustive overview of the open issues and prospective future research trends in interoperability.

The remaining of this paper is arranged as follows: it describes the background for interoperability in Section 2 and enumerates the related work in Section 3. Section 4 presents the discussion and implications of the most common recent issues of data interoperability, and Section 5 provides the conclusion, recommendations, and future work.

II. BACKGROUND

Based on the previous section, some terms associated with interoperability are stated as follows:

A. Interoperability vs. Integration

It is critical to beware of not confusing interoperability with integration as shown in Figure 1. Another definition of interoperability refers to the aptitude of two or more systems to interact without becoming technologically dependent on one another. Interoperability occurs at run-time in a minimal coupling manner while the interconnection of two or more systems results in a new linked technical solution. Integration is nearly difficult since it results in significant coupling in complicated, large-scale, and vigorous systems in which members evolve separately. Interoperability is necessary in this circumstance to address problems including the necessity for transparent system interaction. Understanding what forms of interoperability to be met in the construction and execution of complicated functions is important for this interaction to exist [5] [6].

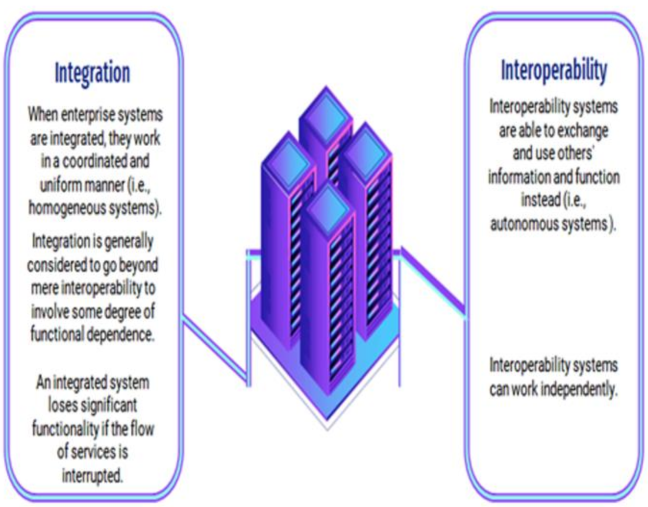

Fig. 1. Interoperability vs. Integration.

B. Classifications of Interoperability

Interoperability has been classified into different classes such as dimensions, levels, attributes and logistics. Achieving a high level of interoperability is costly and takes a long time. Therefore, organizations do not have to search for the maximum level of interoperability and take into account the identification and planning of baseline logistics for managing interoperability [6].

i. Dimensions of Interoperability

There are six dimensions for interoperability as follows [7] [8]:

1. Technical interoperability

Technical interoperability is concerned to the technical aspects of joining systems of computer and services. Data presentation and sharing, open interfaces, interconnection services, accessibility, data integration and middleware and security services are all critical components. The level and types of data exchange like manual, dedicated, incorporated, and consolidated, determine technical interoperability maturity.

2. Organizational interoperability

The organizational interoperability involves identifying business goals, modelling of business processes, and collaboration of administrations that seek to interchange data but may contain diverse interior structures and operations.

3. Semantic interoperability

Semantic interoperability is assuring that the exact meaning of shared data is intelligible via any other application which did not originally designed for this purpose. Semantic interoperability allows systems in order to amalgamate incoming data with additional data resources and to handle them properly.

4. Syntactic interoperability

Syntactic interoperability is referred to a willingness to share data. Syntactic interoperability is commonly related to formats of data. Communication protocols should send messages with clarified grammar and encoding, regardless of whether they just take the structure of bit-tables.

5. Legal interoperability

Legal interoperability makes sure that corporates working under diverse legal frameworks, rules, and strategies may collaborate. It is a standard practice in the business for providing models and documentation to government offices and authorities for legal acceptance.

6. Ethical interoperability

When Artificial Intelligent (AI) systems require or desire to collaborate; that is, it must identify if some AI system is ethically interoperable in the sense that the AI corresponds with the principles and systems of the adopting organization [9].

TABLE I. Levels of Interoperability.

Level	**Focus**	**Key Components**	**Objectives**	**Major Challenges**
Individual	Personal interaction with systems	User interfaces, accessibility, training	User efficiency, satisfaction, productivity	Skill variability, accessibility, support
Organizational	Integration within a single organization	IT infrastructure, data integration, processes	Operational efficiency, data accuracy	Legacy systems, data silos, change management
Inter-Organizational	Collaboration between organizations	Communication protocols, standardized formats	Partnerships, supply chain efficiency	Aligning standards, trust, competitive balance
Societal	Systems across societal domains	Public policies, cross-sector integration	Service quality, accessibility, equity	Diverse needs, data privacy, stakeholder coordination
Global	International cooperation	International standards, global governance	Trade, global challenges, development	Regulatory diversity, cultural differences, equitable access

ii. Levels of Interoperability

Interoperability consists of five main levels as shown in Table 1 [10] [11]:

iii. Logistics of Interoperability

There are twenty-two logistics of interoperability which can be divided into two categories: endogenous and exogenous logistics. Endogenous logistics refer to concerns within the corporation which top management can control and vice versa for exogenous logistics.

Organizational: This attribute is associated to business policies, rules and restrictions, process alignment, and the steps required for making the entities interact. Also describes how members' systems coordinate their operations, duties, and outlooks for meeting predetermined objectives [6].

Legal: This attribute encompasses legal matters regarding the alignment of higher-level organizational functions or governmental policies, which are typically stated in the mold of legal aspects and regulations of business [7].

Operational: This attribute relates to indicators of process in terms of reducing process failure, cost and time through the interaction of systems with each other, with the environment and with participants [8].

Constructive: This attribute is concerned with the connections between the organizations in charge of constructing the architecture of system, design, out-of-the-box commercial items, standards and maintenance [9].

Service: This attribute relates to a organization's interest in proactively registering, collecting and using services derived from an outside source. It refers to resource exchanging while architecting novel cloud-based data services from outside sources. Additionally, this kind of interoperability facilitates data sharing across geographically dispersed multidisciplinary teams [6].

Business: Interoperability at the organizational dimension. Business interoperability is not usually claimed since it is not regarded as a priority at the organizational dimension [6].

Process: This attribute addresses the requirements needed to align the building, drawing, and operation processes that utilize Building Information Model (BIM) rather than traditional 2D CAD, with these firms changing the entire operation process. This corresponds to the information delivery manual of construction smarts that formalizes processes through the construction industry [10].

Data: This attribute indicates the requirement for various platforms, systems and software to communicate among them and use mutual languages [11]. It contains both format of data (syntax) and its purport or meaning (semantics).

Coalition: This attribute denotes to the interoperability's organizational and technological aspects. In order to raise the coalition's interoperability when there is a shortage of technical interoperability, it is helpful to identify organizational ways that can do so [12].

Conceptual: This attribute refers to information set forth as a standard conceptual model with content (contracts and common document forms) that is well-defined. As previously pointed out earlier, conceptual has been used as a synonym of organizational [6].

Programmatic: This attribute involves the connections between offices of programs that oversee arranging for the acquisition of systems [13].

Integrated: All models adhere to a thorough common format. To develop models and construct systems, everyone involved must agree on a common format, which needs not be a standard [14].

Unified: There is an agreed-upon format, even though it only applies to the meta-level/ model. This meta model offers a way through semantic equivalence for facilitating mapping between models, but it is not an executable item because it is in the integrated method [15].

Federated: The use of a federated approach indicates that no partner enforces its models, languages, or working methods because there is no uniform format and that parties must make accommodations in order to ensure interoperability. This implies that they need exchange an ontology for semantically map their notions [16].

Platforms: This attribute refers to the environments permitting the communication among various system services, networks, hardware, programming languages, operating systems, architectures, structures of data and apply mechanisms on data and things [6].

Systems: This attribute seeks to allow systems to work together, with systems described as a "assemblage of interdependent components arranged to accomplish one or more specified objectives"[11].

Procedures: This attribute includes a variety of operational controls, data dictionaries and documented guidance which affect all parts of operational functionality, development and system interoperation. It covers the architecture guidance and standards, policies and procedures, and doctrine which allow data sharing between systems.

Workflows: Workflows often encompass data flow statements, control and rules that execute the analytics needed for performing the desired experiments, involve convoluted orchestration of applications that may extend various fields from heterogeneous workflow platforms [14].

Information: This attribute aims to the capability of systems and processes for using and sharing services of information [6].

Knowledge representation: This attribute is concerned with linking representation formalisms (language and constructs) to the knowledge (concepts) which a human keeps in their mind regarding reality [17].

Enterprise: This attribute relates to the interoperability among organizational units or business processes in a big, distributed corporate or a network of corporates [6].

Security: This attribute concerns how the applications authenticate each other for sharing data with the required application in an approved manner. Shared data among systems may be encoded, so there is necessary to provide a unified interpretation of shared data to enhance interoperability [18].

C. Challenges of Interoperability

The need of interoperability is clearly visible but achieving data interoperability is bounded with various constraints, few of them are listed below [11]:

i. Diverse Data Formats and Standards

Different systems often use varying data formats, models, and standards. For instance, one organization might use XML for data representation while another uses JSON. These differences complicate data exchange, requiring mappings or conversions that may be complex and not always accurate.

ii. Varying Levels of Data Granularity

Data granularity refers to the detail level at which data is stored. Some systems may store fine-grained data (e.g., individual transactions), while others only keep aggregate data (e.g., monthly summaries). Matching data at incompatible granularity levels can lead to information loss or require approximation, impacting interoperability.

iii. Differences in Privacy and Security Regulations

Each region or industry may follow different privacy standards, such as General Data Protection Regulation (GDPR) in the European Union (EU) or Health Insurance Portability and Accountability Act (HIPAA) in healthcare. These regulations specify how personal data should be handled, creating challenges when trying to share data across boundaries without violating compliance requirements.

iv. Authentication and Authorization Variability

Systems often have distinct authentication and authorization protocols, which define who can access what data and under what conditions. Ensuring secure and seamless data exchange requires mechanisms that reconcile these security frameworks without compromising data privacy or integrity.

v. Semantic Discrepancies

Semantic interoperability deals with ensuring that data has the same meaning across different systems. Differences in terminology, units of measure or data interpretation can lead to misunderstandings or misrepresentations of data. For example, "client" might refer to a customer in one system but an internal application in another.

vi. Syntactic Differences

Syntax refers to the structure or format of data, such as the way dates are formatted or how lists are separated. Syntactic inconsistencies require transformations to ensure data is readable and understandable on the receiving end, adding complexity and potential errors to the data exchange process.

vii. Policy and Governance Inconsistencies

Policies governing data usage, sharing, and retention can differ widely between organizations or jurisdictions. Aligning these policies is critical to avoid conflicts in data handling practices, but achieving alignment is difficult when organizations have unique policy requirements.

viii. Ethical and Cultural Sensitivities

Data exchange often involves ethical considerations, particularly when dealing with personal or sensitive information. Cultural differences also play a role, as some data may be considered sensitive in certain cultures and not in others. Balancing these concerns is crucial to maintain trust and avoid ethical pitfalls.

ix. Performance and Scalability Requirements

Different systems may have unique performance and scalability requirements. For example, real-time data sharing in healthcare demands low latency, whereas a batch data transfer in finance might prioritize accuracy over speed. Meeting these varying performance standards is complex, particularly when scaling up data interoperability efforts.

x. Legal and Compliance Barriers

Legal frameworks governing data sharing vary across sectors and countries. Data sovereignty laws may restrict cross-border data flows, while specific sectoral regulations mandate unique data-handling requirements. Addressing these legal constraints adds complexity to designing interoperable systems that can comply with all relevant laws.

III. Literature Review

As a matter of fact, research works about interoperability focus on two main aspects. Researchers in both aspects attempt to find exhaustive solutions for interoperability [15]:

i. Academia (interoperability theoretical aspects). Current research work has focused on the evolution of interoperability architectures beyond finding out the relationship between levels, dimensions, and logistics of interoperability.

ii. Industry (a specific interoperability solution for a specific field). Only existing technical approaches are used as solutions for promoting interoperability. The industry tries to determine interoperability barriers through standardization for establishing interoperability between devices, networks, services, data formats, etc. Table 2 presents a comparison between several approaches for interoperability by finding out in what dimension, level and the logistics used in each of them as well as identifying the challenges that were observed in each approach.

Bokolo [16], presents a layered architecture that facilitates Distributed Ledger Technologies (DLT) interoperability relying on IOTA tangle for making demands, inter-communicating, and exchanging data by RESTful application programming interface which acts as a gateway with other outer digital platforms prevailed via Virtual Enterprise (VE) to build an interoperable eco-system. In addition, this study shows a case scenario about digital payment for seamless electronic mobility as a service to customers involved in VE. IOTA is adopted as DLT in the VE because of its data tracking, stability, and properties of tamper-resistance that enable data integrity verification. IOTA provides the flexibility and performance required to provide an accurate digital solution. Data and asset silos result from DLT platforms' general incompatibility and isolation from one another. Context, service, application and data processing, data space, technology, and physical infrastructure are the seven levels that make up the layered architecture.

Roxin et al. [17], argue the key research problems that the field of digital building twins is currently facing due to the increased need for the digitization of the construction industry. Modern methods for perceiving a building start to emerge. However, there are a number of ISO standards that address real-time monitoring and decision-making in establishing lifecycle stages other than facility management. No standard execution, on the other hand, has been created. Their article expands on the contributions envisioned in the context of the Communicating Material for BIM (ANR McBIM) project and how they can advance current cutting-edge techniques. Concrete recycling, demolition, and structural health monitoring are all impacted in the real world by "communicating concrete" and its applications in improving sensor network lifetime. Contributions to reactive and proactive decision-making are also trailblazing, providing users with the confidence they require for "a trustworthy basis for making decisions."

Azman and Sharma [18], propose a system that provides a better and efficient way to integrate digital setups within airport surroundings by employing digital stamps inspired via digital signatures and also combining certain visions from decentralized distributed ledgers. In addition, they offered a framework for automated passenger management systems in airports, in which the traveler (through elements like e-Passports) takes on a member of the network. Cross-airport interoperability could be achieved with the use of e-Passports (or such as data cards) intended to handle with data in ways inspired via the suggested system. The prospective techniques for automating the various route steps could be recognized through implementations of e-Passport and automated kiosks or digital officers. Their system allows the use of smart technologies that may be standardized internationally on a large scale due to their interoperability to securely store and exchange critical data without the requirement for maintaining common databases. It has the potential to greatly simplify the process for airports, airlines, and certainly passengers. The goal of their study is to help streamline itinerary procedures and boost passenger flow rates through counters and gates. This could enhance the passenger's journey experience via lowering frustration levels and resulting in far shorter real-time waiting times. It would also increase the overall environment security.

Cimmino et al. [19], design CIM tool which offers a strong security and privacy foundation for data transmission, and enables existing systems of Demand Response (DR) to deploy their components in the cloud. Additionally, the CIM employs a semantic interoperability layer to convert data into a normalized form when shared so DR components can consume it invisibly. According to experiments, the CIM enables systems of DR to decentralize their designs and share heterogeneous data even with additional systems of DR which meet various standards of DR.

Juric et al. [20], created a framework and platform for translating codes across multiple coding systems (e.g., ICD-9, Read Codes, and so on). The applied method is made possible in great part by the medical KB built by Babylon Health. They develop a new integration methodology for importing coding systems to the Babylon Health KB that makes use of cutting-edge ontology matching technologies. To avert data loss, all codes from a coding system are mapped to current or newly formed entities in the Babylon Health Knowledge Base. Furthermore, to eliminate ambiguity, all mappings are converted to one-to-one mappings, and appropriate heuristics are used for deciding in which incoming entities should be appended in the KB. They use their code navigation strategy. The translation is simple if there are exact mappings across coding systems, but if none exist, then a near match must be calculated. They enhance the partial mapping methods that were previously described by adding a framework for rating and evaluating the semantic accuracy of the generated codes via information retrieval techniques such as sentence embeddings. They perform their navigation system and estimate it in house doctors.

Paniagua and Delsing [21], use a run-time engineering approach to build interoperability between heterogeneous systems in Service Oriented Architecture (SOA) based environments. A generator system was created for utilizing service interface descriptions for autonomously generating a corresponding service consumer interface. Service interface code generation is determined via six important features: autonomy, runtime, security, timeframe, robustness, and generality [21]. The generation is carried out within the Arrowhead framework that aims to allow interoperability among heterogeneous systems with current protocols and standards and treat legacy systems. It upholds the following SOA-based design principles: standardized service contracts, late binding, loose coupling, service abstraction and autonomy. The generator of consumer interface is an Arrowhead system which generates and deploys consumer interfaces using the service interface definition as input. In the Arrowhead framework, the authors give a theoretical definition of this system and the generation process. However, there are challenges to testing the validity of this approach and defining its basic security requirements.

Barata et al. [22], encompass a bibliometric analysis of interoperability standards embracing circular manufacturing practices. Their study is a part of the KYKLOS 4.0 H2020 project, which aims to develop a cyber-physical ecosystem through pilot projects in healthcare, transportation (e.g., aerospace, maritime, automotive), and other manufacturing sectors. Interoperability must adopt applicable standards in these complicated settings involving energy efficiency and waste control. Their contribution differentiates the parameters for selecting circular manufacturing standards and provides examples. A recent bibliometric study is also available in two main databases, WoS and SCOPUS. The four interoperability dimensions: legal (e.g., regulations), technical (e.g., data integration, security), organizational (e.g., management support, financial), and semantic (e.g., dictionaries, definitions) derived from these bibliometric networks and earlier studies on the subject emphasize the necessity to reconcile the most pressing standardization needs for data formats or data exchange protocols with ongoing interoperability improvements. However, they ignored determining a final set of interoperability logistics for standards-compliant circular manufacturing.

Brilhault et al. [23], provide a comparison between ontology-based interoperability and Model-Driven Interoperability (MDI) in order to ensure semantic interoperability of heterogeneous information systems because the demands made on the present digital corporate architecture are not met. So, there is a need to determine a plug and play system and define various criteria that correspond with the Industry 4.0 requirements. According to the authors' analysis, the MDI techniques have enormous avenues for linking models, federating new sources of information, and broaden federation in an agile and adaptable manner. However, they need systems to adhere to standards, technologies, or even a common vocabulary to assure state of interoperability, these solutions do not in any way address the issues associated with heterogeneity.

Chen et al. [24], propose the categorization of various kinds of data models based on three major capability criteria (structural capability, semantical capability, and functional capability) to aid align the definition of the model. Industrial models have to adhere to requirements such as standards and organizational rules. However, data conception and data exploitation may suffer if existing data models are integrated with external standards for interoperability.

Justo-López et al. [25], present EMPC process capacity evaluation model regarding e-learning interoperability. This reference model serves as an example of several dimensions of interoperability capabilities according to the organizational, business, and governmental domains they target. In this, a university attains a level of capacity based on the completion of the tasks outlined in the Process Pattern. The IF-LOE served as a guide document for interviews and data from the interoperability processes. Additionally, the analysis classified the actions as falling under the technical, semantic, and organizational dimensions of interoperability. This model focused on improving the interoperability of processes in the educational environment, but there is an omission of sharing data such as educational content concerned for the process of educational platforms, the construction of cooperation conventions between universities, the development of LO, and the utilization of international interoperability standards.

IV. Discussion

In this research, a limited number of studies were conducted to look into interoperability issues using a multidisciplinary approach according to levels, dimensions, and logistics. Theoretical studies in this area lacked life cycle process of interoperability. In pursuance of practical studies, previous interoperability techniques relied on the opinions and experience of experts and practitioners using cutting-edge technologies to tackle a specific problem. Certain studies use the developing of questionnaires to gather expert comments on the logistics required for interoperability, but solely from a technical perspective. In light of the aforementioned, it is important to point out that numerous articles demonstrate the lack of thorough data that could be used to construct an adaptive framework for interoperability across multiple disciplines, which would aid in defining the baseline logistics according to the level and dimension of interoperability. Due to a shortage of open models and standards, reference frameworks are a crucial tool used in many study fields to direct and enhance research solutions. The field of interoperability research was no exception.

According to the preceding discussion, all solutions rely on the employment of technology to tackle a specific problem in a given field, and there is a lack of investigation into interoperability standards. As a result, there is a need to develop an adaptable intelligent framework for interoperability that contributes to addressing the following major interoperability issues that have been overlooked in present research.

i. Find out the relationship among dimensions, levels and logistics of interoperability.

ii. Classify dependent and independent logistics for interoperability.

iii. How to select appropriate baseline interoperability logistics in terms of achieving (Findable, Interoperable, Accessible, Reusable, Updatable) Data.

V. Conclusion

This study provides the difference between interoperability and integration and a detailed definition of the classifications of interoperability in terms of levels, dimensions, and logistics that are presented. Then, it presents a discussion of the previous research in the interoperability. The research has attempted to discuss the proposed models and frameworks for interoperability in many industries which highlighted that it lacks some development and updating. A large number of the surveyed interoperability approaches draw attention to investigating the relationship among levels, dimensions, and logistics of interoperability among all of the outlined perspectives. Despite numerous academic and industry approaches to addressing interoperability concerns, there is a lack of standardized framework that can handle associated research issues. According to the presented discussion, the main issues in this topic are also highlighted. In conclusion, this literature review opens up a new debate in evolving a roadmap for removing obstacles to interoperability via decision-makers. Future work could entail building an adaptive intelligent framework for interoperability to be further implemented in the different environments and industries.

TABLE II. Summary of Different Data Interoperability Approaches.

Approaches [Ref.]	**Used Logistics of Interoperability**	**Dimensions of Interoperability**						**Levels of Interoperability**					**Challenges at Using Logistics of Interoperability in each Approach**
		Technical	Organizational	Semantic	Syntactic	Legal	Ethical	Level 0 (Individual)	Level 1 (Organizational)	Level 2 (Inter-organizational)	Level 3 (Societal)	Level 4 (Global)	
layered architecture [16]	- Distributed Ledger Technologies (DLT) - IOTA Tangle - RESTful	✓										✓	- Anonymization - Standardized APIs for cross DLT token transfers - Interoperable processes and policies - Rapidity of data transaction confirmation - Standardization challenges to speed up interoperability among existing DLTs - Limited protocols and forms
ANR McBIM (Communicating Material for BIM) [17]	-ISO 19650 standard -Implement Explainable Decision-Support			✓								✓	- Standardization challenges
Electronic boarding system for e-Passports [18]	-Bidirectional communication (Bar-code, QR Code or RFID chips)	✓										✓	- Lack of security -Interoperable operations and policies
CIM tool for cloud-enabled Demand Response [19]	The GUI API and Management API are two primary aspects of CIM that are responsible for adjusting its features.	✓		✓					✓				- Limited protocols and forms
Integrating Coding Systems into the Babylon Health KB [20]	- Platform that enables translation among different coding systems (ICD-9, ICD-10, and Read Codes). -Algorithms (CodingIntegration and concept2code)			✓								✓	Increased cost of platform deployment
Run-time engineering approach for service interoperability [21]	- Code generation - Consumer interface generation	✓						✓					- Standardization of APIs and data models

Approaches [Ref.]	**Used Logistics of Interoperability**	**Dimensions of Interoperability**						**Levels of Interoperability**					**Challenges at Using Logistics of Interoperability in each Approach**
		Technical	Organizational	Semantic	Syntactic	Legal	Ethical	Level 0 (Individual)	Level 1 (Organizational)	Level 2 (Inter-organizational)	Level 3 (Societal)	Level 4 (Global)	
plug and play approach [23]	-Model Transformation by Example (MTBE) -Search-based approach -Learning approach			✓						✓			-Ontology-based interoperability: converting data heterogeneity to the conceptual level (metadata). -Model-Driven Interoperability (MDI): to ensure interoperability between models.
Data model classification for interoperability[24]	- Internal Renault techniques include the construction of a common variable dictionary to ensure global interoperability across disciplines.			✓	✓			✓					- Standardization of data models
A Reference Model of Processes for Interoperability in Learning Object Environments [RMPI] [25]	- Process Pattern -Assessment Model of Process Capability [AMPC]	✓	✓	✓						✓			-the lack of standardized syntax and legal policies in educational platforms.
IgnisHPC architecture [26]	- Message Passing Interface (MPI). - Docker container - JVM and non-JVM based languages.	✓							✓				-Perform in shared mode. -This architecture can't provide execution on different hosts. -These configurations can be arduous for treating and executing via resource managers in big data milieu.

Approaches [Ref.]	**Used Logistics of Interoperability**	**Dimensions of Interoperability**						**Levels of Interoperability**					**Challenges at Using Logistics of Interoperability in each Approach**
		Technical	Organizational	Semantic	Syntactic	Legal	Ethical	Level 0 (Individual)	Level 1 (Organizational)	Level 2 (Inter-organizational)	Level 3 (Societal)	Level 4 (Global)	
Framework for selection of Health Terminology Systems [27]	-Terminology Main Group (TMG). -Important Related Terminologies (IRTs). - Message Exchange Standards (MESs). - Architecture of Terminology Standards performed by NCVHS.			✓							✓		-Find a proper way for terminology developers to determine the architecture logistics to create a more effective mapping between the relevant terminologies instead of analyzing expert's opinions through developing questionnaire to determine logistics of framework. - Lack of security in the message exchange.
Proposed trust-based middleware framework [28]	-This framework represented IoT heterogeneity and interoperability concerns in various service interactions such as Smart home, Agriculture, healthcare, Weather and Traffic service domains in dynamic environments and cross platform coordination among IoT/services.	✓	✓								✓		- Global industry standards, common communication protocols, greatly promoted security capabilities and middleware issues are still outstanding. -Determine the way to choose dynamically which parameters should be considered when calculating trust at a specific time instead of equal trust parameters selection like in this framework because not every service interaction ought to be handled in the same way.
PCH Framework Reference Architecture [29]	-Blockchain -Cloud - Internet of Things (IoT	✓		✓						✓			- There is difficulty in exchanging patient records between different participants, so it is required to use PCHs. -A standard like HL7 FHIR is essential to ensure the security and consistency of data sharing implementation.

Approaches [Ref.]	**Used Logistics of Interoperability**	**Dimensions of Interoperability**						**Levels of Interoperability**					**Challenges at Using Logistics of Interoperability in each Approach**
		Technical	Organizational	Semantic	Syntactic	Legal	Ethical	Level 0 (Individual)	Level 1 (Organizational)	Level 2 (Inter-organizational)	Level 3 (Societal)	Level 4 (Global)	
A framework for interoperability between models with hybrid tools [30]	- The framework FaCIL was proposed to combine UML, ER, and ORM2 into a single metamodel with guidelines for model management and connections to formalization and logic-based automated reasoning and executed in crowd 2.0.			✓								✓	- Visual models or Controlled Natural Language (CNL) specifications from other tools demand conformity to specific data structures of those tools for each of them independently for enhancing interoperability but there is no standard for serializing them.

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