Complementary Material
Paper “Systems Interoperability Types: A Tertiary Study”

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This document provides additional information about the tertiary study that we conducted.

1. Tertiary Studies

Table 1 presents the list of 51 tertiary studies found in our research. The list of tertiary studies references can be found at the end of this document.

2. Quality Assessment

Table 2 presents the score of quality assessment of secondary studies considered in our tertiary study.

3. Summary of Secondary Studies

Table 3 presents the summary of the 37 secondary studies considered in our tertiary study.

4. Definition of Interoperability Types

Table 4 presents the definitions of the 36 interoperability types found in the 37 secondary studies.

5. Solutions for Interoperability

Table 5 presents the interoperability solutions found in the secondary studies.

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Table 1
List of Tertiary Studies

ID	Title	Year	Reference
1	Systematic literature reviews in software engineering-A tertiary	2010	[1]
2	Signs of Agile Trends in Global Software Engineering Research: A Tertiary Study	2011	[2]
3	Research synthesis in software engineering: A tertiary study	2011	[3]
4	Six years of systematic literature reviews in software engineering: An updated tertiary study	2011	[4]
5	Systematic literature reviews in distributed software development: A tertiary study	2012	[5]
6	A systematic tertiary study of communication in distributed software development projects	2012	[6]
7	Systematic reviews in software engineering: An empirical investigation	2013	[7]
8	A Tertiary Study: Experiences of Conducting Systematic Literature Reviews in Software Engineering	2013	[8]
9	Risks and risk mitigation in global software development: A tertiary study	2014	[9]
10	Systematic reviews in requirements engineering: A systematic review	2014	[10]
11	Quality Assessment of Systematic Reviews in Software Engineering: A Tertiary Study	2015	[11]
12	A systematic literature review of literature reviews in software testing	2016	[12]
13	A survey of secondary studies in software process improvement	2016	[13]
14	The impacts of agile and lean practices on project constraints: A tertiary study	2016	[14]
15	Quality in model-driven engineering: a tertiary study	2016	[15]
16	A map of threats to validity of systematic literature reviews in software engineering	2016	[16]
17	Quality in Model-Driven Engineering: A Tertiary Study	2016	[17]
18	Systematic Studies in Software Product Lines: A Tertiary Study	2017	[18]
19	Systematic literature reviews in agile software development: A tertiary study	2017	[19]
20	Consolidating evidence based studies in software cost/effort estimation - A tertiary study	2017	[20]
21	A tertiary study on technical debt: Types, management strategies, research trends, and base information for practitioners	2018	[21]
22	AAL Platforms challenges in IoT era: A tertiary study	2018	[22]
23	Reporting systematic reviews: Some lessons from a tertiary study	2018	[23]
24	The contribution that empirical studies performed in industry make to the findings of systematic reviews: A tertiary study	2018	[24]
25	Software product lines and variability modeling: A tertiary study	2019	[25]
26	Landscaping systematic mapping studies in software engineering: A tertiary study	2019	[26]
27	Identifying, categorizing and mitigating threats to validity in software engineering secondary studies	2019	[27]
28	Multivocal literature reviews in software engineering: Preliminary findings from a tertiary study	2019	[28]
29	Usability in Agile Software Development: A Tertiary Study	2019	[29]
30	Trends in software reuse research: A tertiary study	2019	[30]
31	On the need to update systematic literature reviews	2019	[31]
32	The Use of Grey Literature and Google Scholar in Software Engineering Systematic Literature Reviews	2020	[32]
33	Operations Management for Social Good	2020	[33]
34	Architecting Systems of Systems: A Tertiary Study	2020	[34]
35	Blockchain-based Solutions for IoT: A Tertiary Study	2020	[35]
36	Systematic literature reviews in software engineering—enhancement of the study selection process using Cohen's Kappa	2020	[36]
37	Bibliometric Analysis of the Tertiary Study on Agile Software Development using Social Network Analysis	2020	[37]
38	Google Scholar vs. Dblp vs. Microsoft Academic Search: An Indexing Comparison for Software Engineering Literature	2020	[38]
39	A Research Landscape of Software Engineering Education	2021	[39]
40	Tertiary Study on Landscaping the Review in Code Smells	2021	[40]
41	A Systematic Study as Foundation for a Variability Modeling Body of Knowledge	2021	[41]
42	Assessing test artifact quality—A tertiary study	2021	[42]
43	Inclusion and Exclusion Criteria in Software Engineering Tertiary Studies: A Systematic Mapping and Emerging Framework	2021	[43]
44	Human Factors and Their Influence on Software Development Teams - A Tertiary Study	2021	[44]
45	Quality Assessment in Systematic Literature Reviews: A Software Engineering Perspective	2021	[45]
46	Grey Literature in Software Engineering: A critical review	2021	[46]
47	Interoperability Types Classifications: A Tertiary Study	2021	[47]
48	Blockchain and Sustainability: A Tertiary Study	2021	[48]
49	Systematic Reviews in Sentiment Analysis: A Tertiary Study	2021	[49]
50	The Integrated List of Agile Practices - A Tertiary Study	2022	[50]
51	Machine Learning for Software Engineering: A Tertiary Study	2022	[51]

Table 2
Quality Assessment of Secondary Studies

ID	QA1	QA2	Q03	Q04	Total
S1	0	0	0	0,5	0,5
S2	0	0	0	0,5	0,5
S3	0	0	0	0,5	0,5
S4	0	0	0	0,5	0,5
S5	0	0,5	0	0,5	1
S6	0	0,5	0	0,5	1
S7	1	0,5	0	0,5	2
S8	1	1	0	0,5	2,5
S9	1	1	0	0,5	2,5
S10	1	1	0,5	1	3,5
S11	0	0	0	1	1
S12	0,5	0	0	0,5	1
S13	0,5	1	0	1	2,5
S14	1	1	0,5	1	3,5
S15	0	0	0	0,5	0,5
S16	0	0	0	0,5	0,5
S17	0	0,5	0,5	0,5	1,5
S18	0	0	0	0,5	0,5
S19	0	0,5	0	1	1,5
S20	1	1	0	0,5	2,5
S21	0,5	0	0	1	1,5
S22	1	1	0	1	3
S23	0	0	0	0,5	0,5
S24	1	1	1	0,5	3,5
S25	1	1	1	1	4
S26	0,5	1	1	0,5	3
S27	1	0	0	0,5	1,5
S28	1	1	1	0,5	3,5
S29	1	1	1	1	4
S30	0	0	0	0,5	0,5
S31	1	1	1	1	4
S32	0	0	0	0,5	0,5
S33	0	0	0	0,5	0,5
S34	0	1	0	0,5	1,5
S35	0	0	0,5	0,5	1
S36	1	1	0	0,5	2,5
S37	0	0	0	0,5	0,5

Table 3
Summary of Secondary Studies

ID	Description of Studies
S1	An LR of research works was developed to define and solve interoperability problems in product development link the different Product Lifecycle Management tools.
S2	An LR of a set of concepts covering the Enterprise Architecture (EA) and interoperability domains. The authors identify key aspects of interoperability and EA and their associations, resulting in a reference conceptual model for integrated Enterprise Architecture Interoperability.
S3	An LR of what interoperability entails in the healthcare domain and the special role of standardization in the achievement
S4	An LR on existing interoperability frameworks for e-business and a comparative analysis among their findings to determine the similarities and differences in their philosophy and implementation.
S5	An LR on data models suggested for the public sector in light of four features: standard modeling language, entity relationship modeling, vocabulary for data exchange, and methodology.
S6	An SLR for describing the existing interoperability evaluation models. In addition, it performs a comparative analysis of their findings to determine the similarities and differences in their philosophy and implementation.
S7	An SLR to provide a holistic view of new ways of applying semantic technologies in cloud computing and to analyze the proposed solutions. It is sought through semantics to achieve interoperability and portability between different cloud providers.
S8	An SLR to present an overview of the literature about interoperability assessment methods.
S9	An SLR to examine and explore the role of Semantic Web Technologies in the cloud from a wide variety of literatures.
S10	An LRS and SMS to identify, analyze and classify the published solutions to achieve pragmatic interoperability.
S11	An LR to analyze and categorize various solutions suggested in literature for solving the interoperability and portability issues of inter-connected clouds.
S12	An qSLR to collect interoperability characteristics regarding context-awareness software systems.
S13	An SLR to identify the main research and the milestones reference works in the semantic interoperability field.
S14	An SLR to identify concepts valuable to transfer from the interoperability to the tool integration research field.
S15	An LR to develop a definition of interoperability governance from the published literature and to investigate interoperability governance patterns at European Member State levels.
S16	An LR to identify automation approaches that address semantic interoperability, in dynamic cyber-physical systems at a large scale.
S17	An qSLR to discuss how interoperability has been addressed in context-aware software systems, strengthening the scientific basis for its understanding and conceptualization.
S18	An LR to identify the current Industry 4.0 technologies and current interoperability standards was be undertake.
S19	An SLR was performed considering sustainability factors, interoperability concerns, and lifecycle stages.
S20	An LR reviewed the e-government interoperability frameworks (e-GIFs) of English and Arabic-speaking African countries to identify the evidence and conflict approaches to semantic interoperability.
S21	An SLR to identify the relevant Interoperability Assessment (INAS) approaches performing a comparison based on their similar and different properties (type of assessment, used measurement mechanism, and addressed interoperability barriers).
S22	An SMS to identify the state-of-the-art of interoperability in the IoT context.
S23	An SLR to examine the progress that is being in order to establish interoperability across a diverse set of systems and also to identify the challenges in establishing this level of interoperability.
S24	An SLR An SLR to answer various research questions regarding the methodical composition of system components and services in semantic interoperability for smart service systems context.
S25	An SLR to identify the most relevant elements to consider in the development of an ontology-based solution and how these solutions are being deployed in the industry.
S26	An SLR to conduct on the current state-of-the-art semantic IoT solutions used in the health domain, identify the associated challenges, and propose a federated edge-cloud semantic IoT architecture to facilitate healthcare and public health (HC-PH) collaborations.
S27	An RL to define level-specific interoperability guidelines, business processes, and requirements for the Transnational Health Record system framework.
S28	An SLR is presented to investigate where interoperability of application layer protocols is performed for IIoT.
S29	An SLR to explore the literature related to Fast Health Interoperability Resources (FHIR), including the challenges, implementation, opportunities, and future FHIR applications.
S30	An LR on blockchain interoperability, analyzing 102 studies, to classify studies into three categories: Public Connectors, Blockchain of Blockchains, and Hybrid Connectors. Each category is further divided into sub-categories based on defined criteria.
S31	An SLR on semantic interoperability in electronic health records, showing the most chosen scenarios, technologies, and tools employed to solve interoperability problems.
S32	An SLR to identify the most challenging trend in the healthcare system using blockchain interoperability.
S33	An LR to show blockchain interoperability, with a special highlight on blockchain Oracles being state-of-the-art.
S34	A MLR to provide state-of-the-art related to security and privacy challenges in blockchain interoperability.
S35	An SLR to investigate the interoperability requirements for heterogeneous health information systems.
S36	An SLR to explore architectural mechanisms used to support the interoperability and security of Blockchain-based Health Management Systems.
S37	An LR to investigate sufficient in-the-wild projects that claim to achieve blockchain interoperability.

Table 4: Definitions of Interoperability Types

Interoperability type	Definition
Blockchain	is a composition of distinguishable blockchain systems, each representing a unique distributed data ledger, where atomic transaction execution may span multiple heterogeneous blockchain systems, and where data recorded in one blockchain are reachable, verifiable, and referable by another possibly foreign transaction in a semantically compatible manner [S32 e S33]. It is as the ability to easily share, see, transact, and access information across different blockchain networks without any centralized authority [S34]
Business	It works harmonized to share and develop business between companies despite the difference in methods, decision making, and the culture of enterprises [S2]. It involves working harmoniously at the company and organizational levels despite different modes of decision making, work practices, culture,legislations, commercial approaches, and so on [S4]. It is related to the strategic and organizational levels. This correlates to BIM (Building Information Modelling) because the use of BIM is usually a strategic action in the company. Stakeholders need to be involved in the adoption process [S19].
Business Process	It is associated with the functional aspects, such as workflow, that must be defined to share healthcare data between different countries effectively. It contributes to solving the current challenging issue—the lack of organizational interoperability [S27].
Cloud	It defines the ability of cloud services to be able to work together with both different cloud services and providers, and other applications or platforms that are not cloud-dependent [S4], [S6].
Coalition	It is definitely not limited to the technical domain but also depends on organizational. Coalition should deals with political, aligned procedures, and operations, and harmonized strategies [S21].
Conceptual	At this level, the systems are completely aware of each other's information, processes, contexts, and modeling assumptions [S17]. When the assumptions and restrictions of a meaningful abstraction of realityare aligned, conceptual interoperability is achieved [S35].
Constructive	It is the ability of organizations responsible for constructing or maintaining a system to cooperate [S14]. It addresses those activities related to the construction and maintenance of one system in the context of another system [S21].
Cultural	It is the degree to which knowledge and information are anchored to a unified model of meaning across cultures. Enterprise systems that take into consideration cultural interoperability aspects can be used by transnational groups in different languages and cultures with the same domain of interest in a cost-effective and efficient manner [S4] [S6].
Data	It works with different data models and query languages to share information from heterogeneous systems [S2]. It relates to making different query languages and data models work together [S4]. It describes the ability of data (including documents, multimedia content and digital resources) to be universally accessible, reusable and comprehensible by all transaction parties (in a human-to-machine and machine-tomachine basis), by addressing the lack of common understanding caused by the use of different representations, different purposes, different contexts, and different syntax-dependent approaches [S6]. It is defined as the ability of data (including documents, multimedia content, and digital resources) to be universally accessible, reusable, and comprehensible by all transaction parties (in a human-to-machine and machine-to-machine basis) by addressing the lack of common understanding caused by the use of different representations, different purposes, different contexts, and different syntax-dependent approaches [S14, S16]. It refers to make different data models and query languages working together [S19]. It is related to data acquisition among several different devices and shared among application layers [S28].
Device	It refers to enabling the integration and interoperability of such heterogeneous devices with various communication protocols and standards supported by heterogeneous IoT services [24]. It provides information exchange between physical and software components of the smart devices including communication protocols; where the heterogeneity of application layer protocols is a primary concern [S28].
Ecosystems	It is the ability of instant and seamless collaboration between different ecosystems and independent entities, entities within the ecosystems, and the ability of different independent entities to formulate virtual structures for specific purposes [S4], [S6].
Electronic Identity	It refers to the ability of different electronic identity systems within or across the boundaries of an enterprise to collaborate in order to automatically authenticate and authorize entities and to pass on security roles and permissions to the corresponding electronic identity holders, regardless of the system that they originate from [S4], [S6].

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Interoperability type	**Understanding**
Dynamic	Two or more systems are considered to have achieved dynamic interoperability when they can understand and take advantage of state changes in the assumptions and limitations they are making over time [S35].
Enterprise	It requires consideration of the enterprise from a general perspective, taking into account not only its different components and their interactions but also the environment in which it evolves and the interface through which it communicates with its environment [S2]. It is concerned with interoperability between organizational units or business processes, either within a large distributed enterprise or within a network of enterprises [S14, S16].
Functional	It is the capability to reliably exchange information without error [S14]. Refers to the requirement for functional requirements to be delivered in a consistent, established manner [35].
Hardware	It involves the integration of different computers, computer networks, etc. At this level network protocols are used so that two or more networks can communicate [S23].
Information	It is the ability of processes and systems to effectively exchange and use information services [S14, S16].
Knowledge	It is the ability of two or more different entities to share their intellectual assets, take immediate advantage of the mutual knowledge and utilize it, and to further extend them through cooperation [S4], [S6].
Legal	It is about ensuring that organizations operating under different legal frameworks, policies and strategies are able to work together [S5]. It encompasses legislation issues involving the alignment of higher enterprise functions or government policies, usually to be expressed in the form of legal elements and business rules [S21]. refers to the ensures that organizations operating under different legal frameworks, policies, and strategies are able to work together (S30).
Network	It concerns with required to deal with seamless communication of devices over different networks [S28].
Objects	It refers to the networked interconnection and cooperation of everyday objects. These objects can embrace aspects besides and beyond software components, consistent with the concept of the Internet of Things [S4], [S6].
Operational	It is the relation between/among actors cooperating to achieve a common goal, an overall, mutual capability necessary to ensure successful and efficient cooperation [S14]. It is related to the process indicators related to cost, time, and process failure reduction [S21].
Organizational	It concerns the business unit, process and people interactions across organization borders [S1] It facilitates the integration of business processes and workflows beyond the boundaries of a single organization [S3]. It pertains to the capability of organizations to effectively communicate and transfer meaningful data (information) despite the use of a variety of information systems over significantly different types of infrastructure, possibly across various geographic regions and cultures [S4], [S6]. It refers to the way in which public administrations align their business processes, responsibilities, and expectations to achieve commonly agreed and mutually beneficial goals [S5]. It requests formal agreements on the conditions applicable to cross-organizational interactions [S15]. It is concerned with business rules, policies and constraints, process alignment, and the actions necessary to make the entities collaborate [S17]. It creates cohesion amongst approaches to governance, finance, legislation, and business processes [S19]. It is concerned with defining business goals, modeling business processes and collaboration of administrations that wish to exchange information and may have different internal structures and processes [S20]. It involves the identification of the inter-actors and organizational procedures [S25]. It includes legal, political, or even cultural aspects of the institutions that participate in data sharing [S27]. It is the working relationship between political, legal, and social entities to exchange information and achieve common interests [32].
Platform	It concerns the offers collaboration of the diverse platforms used in IoT due to diverse operating systems, programming languages, and access [S23]. It enables interoperability across separate IoT platforms specific to one vertical domain such as smart home, smart healthcare, smart garden, etc. [S24]. It offers a collaboration of the diverse platforms used in IoT due to diverse operating systems, programming languages, and access mechanisms for data and things [S28].

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Interoperability type	Understanding
Pragmatic	It is when the sender and the receiver of the message share the same expectations about the effect of the messages exchanged, and the context in which this exchange takes place plays an important role [S10]. When interoperating systems are aware of one other's processes and procedures; this level of interoperability is attained. This means that the participating systems comprehend the data's use or the context in which it is used [S35].
Process	It makes various processes work together. In the networked enterprise, the aim will be to connect the internal processes of two companies to create a common process [S2, S19]. It intends to make various processes work together. A process refers to the sequence of functions or services depending on company needs [S4]. It is defined as the ability to align processes of different entities (enterprises), in order for them to exchange data and to conduct business in a seamless way [S6]. It is the ability of diverse business processes to work together, to interoperate [S14].
Programmatic	It is concerned with ensuring that the message sender and receiver share the same expectations about the effect of the exchanged messages and the context where this exchange occurs plays an important role [S8]. It is the ability of a set of communicating entities engaged in acquisition management activities to exchange specified acquisition management information and operate on that acquisition management information according to specified, agreed-upon operational semantic [S14].
Rules	The ability of entities to align and match their business and legal rules for conducting legitimate automated transactions that are also compatible with the internal business operation rules of each other [S4], [S6].

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Interoperability type	Understanding
Semantic	It ensures the sharing of information and service for preserving the semantic flow [S1]. It enables multiple systems to interpret the information that has been exchanged in a similar way through pre-defined shared meaning of concepts [S3]. It is defined as the ability to operate on that data according to agreed-upon semantics [S4]. It is pursued by the meaning of data elements and the relationships between them [S5]. It is normally related to the definition of content, and deals with the human rather than machine interpretation of this content [S6]. It expresses and understands the same information [S9, S11]. It is concerned with ensuring that the meaning of the data, in other words, which the data refers to, is shared unambiguously way [S10]. It is achievable when the captured information and knowledge can be effectively exchanged in a collaborative environment without any information and knowledge meaning and intent loss during this process [S13]. It ensures the use of common descriptions of exchanged data [S15]. It is the ability of systems to exchange information with unambiguous meaning [S16]. It concerns the interpretation and mutual understanding between the interacting entities [S17]. It is when systems exchange information with unequivocal meaning, ensuring that data meaning is shared unequivocally [S18]. It enables collaborating systems to exchange and use the information using the correct meaning and provides the means and tools for automatic integration and processing of information without the intervention of humans [S20]. It is refers to the ability of two or more computational systems to exchange information through a shared meaning that can be interpreted automatically and correctly [S22]. It encompasses the intended meaning of the concepts in the data schema [S23]. It is the ability to communicate entities to infer the correct "meaning" of messages [S24]. It enables a seamless integration of different data sources and leverages risk identification. Related to the business-level understanding between different actors [S25]. It is related to the common understanding of the meaning of certain data; a vocabulary (i.e., ontology) of the terms used in that specific context has to be shared first [26]. It is about making sure that the shared information has the same meanings between different institutions or countries [27]. It is linked with the meaning of the content for humans rather than machine interpretation of the content [S28]. It is the ability, of health information systems, to exchange information and automatically interpret the information exchanged meaningfully and accurately in order to produce useful results as defined by the end users of both systems [S29]. It aims to share data among organizations or systems and ensure they understand and interpret data regardless of who is involved, using domain concepts, context knowledge, and formal data representation [S31]. It represents the tools and models utilized in designing interoperable platforms [S32]. Refers to the ability of two or more systems to automatically comprehend meaningful and correct information transferred in order to deliver useful results as defined by the systems' end users [[3].
Service	It makes it possible for various services or applications (designed and implemented independently) to work together by solving the syntactic and semantic differences [S2]. It refers to identifying, composing, and making various applications that are implemented and designed independently function together [S4]. It is a concern of a company to dynamically register, aggregate and consume services composed from an external source. It corresponds to resource sharing in the design of new cloud-based data services as external sources. Also, this type of interoperability present the exchange of information between geographically distributed multidisciplinary teams [S19].
Social Networks	It refers to the ability of enterprises to seamlessly interconnect and utilize social networks for collaboration purposes, by aligning their internal structure to the fundamental aspects of the social networks [S4], [S6].
Software Systems	It refers to the ability of an enterprise system or a product to work with other enterprise systems or products without special effort from the stakeholders [S4], [S6].

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Interoperability type	Understanding
Syntactic	It guarantees the preservation of the clinical purpose of the data during transmission among healthcare systems [S3]. It is defined as the ability to exchange data. Syntactic interoperability is generally associated with data formats. The messages transferred by communication protocols should possess a well-defined syntax and encoding, even if only in the form of bit-tables [S4], [S6]. It is related to the data that are exchanged act as a sign and, to achieve this interoperability level, the sign syntax must be previously established as a standard [S10]. It is concerned with communication, data exchange, and syntax consistency [S17]. It concerns the information format to be exchanged [S21] It refers to interoperation of the format as well as the data structure used in any exchanged information or service between heterogeneous IoT system entities [S24]. It deals with the format of messages exchanged between systems [26]. It should include a data validation process related to the format, syntax, grammar, or schema [S27]. It includes the platform, designing, or developing compatible interfaces according to the concerned field and specific guidelines. Different applications cooperate to exchange and share data utilizing interoperable functions [32]. Is the capacity of two or more systems to share data and services using a common interoperability protocol like the High Level Architecture [S35].
System	It is the ability of systems to operate together, with systems defined in line with the generic combination of interacting elements organized to achieve one or more stated purposes [S14, S16].
Technical	It ensures the continuity of the semantic flow (e.g. technology solutions, standards and tools for the exchange of data between IS) [S1]. It enables heterogeneous systems to exchange data, but it does not guarantee that the receiving system with be able to use the exchanged data in a meaningful way [S3]. It is achieved among communications electronics systems or items of communications electronics equipment when services or information could be exchanged directly and satisfactorily between them and their users [S4]. It covers the applications and infrastructures linking systems and services. Aspects of technical interoperability include interface specifications, interconnection services, data integration services, data presentation and exchange, and secure communication protocols [S5]. It is achieved among communication selectronics systems or items of communications-electronics equipment when services or information could be exchanged directly and satisfactorily between them and their users [S6]. It is the ability of systems to provide dynamic interactive information and data exchange among systems [S12]. It is the ability achieved by communication and electronic systems when information or services can be exchanged directly and satisfactorily between them and/or their use [S14, 16]. It is related to setting up the necessary information systems environment to allow an uninterrupted flow of bits and bytes [S15]. It concerns with the connectivity, communication, and operation regarding the interacting entities, and middleware elements regarding authentication and authorization, the use of technical standards, protocols for communication and transport, and interfaces between components [S17]. It is concerned with the technical issues of linking up computer systems for sharing information [S20] It covers the applications and infrastructures linking systems and services. It includes interface specifications, interconnection and data integration services, data presentation and exchanging, and secure communication protocols [S21]. It is related to the standardization of hardware and software interfaces [S25]. In the health context, this interoperability is achieved by directing exchanged information to the smart e-Health gateway, which has multiple interfaces [26]. It ensures information exchange requirements between different systems [S27]. At this level of interoperability, data is exchanged across systems using a communication protocol [S35].

Table 5
Solutions for Interoperability Reported by Secondary Studies

ID	Solutions for Interoperability	Category
S1	Technology Solutions, Mediator Architecture	Platforms (Tools,Tecnologies, Services)
S2	Enterprise Interoperability (EI)	Framework for problems and solutions
S3	SNOMED-CT, HL7, Frameworks, Architectures, Models	Framework (architecture and model) and Standards
S4	E-business Interoperability Framework	Framework as primary goal
S5	Generic data models, European Interoperability Framework (EIF), Ontologies	Conceptual Model, Framework, Ontology
S6	Interoperability Evaluation Models	Asssement Models (maturity models)
S7	Clinical Information Models (CIMs), Semantic Interoperability of Eletronic Health Record (EHR) Systems	Domain-specific model, framework, and standard
S8	LISI, OIM, LCIM, SoSI	Models
S9	Technologies for Web, Ontologies, OWL, SPARQL, RDF/RDFS, BP to denote BPaaS, Protege, Hermit, REST services	Domain-specific models, platform (tool and technology), Ontology, and Standard
S10	Service Discovery, Ontologies, Software Agentes, Pragmatic Web Services, Pragmatic grid, Meta Model	Meta model, platform (tool and service), Ontology
S11	Open Standards, APIs, MDE, Open Library, Open Service	Ontology, platform (tool and service), and Standard
S12	No Solution	No solution
S13	Algoritms, Ontologies, Design Structure Matrix (DSM), Domain Mapping Matrix (DMM), Framework, MDE, SNM, Semantic Annotation	Domain-specific model, framework, meta model, and ontology
S14	LCIM, LISI, NTI, OIM, SoSI	Conceptual Model
S15	EIF, EIRA, Model Template	Frameworks (from Organization)
S16	OSF, SWoT4CPS, Ontologies, SIMB-IoT, APIs,	Domain-specific model, framework, ontology, and reference architecture
S17	Interoperability Theoretical Framework	Framework
S18	IIRA, Core Ontologies, Standards, OSF, SWoT for CPS, STO	Domain-specific model, framework, ontology, and standard
S19	BIM	Domains Specific Models
S20	e-GIF, EIA, eGMS, Dublin's Core Metadata (DC), XML Schemas	Frameworks, Standars and Domain Specific Models
S21	Maturity Models	Assesment Moldes
S22	Web Technologies, Ontologies	Ontology and platform (API, gateway, and service)
S23	Ontologies	Ontology
S24	OWL, OWL-S, RDF, SPARQL, REST. Formal Standards, Ontologies	Ontology, platform (API and service), and standard
S25	Ontologies and Tools	Ontology and platform (API, middleware and service)
S26	IoT Architecture, Smart Semantic Gateway, Ontologies	Ontology and Platforms (Gateway and Architecture)
S27	EHR	Framework
S28	Gateway, AMQP, CoAP, XMPP, REST, API, Middleware, Atlas, Kryo, REST, Netty, Eclipse, Mosquitto, Copper, Vivado, SPIN	Framework, platform (gateway, tool, middleware, and API), protocols, reference architecture, and standard
S29	FHIR, Standards	Standard
S30	Blochain Interoperability Framework	Framework
S31	Models, Ontologies, Taxonomy, RDF, OWL, SPARQL, SKOS, HL	Ontology, platform (semantic web technologies), and standards
S32	Electronic Health Records (EHR)	Standards
S33	Cryptocurrency-Directed, Blockchain Engines, Bockchain Connectors, Cross, Authentication Approach, API, Gateway and Oracles	Plataforms (Gateway), Oracles, Cyptocurrency-Directed, Blockchain Engines and Connectors
S34	HTCL and Interledger Protocol (ILP)	Protocols
S35	HL7 FHIR, CDA, HIPAA and SNOMED-CT, SOA, RIM, XML, API, JAVA and SQL	Standards and Technologies
S36	Frameworks, Gateways, Proxies, API, DSL's and MDE	Frameworks, Platforms (Gateways and API), Proxies
S37	Sidechain, Notary Scheme, Hash-locking, Trusted-Relay, Blockchain Engine, Blockchain of Blockchains, Blockchain Adaptor, Blockchain Agnostic Protocol	Technologies and Protocols

References

[1] Barbara Kitchenham, Rialette Pretorius, David Budgen, O Pearl Brereton, Mark Turner, Mahmood Niazi, and Stephen Linkman. Systematic literature reviews in software engineering-a tertiary study. *Information and Software Technology*, 52:792–805, 2010.

[2] Geir K Hanssen, Darja Šmite, and Nils Brede Moe. Signs of agile trends in global software engineering research: A tertiary study. pages 17–23. IEEE Computer Society, 2011.

[3] Daniela S Cruzes and Tore Dyb. Research synthesis in software engineering: A tertiary study. *Information and Software Technology*, 53:440–455, 2011.

[4] Fabio Q B Da Silva, André L M Santos, Sérgio Soares, A César C Frana, Cleviton V F Monteiro, and Felipe Farias MacIel. Six years of systematic literature reviews in software engineering: An updated tertiary study. *Information and Software Technology*, 53:899–913, 2011.

[5] Anna Beatriz Marques, Rosiane Rodrigues, and Tayana Conte. Systematic literature reviews in distributed software development: A tertiary study. *Proceedings - 2012 IEEE 7th International Conference on Global Software Engineering, ICGSE 2012*, pages 134–143, 2012.

[6] Alinne C C Dos Santos, Ivaldir H De Farias, Hermano P De Moura, and Sabrina Marczak. A systematic tertiary study of communication in distributed software development projects. *Proceedings - 2012 IEEE 7th International Conference on Global Software Engineering, ICGSE 2012*, 29:182, 2012.

[7] He Zhang and Muhammad Ali Babar. Systematic reviews in software engineering: An empirical investigation. *Information and Software Technology*, 55:1341–1354, 2013.

[8] Salma Imtiaz, Muneera Bano, Naveed Ikram, and Mahmood Niazi. A tertiary study: Experiences of conducting systematic literature reviews in software engineering. pages 177–182. Association for Computing Machinery, 2013.

[9] J M Verner, O P Brereton, B A Kitchenham, M Turner, and M Niazi. Risks and risk mitigation in global software development: A tertiary study. *Information and Software Technology*, 56:54–78, 2014.

[10] Muhammad Imran Babar, Masitah Ghazali, and Dayang N A Jawawi. Systematic reviews in requirements engineering: A systematic review. *2014 8th Malaysian Software Engineering Conference, MySEC 2014*, pages 43–48, 2014.

[11] You Zhou, He Zhang, Xin Huang, Song Yang, Muhammad Ali Babar, and Hao Tang. Quality assessment of systematic reviews in software engineering: A tertiary study. Association for Computing Machinery, 2015.

[12] Vahid Garousi and Mika V Mäntylä. A systematic literature review of literature reviews in software testing. *Information and Software Technology*, 80:195–216, 2016.

[13] Ali Idri and Laila Cheikhi. A survey of secondary studies in software process improvement. *Proceedings of IEEE/ACS International Conference on Computer Systems and Applications, AICCSA*, 0, 2016.

[14] Indira Nurdiani, Jürgen Börstler, and Samuel A Fricker. The impacts of agile and lean practices on project constraints: A tertiary study. *Journal of Systems and Software*, 119:162–183, 2016.

[15] Miguel Goulão, Vasco Amaral, and Marjan Mernik. Quality in model-driven engineering: a tertiary study. *Software Quality Journal*, 24:601–633, 2016.

[16] Xin Zhou, Yuqin Jin, He Zhang, Shanshan Li, and Xin Huang. A map of threats to validity of systematic literature reviews in software engineering. *Proceedings - Asia-Pacific Software Engineering Conference, APSEC*, 0:153–160, 2016.

[17] Apostolos Ampatzoglou, Stamatia Bibi, Paris Avgeriou, Marijn Verbeek, Alexander Chatzigeorgiou, Egemen Bayram, Buket Dogan, Volkan Tunali, David Budgen, Pearl Brereton, Sarah Drummond, Nikki Williams, Sarah Drummond, Daniela S Cruzes, Tore Dyb, Eliezer Dutra, Bruna Diirr, Gleison Santos, Vahid Garousi, Mika V Mäntylä, Miguel Goulão, Vasco Amaral, Marjan Mernik, Rashina Hoda, Norsaremah Salleh, John Grundy, Hui Mien Tee, Anna Beatriz Marques, Rosiane Rodrigues, Tayana Conte, Indira Nurdiani, Jürgen Börstler, Samuel A Fricker, Jorge Pérez, Jessica Díaz, Javier Garcia-Martin, Bernardo Tabuenca, Sreekumar P Pillai, S D Madhukumar, T Radharamanan, Mikko Raatikainen, Juha Tiihonen, Tomi Männistö, He Zhang, Muhammad Ali Babar, Xin Zhou, Yuqin Jin, He Zhang, Shanshan Li, and Xin Huang. Quality in model-driven engineering: A tertiary study. *Information and Software Technology*, 24:442–451, 9 2016.

[18] C Marimuthu and K Chandrasekaran. Systematic studies in software product lines: A tertiary study. pages 143–152. Association for Computing Machinery, 2017.

[19] Rashina Hoda, Norsaremah Salleh, John Grundy, and Hui Mien Tee. Systematic literature reviews in agile software development: A tertiary study. *Information and Software Technology*, 85:60–70, 2017.

[20] Sreekumar P Pillai, S D Madhukumar, and T Radharamanan. Consolidating evidence based studies in software cost/effort estimation - a tertiary study. *IEEE Region 10 Annual International Conference, Proceedings/TENCON*, 2017-Decem:833–838, 2017.

[21] Nicolli Rios, Manoel Gomes de Mendonça Neto, and Rodrigo Oliveira Spínola. A tertiary study on technical debt: Types, management strategies, research trends, and base information for practitioners. *Information and Software Technology*, 102:117–145, 2018.

[22] Paulo A S Duarte, Felipe M Barreto, Paulo A C Aguilar, Jerome Boudy, Rossana M C Andrade, and Windson Viana. Aal platforms challenges in iot era: A tertiary study. *2018 13th System of Systems Engineering Conference, SoSE 2018*, pages 106–113, 2018.

[23] David Budgen, Pearl Brereton, Sarah Drummond, and Nikki Williams. Reporting systematic reviews: Some lessons from a tertiary study. *Information and Software Technology*, 95:62–74, 2018.

[24] David Budgen, Pearl Brereton, Nikki Williams, and Sarah Drummond. The contribution that empirical studies performed in industry make to the findings of systematic reviews: A tertiary study. *Information and Software Technology*, 94:234–244, 2018.

[25] Mikko Raatikainen, Juha Tiihonen, and Tomi Männistö. Software product lines and variability modeling: A tertiary study. *Journal of Systems and Software*, 149:485–510, 2019.

[26] Muhammad Uzair Khan, Salman Sherin, Muhammad Zohaib Iqbal, and Rubab Zahid. Landscaping systematic mapping studies in software engineering: A tertiary study. *Journal of Systems and Software*, 149:396–436, 2019.

[27] Apostolos Ampatzoglou, Stamatia Bibi, Paris Avgeriou, Marijn Verbeek, and Alexander Chatzigeorgiou. Identifying, categorizing and mitigating threats to validity in software engineering secondary studies. *Information and Software Technology*, 106:201–230, 2019.

[28] Geraldo Torres G Neto, Wylliams B Santos, Patricia Takako Endo, and A A Roberta Fagundes. Multivocal literature reviews in software engineering: Preliminary findings from a tertiary study. *International Symposium on Empirical Software Engineering and Measurement*, 2019-Septe, 2019.

[29] Karina Curcio, Rodolfo Santana, Sheila Reinehr, and Andreia Malucelli. Usability in agile software development: A tertiary study. *Comput. Stand. Interfaces*, 64:61–77, 5 2019.

[30] José L Barros-Justo, Fabiane B V Benitti, and Santiago Matalonga. Trends in software reuse research: A tertiary study. *Computer Standards and Interfaces*, 66:103352, 2019.

[31] Vilmar Nepomuceno and Sergio Soares. On the need to update systematic literature reviews. *Information and Software Technology*, 109:40–42, 2019.

[32] Rubia Fatima, Affan Yasin, Lin Liu, and Jianmin Wang. The use of grey literature and google scholar in software engineering systematic literature reviews. *Proceedings - 2020 IEEE 44th Annual Computers, Software, and Applications Conference, COMPSAC 2020*, 8:1099–1100, 2020.

[33] Rodrigo Caiado and Tecgraf Puc-rio. Operations management for social good. 2020.

[34] Héctor Cadavid, Vasilios Andrikopoulos, and Paris Avgeriou. Architecting systems of systems: A tertiary study. *Inf. Softw. Technol.*, 118, 2 2020.

[35] Qianwen Xu, Xiudi Chen, Shanshan Li, He Zhang, Muhammad Ali Babar, and Nguyen Khoi Tran. Blockchain-based solutions for iot: A tertiary study. *Proceedings - Companion of the 2020 IEEE 20th International Conference on Software Quality, Reliability, and Security, QRS-C 2020*, pages 124–131, 2020.

[36] Jorge Pérez, Jessica Díaz, Javier Garcia-Martin, and Bernardo Tabuenca. Systematic literature reviews in software engineering—enhancement of the study selection process using cohen's kappa statistic. *Journal of Systems and Software*, 168:110657, 2020.

[37] Egemen Bayram, Buket Dogan, and Volkan Tunali. Bibliometric analysis of the tertiary study on agile software development using social network analysis. *Proceedings - 2020 Innovations in Intelligent Systems and Applications Conference, ASYU 2020*, pages 2020–2023, 2020.

[38] Rubia Fatima, Affan Yasin, Lin Liu, and Jianmin Wang. Google scholar vs. dblp vs. microsoft academic search: An indexing comparison for software engineering literature. *Proceedings - 2020 IEEE 44th Annual Computers, Software, and Applications Conference, COMPSAC 2020*, pages 1097–1098, 2020. Considerei um tertiatio pois pega varios secundaruioa de 18 tertiarios.

[39] Xin Huang, He Zhang, Xin Zhou, Dong Shao, and Letizia Jaccheri. A research landscape of software engineering education. *Proceedings - Asia-Pacific Software Engineering Conference, APSEC*, 2021-Decem:181–191, 2021.

[40] Rida Yaqoob, Sanaa, Saif U R Khan, and Munam Ali Shah. Tertiary study on landscaping the review in code smells. *IET Conference Publications*, 2021:1–6, 2021.

[41] Kevin Feichtinger, Kristof Meixner, Rick Rabiser, and Stefan Biffl. A systematic study as foundation for a variability modeling body of knowledge. *Proceedings - 2021 47th Euromicro Conference on Software Engineering and Advanced Applications, SEAA 2021*, pages 25–28, 2021.

[42] Huynh Khanh Vi Tran, Michael Unterkalmsteiner, Jürgen Börstler, and Nauman bin Ali. Assessing test artifact quality—a tertiary study. *Information and Software Technology*, 139, 2021.

[43] Dolors Costal, Carles Farré, Xavier Franch, and Carme Quer. Inclusion and exclusion criteria in software engineering tertiary studies: A systematic mapping and emerging framework, 2021.

[44] Eliezer Dutra, Bruna Diirr, and Gleison Santos. Human factors and their influence on software development teams - a tertiary study, 2021.

[45] Lanxin Yang, He Zhang, Haifeng Shen, Xin Huang, Xin Zhou, Guoping Rong, and Dong Shao. Quality assessment in systematic literature reviews: A software engineering perspective. *Information and Software Technology*, 130:106397, 2021.

[46] Fernando Kamei, Igor Wiese, Crescencio Lima, Ivanilton Polato, Vilmar Nepomuceno, Waldemar Ferreira, Márcio Ribeiro, Carolline Pena, Bruno Cartaxo, Gustavo Pinto, and Sérgio Soares. Grey literature in software engineering: A critical review. *Information and Software Technology*, 138, 2021.

[47] Kécia Souza Santana Santos, Larissa Barbosa Leoncio Pinheiro, and Rita Suzana Pitangueira Maciel. Interoperability types classifications: A tertiary study. Association for Computing Machinery, 2021.

[48] Shanshan Jiang, Kine Jakobsen, Letizia Jaccheri, and Jingyue Li. Blockchain and sustainability: A tertiary study. *Proceedings - 2021 IEEE/ACM International Workshop on Body of Knowledge for Software Sustainability, BoKSS 2021*, pages 7–8, 2021.

[49] Alexander Ligthart, Cagatay Catal, and Bedir Tekinerdogan. Systematic reviews in sentiment analysis: A tertiary study. *Artif. Intell. Rev.*, 54:4997–5053, 10 2021.

[50] Michael Neumann. The integrated list of agile practices - a tertiary study. *Lecture Notes in Business Information Processing*, 438 LNBIP:19–37, 2022.

[51] Zoe Kotti, Rafaila Galanopoulou, and Diomidis Spinellis. Machine learning for software engineering: A tertiary study. *ACM Computing Surveys*, 55.