The *Status Quo* of Systems-of-Information Systems

Paulo Gabriel Teixeira
Universidade Federal de Goiás
Goiânia, Brazil
paulogabriel.teixeira@gmail.com

Victor Hugo L. Lopes
Instituto Federal de Goiás
Inhumas, Brazil
victor.lopes@ifg.edu.br

Rodrigo Pereira dos Santos
Universidade Federal do Estado do Rio de Janeiro
Rio de Janeiro, Brazil
rps@uniriotec.br

Mohamad Kassab
Penn State University
Malvern, United States
muk36@psu.edu

Valdemar Vicente Graciano Neto
Universidade Federal de Goiás
Goiânia, Brazil
valdemarneto@inf.ufg.br

***Abstract*—The modernization of business processes have pressured Software-Intensive Information Systems (IS) to interoperate with several other systems, arising a new type of complex systems so-called Systems-of-Information Systems (SoIS). Despite the novelty of the area as it has been known, it follows a trend of previous complex systems, such as Federated Information Systems and Large-Scale Information Systems. However, operational and managerial independence of IS constituents have created a new type of system that must be understood to suitably support new business and modernize old ones, such as pizza delivery via drone swarms. Hence, to sustain the area and achieve advances, it is necessary to externalize its state of the art and practice. However, the lack of literature mappings on this topic can pose difficulties to its progress, besides making it difficult to obtain relevant information about existing gaps and advances to be achieved in the future. This paper presents results of a Systematic Mapping (SM) carried out to investigate the *status quo* of SoIS domain. We bring a panorama of this research topic and also indicate research perspectives. From a set of 212 studies, 25 were selected, analyzed and had their data extracted. Results reveal that interoperability between different IS is still a challenge and the low number of studies referring to languages, techniques and tools for modeling SoIS architectures points to an important area of study to be researched in the forthcoming years.**

I. Introduction

Systems-of-Information Systems (SoIS) are a specialization of Systems-of-Systems (SoS) formed by the combinaton of software-intensive Information Systems (IS) and potentially other types of systems, such as drones, satellites, and mobiles. SoIS are the result of the modernization of business processes and globalization of a world where IS are required to interoperate with many other systems to offer services, establish commercial partnerships with suppliers, comply with laws, and deliver products in a more agile and optimized fashion [1].

A remarkable example of a SoIS is a smart city [2], which involves one or more IS as constituent systems that interoperate to (i) leverage the citizens experience, (ii) manage important concerns (e.g., sustainable power distribution, power billing and economy, and integration of public services such as health and emergency response systems), and (iii) improve city services, including touristic information and city-wide wifi connection. As a simplistic example, a pizzeria IS can be sees as a SoIS, which has the potential to be involved in a SoIS composed of (i) drones that deliver pizzas, (ii) mobiles and apps that establish the interface with clients, and (iii) occasional deliverers, who can join and leave the SoIS to offer free-lancer deliveries at their convenience, turning the pizzeria IS into inherently dynamic SoIS.

Although SoIS emerged in the 1990s [3], it has only well reached the impetus of the research community in the past five years. This was motivated by the limitation of old IS, which have not accordingly matched the organizational needs when working isolately. Given such context, this paper reports results of a Systematic Mapping (SM) carried out to investigate the *status quo* of SoIS domain. We present a panorama of this topic and indicate research directions.

The remainder of this paper is structured as follows: Section II brings foundations and useful definitions. Section III details the planning, conduction, and results of our study. Section IV discusses the findings, while Section V concludes the paper with final remarks.

II. Background

An IS is a set of associated components that collect (or retrieve), process, store and distribute information [4, 5]. When a software directly affects the IS life cycle from conception to deployment, an IS is considered *software-intensive* [6]. A SoIS results from one or more software-intensive, operationally and managerially independent IS interoperating with other systems to achieve common business goals [7]. Following this perspective, a SoIS has a strong *business* nature. Saleh and Abel [7] synthesize that SoIS should (i) be concerned about the flow of information and knowledge between several IS, i.e., a well-defined business process between the constituents; (ii) control the impact of the interrelationships between different SoIS (SoIS as constituents); (iii) be responsible for the generation of information of the emerging SoIS; and (iv) address information interoperability as a key issue.

SoIS share well-defined characteristics with SoS, which are [8, 9]: (i) managerial independence of constituents, i.e., constituents are owned and managed by distinct organizations and stakeholders; (ii) operational independence of constituents, as constituents perform their own activities when they are not contributing to one of the SoS goals; (iii) distribution, i.e., constituents require a network technology to communicate among themselves; (iv) evolutionary development, as SoS evolve due to the evolution of its constituent parts; and (v) emergent behavior, which corresponds to complex functionalities that arise from the interoperability among constituents. Dynamic architecture is also an important aspect of SoS and a consequence of the other SoS characteristics [10].

Combining several IS is not a novel trend. Several classes of interoperated IS emerged over the past decades, namely Large-Scale Information Systems, Federated Information Systems, Ultra-Large Information Systems and Complex Information Systems [11]. However, interoperability in such classes of systems was investigated in the technical perspective, not reaching other levels of interoperability (such as semantic, pragmatic, and conceptual) [12]. Moreover, these IS were mostly *integrated*, which means their constituents did not have operational and managerial independence, resulting in high coupling and low cohesion. In order to better understand this emerging form of interoperating IS, the next setion presents the protocol and results of our study.

III. Systematic Literature Mapping

The objective of the SM was to raise the level of awarness on the current state of research on SoIS from the literature in order to understand different aspects of the SoIS characteristics (e.g., most commonly discussed characteristic, first mention in the literature, where it has been advanced). The study was conducted from August, 2018 to January, 2019 and involved five researchers. We followed the guidelines of Kitchenham and Charles [13] and Petersen et al. [14], which prescribe the following three main phases: Planning, Conduction, and Reporting, detailed as follows.

A. Phase 1: Planning

The PICOC structure was adopted in alignment with SM guidelines [14]. Under this perspective, the “Population” (P) was defined as `Systems of Information Systems` and its singular and plural variants with and without hyphen, and “Intervention” (I) was defined as `Models OR methods OR tools OR processes`, as recommended by Petersen et al. [14]. However, during the search string elaboration and calibration, results revealed that the use of the Intervention highly restricted the results of the search, reducing the retrieved studies. Then, we opted to use only the Population and its synonyms.

1) Research Questions. In order to find all relevant studies related to the SoIS domain, the following research questions (RQ) and sub-questions were established:

RQ 1 - What is a SoIS?

RQ 1.1 - How have SoIS been defined in the specialized literature?

Rationale: SoIS definition is not consensual yet. Hence, it is important to map how authors have defined SoIS in their studies. Answers to this RQ bring information about those definitions.

RQ 1.2 - Which characteristics/attributes have been associated to SoIS?

Rationale: By characterizing a system, a deeper understanding should be reached. This RQ collects the main characteristics that have been assigned to SoS in literature.

RQ 2 - Which are the application domains of SoIS?
Rationale: Understanding the current application domains for SoIS will raise the knowledge with the potential applications of SoIS as well as the characteristics of the domains that favor the particular SoIS applications.

RQ 3 - What types of formalisms, languages and models have been used to specify SoIS?
Rationale: Modeling is an activity of abstracting and capturing a useful portion of the reality to help on an early understanding of a problem. This RQ brings information about how SoIS practitioners have modeled their SoIS during their engineering, opening perspectives for languages and models development and adoption.

RQ 4 - What future research directions have been described?
Rationale: This RQ collects future work directions that have been reported by authors. Such information can assist researchers to focus their work and draw a roadmap that is still necessary to be developed in this domain.

2) Search Strategy. The search strategy combines automatic search and forward and backward snowballing in the selected studies. Following the population defined using PICOC, we used the boolean operator `OR` to link the main term and their synonyms, resulting in the search string presented in Table I.

TABLE I
SEARCH STRING WITHOUT WILDCARD

(”System of Information System”) **OR** (”System-of-Information-System”) **OR** (”Systems of Information Systems”) **OR** (”Systems-of-Information-Systems”) **OR** (”Systems of Information System”) **OR** (”System of Information Systems”) **OR** (”Systems-of-Information-System”) **OR** (”System-of-Information-Systems”)

For coverage purposes, we selected eight databases (namely ACM Digital Library[1], IEEE Xplore[2], Scopus[3], Springer[4], Engineering Village[5], Web of Science[6], ProQuest[7] and Google Scholar[8]). According to Dyba et al. [14] and Kitchenham and Charters [13], these publication databases are the highly relevant sources in the Computer Science and Information Systems areas. About Google Scholar, we planned to analyze all the studies found in the 10 first pages. Additionally, we chose ProQuest base because we found potentially relevant

[1]https://dl.acm.org/
[2]https://ieeexplore.ieee.org/Xplore/home.jsp
[3]https://www.scopus.com/home.uri
[4]https://www.springer.com
[5]https://www.engineeringvillage.com/home.url
[6]https://login.webofknowledge.com/
[7]http://www.proquest.com/
[8]https://scholar.google.com/

studies during a pilot search. The search string was adapted for each base. Pilot queries were executed in each base to calibrate the search string.

3) Inclusion and Exclusion Criteria. The selection criteria is used to evaluate studies obtained from the publication databases. The Inclusion Criterion (IC) used to include relevant studies in our SM are:

IC 1: The study addresses SoIS.

Conversely, the Exclusion Criteria (EC) used to exclude the not relevant studies are:
EC 1: The study is written in a language other than English;
EC 2: The full text of the study is not available;
EC 3: The study is directly related to another primary study of the same author. In this case, only the most recent primary study is considered;
EC 4: The study was not peer-reviewed.

4) Quality Assessment. Additionally, aiming to evaluate the quality of the studies included in our SM, we defined Quality Questions (QQ) based on questions commonly used in similar evidence-based studies [15, 16], presented as follows:
QQ1: Is there a rationale for the executed study?
QQ2: Do the authors present an overview of related work and background regarding the area of the study?
QQ3: Is there a description of the context (industry, laboratory setting etc.) in which the work was carried out?
QQ4: Does the study provide a clear justification about the methods used in the study?
QQ5: Is there a clear statement of contributions and has sufficient data been presented to support them?
QQ6: Do the authors explicitly discuss the credibility and limitations of their findings?
QQ7: Do the authors discuss perspectives of future work based on the contributions of the study?

TABLE II
BASES OF RESEARCH AND THE WORKS FOUND IN THE SELECTIONS PHASE

Base	Total	Filtering steps		
		Duplications	EC	IC
IEEE Explore	52	0	41	11
ACM DL	4	1	1	2
Springer Link	25	2	18	5
Scopus	58	22	32	4
Engineering Village	39	36	3	0
ProQuest	13	2	11	0
Web of Science	21	17	4	0
Total	**212**	**80**	**110**	**22**

5) Data Extraction

A data extraction form using Google Forms[9] was created to support extraction of data from the included studies.

[9]https://www.google.com/forms

B. Phase 2: Conduction

During this phase, studies were selected and evaluated according to the protocol. We used Mendeley[10] to manage the primary studies information (e.g., title, authors, book title, and abstract), as well as the set of IC/EC applied to the selected primary studies. The selection and evaluation of primary studies was performed in well defined steps, as follows:

Initial Selection: Table II shows the results of the search. The search string was customized and applied to each selected publication database. The automatic search was performed in the full text and metadata. As a result, 212 studies potentially relevant were selected, as shown in Table II. We removed duplicated ones (i.e., 80 studies), then 132 studies for analysis. Titles, abstracts, and keywords were read, and inclusion and exclusion criteria were applied. Introduction and conclusion sections of each study were also considered as well as the full text (if necessary). When any of the researchers did not had clarity about the decision, a consensual meeting was conducted. As result of this first selection activity, a total of 22 studies were included for detailed inspection.

Data extraction: After the initial selection phase, each study was completely read, searching for data and information to answer each RQ. A Google Forms document was employed and helped in the data extraction and tabulation.

Google Scholar (GS) Search: One more study ([36]) was included after GS search. Apart from this study, other retrived studies have already appeared in previous searches. 25 studies were included, as shown in Table III.

Snowballing: We applied the backward and forward snowballing technique looking for potentially revelant studies that were not retrieved by our searches. Among the evaluated works, we selected two relevants studies (Graciano Neto et al. [35] and Graciano Neto et al. [9]), which had not been previously identified.

C. Phase 3: Reporting

SoIS is a novel research topic, but few earlier studies were also found. Table III lists all the included studies. As it can be seen in Figure 1, the trend started during the 1990s [S1], emerging again in the end of the decade of 2000. A growing interest in the theme was observed, since several researches on this topic were published over the past three years.

RQ 1 - What is a SoIS?: To answer this question, we looked for definitions and characteristics that are assigned to SoIS.
RQ 1.1 - How have SoIS been defined in the specialized literature?: Twenty studies provided definitions to the notion of SoIS. We examined all these definitions for similarities / differences and we concluded that a set of three particular definitions are prominant enough to cover the entire class of definitions:

- *SoIS is a special type of SoS that links together several information systems producing overwhelming amount of information to achieve an added value for organizations* [S15];

[10]https://www.mendeley.com

TABLE III
INCLUDED WORKS.

#	Title	Authors	Year	Ref
S1	Integration of statistical information systems-theory and practice	Malmborg, Erik, and Bo Sundgren.	1994	[3]
S2	On the Use of Description Logic for Semantic Interoperability of Enterprise Systems	Yahia et al.	2009	[17]
S3	e-Agency: Implementation of the Croatian Post and Electronic Communications Agency	Caric, Antun, and Silvije Seremet.	2009	[18]
S4	Managing the trust relationship in Financial Services Information Systems	Chan, Weng Tat, and Ying Feng-wei.	2010	[19]
S5	Integration Principle as the Master Equation of the Dynamics of an Information System	Korotkikh, Victor, and Galina Korotkikh.	2012	[20]
S6	Information systems: Towards a system of information systems	Saleh, Majd, and Marie-Hélène Abel.	2015	[7]
S7	An Architectural Model for System of Information Systems	Majd, Saleh, Abel Marie-Hélène, and Mishra Alok	2015	[21]
S8	Managing heterogeneous information in a system of information systems	Saleh, Majd, Véronique Misséri, and Marie-Hélène Abel.	2016	[22]
S9	Integration of Brainstorming Platform in a System of Information Systems	Saleh et al.	2016	[23]
S10	Moving from Digital Ecosystem to System of Information Systems	Saleh, Majd, and Marie-Hélène Abel.	2016	[24]
S11	Resources management and decision support in a system of information systems	Saleh, Majd, and Marie-Hélène Abel.	2016	[25]
S12	Smart Systems-of-Information Systems: Foundations and an Assessment Model for Research Development	Graciano Neto, Valdemar V., Flavio Oquendo, and Elisa Y. Nakagawa.	2016	[9]
S13	New challenges in the social web: Towards systems-of-information systems ecosystems	Graciano Neto, Valdemar V., Renata Araujo, and Rodrigo P Dos Santos.	2017	[26]
S14	System of Information Systems as Support for Learning Ecosystem	Saleh Majd, Abel Marie-Hélène	2017	[27]
S15	Towards a Proactive Interoperability Solution in Systems of Information Systems: A PLM Perspective	Afoutni et al.	2017	[28]
S16	Recommendation of Pedagogical Resources Within a Learning Ecosystem	Ali et al.	2017	[29]
S17	On the Interplay of Business Process Modeling and Missions in Systems-of-Information Systems	Graciano Neto et al.	2017	[1]
S18	Modeling and developing a system of information systems for managing heterogeneous resources	Saleh, Majd, and Marie-Hélène Abel.	2017	[30]
S19	System of Information Systems to support learners (a case study at the University of Technology of Compiègne)	Saleh, Majd, and Marie-Hélène Abel.	2018	[31]
S20	How are combined expertise elements in early-warning systems? Observations and propositions from the French system	Arru, Maude, Elsa Negre, and Camille Rosenthal-Sabroux.	2018	[32]
S21	Mandala: An Agent-Based Platform to Support Interoperability in Systems-of-Systems	Mendes, Altair, et al.	2018	[2]
S22	System of Information Systems and Organizational Memory	Saleh, Majd, and Marie-Hélène Abel.	2018	[33]
S23	A System of Information Systems to Capitalize Resources of Collaborative Activities: the ECOPACK Project	Afoutni, Zoubida, et al.	2018	[34]
S24	A Study on Goals Specification for Systems-of-Information Systems: Design Principles and a Conceptual Model	Graciano Neto et al.	2018	[35]
S25	Model-based engineering & simulation of software-intensive systems-of-systems: experience report and lessons learned	Graciano Neto et al.	2018	[36]

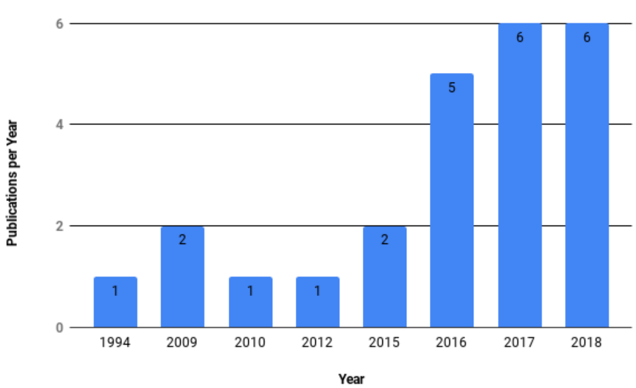

Fig. 1. Number of publications per year.

- *A specific class of SoS oriented to business processes in which constituent systems are information system belonging to different organizations* [S14];
- *SoIS can be considered as a macro-information system giving access to information distributed in component systems and offering functionality using the accessed information* [S5].

Two of these definitions emphasize that SoIS is a type of SoS. Therefore, a SoIS has the same characteristics of a SoS but having IS as its constituents and also a focus on business objectives. While the other one focus on demonstrating the manipulation of information distributed across different systems. It is also clear the similarity between all definitions, where the interoperability of IS prevails with the objective of meeting the business needs through the exchange of information. A total of 15 studies [S2, S4, S6, S7, S8, S9, S10, S12, S15, S16, S17, S19, S20, S22, S23] were supported by the literature when including their own definitions of SoIS, often using the literature on the SoS topic. This can be explained by the fact that SoS is forming a mature basis of concepts and knowledge that favor the study of SoIS.

RQ 1.2 - Which are the characteristics of a SoIS? In Figure 2, we answer this question. S1 was included because it clearly states that the constituents had operational independence (and consequently dynamic architecture). Its authors firstly used the SoIS acronym. The classic characteristics of SoS are considered in most of the studies. Indeed, several studies reinforce this perception and classify SoIS as a type of SoS [S16, S17, S21]. Only four studies did not use any of these characteristics [S1, S2, S3, S5]. Maier's classic characteristics are found in most of the studies, with operational and managerial independence in 64% of them. Other characteristics related to SoS (belonging, connectivity, and diversity) defined by Boardman and Sauser [37] are also found in eight different studies. One study [S14] exclusively considers 'connectivity' in spite of Maier's dimensions.

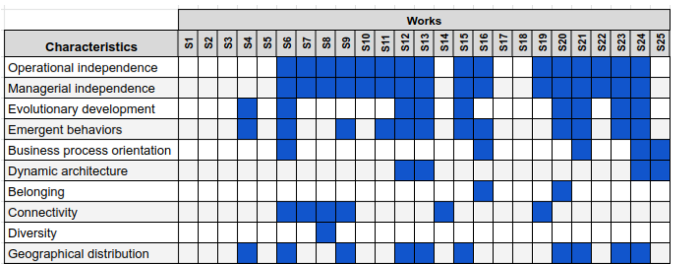

Fig. 2. SoS characteristics associated to SoIS.

Besides the SoS characteristics, other remarkable characteristics different from Maier's and Boardman and Sauser's perspectives were assigned to SoIS. Figure 3 presents them and reveals the technical, business and innovation natures hold by SoIS, including interoperability and interrelationships between different IS, flow of information and knowledge, orchestration, access to distributed information, and delivery of new services using the resources available in that set of constituents.

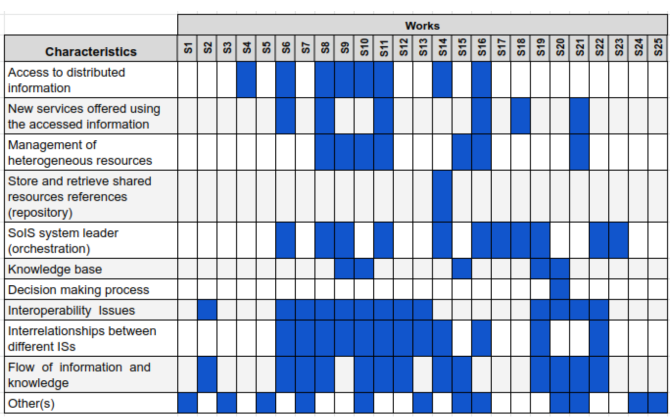

Fig. 3. Described features related to SoIS.

In our analysis, we have also collected the quality attributes observed in the studies according to the ISO 25010 [38]. Figure 4 shows that interoperability was present in the vast majority (68% of the studies). However, several other attributes were not covered, such as accountability, correctness, dependability, sustainability, longevity, maintainability, predictability, resilience, and safety, evidencing gaps to be explored.

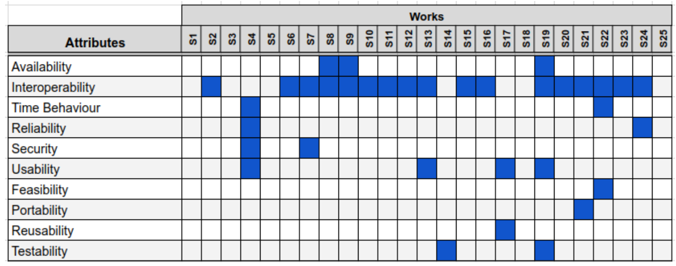

Fig. 4. Quality attributes associated with SoIS.

RQ 2 - Which are the SoIS application domains? Table IV presents the application domains for SoIS. Eleven distinctive domains are considered in addition to one general domain i.e., general solutions that are not restricted to specific domains and could be implemented in different areas. These domains classes are not mutually exclusive. The results from this mapping revealed that areas such as Business/Corporate, Educational and Government are areas of interest, with several related studies.

TABLE IV
APPLICATION DOMAINS FOR SOIS.

#	Domain	Studies
1	Business/Corporate	[18, 19, 22, 23, 28, 31]
2	Educational	[27, 29–31]
3	Finances	[19]
4	General	[1–3, 7, 20–26, 28, 30, 31, 36]
5	Government	[2, 18, 26]
6	Health	[39]
7	Manufacturing	[17]
8	Military	[34]
9	Science	[39]
10	Security	[32, 34]
11	Smart City	[2]
12	Social Media	[7]

RQ 3 - What types of formalism, language or model have been used to specify SoIS? Table V presents models, languages and methods documented in the evaluated studies. Over a half of the studies (13) do not present or consider any formalism to document SoIS. UML is only mentioned in six studies (24%). However, S24, for instance, reports that SysML and UML do not support the representation of multiple interoperating systems and constituents not known at design-time, as well a dynamic environment (flexibility). Hence, despite being mentioned, it does not mean that the language is suitable for that purpose.

The Business Process Modeling Notation (BPMN) is applied (or considered as an option) to SoIS in three studies [S17, S21, and S24 - 12%]. The authors in S24 glimpsed the potential of BPMN to support SoIS goals modeling. However, they remark that BPMN requires few adaptations to address SoIS particularities, and consider mKAOS [40] language to support mission modeling in SoIS. According to the authors, BPMN should be encouraged, since it is widely accepted and adopted in industry.

The authors in S7 and S19 present case studies of SoIS architectures that implement their own models applied to the educational domain. These studies present the SoIS architectures using undefined modeling artifacts, including diagrams which represent the processes between constituent systems. They did not focus on modeling, but rather in the evaluation of the proposed architectures.

Some studies use models for formalizing the ontology associated with SoIS [S8, S9] that consider the Ontology Web Language (OWL[11]), and others [S9 and S16] consider the Semantically Interlinked Online Communities (SIOC[12]), The Friend Of A Friend Ontology (FOAF[13]) and Bibliographic Ontology Specification (BIBO[14]). This association is interesting for this topic, since it allows the emergence of Social Web of Data by the description of information contained in online community sites (blogs, forums, wikis, colaborative tools etc.) as well as the interconnection of such constituent systems.

TABLE V
MODELS, LANGUAGES AND METHODS RELATED TO SOIS.

Model/Language/Method	ref
None	[3, 9, 17–20, 25, 26, 28, 31, 32, 34, 36]
UML	[2, 7, 24, 27, 30, 35]
Undefined	[21, 31]
MER	[22]
OWL	[22, 23]
SIOC,FOAF,BIBO	[23, 29]
BPMN	[1, 2, 35]
SPEM	[2]
BPD	[2]
SysML, mKAOS	[35]

RQ 4 - What future research directions have been described? A total of nine studies neither present future work, nor point out open questions (38.5% of the studies). In general, studies point to (i) improvement of their own proposed model [S6, S7, S8, S10, S11, S14], and conducting evaluations in real scenarios [S9, S18], (ii) the need for evaluating the simplicity of SoIS user interfaces, (iii) the need for extending the complexity of the constituent systems and evaluating the impact of test and integration on prototypes [S19, S20], and (iv) the need for evaluating resource reusability, and the implementation of a recommendation system and resource discovery [S23].

Quality Assessment. Included studies were evaluated according to each quality question (QQ). Answers were obtained from a scale [41] as follows: (i) the study fully meets a given quality criterion (1.0 point); (ii) the study meets the quality criterion to some extent (0.5 point); and (iii) the study does not meet a quality criterion (0 point). The total quality score for each study ranges from 0 - 1.0 (very poor) to 6.1 - 7.0 (excellent). The results are presented in Table VI. 80% of the studies present a good or higher quality. However, despite the good quality, only nine studies completely complied with QQ4 by reaching 1.0 (Methodology justification) and only six studies reached 1.0 in QQ6 (credibility and limitations of findings). It shows that more evidence-based results are needed for maturing this research topic.

TABLE VI
QUALITY ASSESSMENT OF PRIMARY STUDIES.

#	QQ1	QQ2	QQ3	QQ4	QQ5	QQ6	QQ7	Total	Quality
S13	1	1	1	1	1	1	1	**7**	**Excelent**
S19	1	1	1	1	1	1	1	**7**	**Excelent**
S24	1	1	1	1	1	1	1	**7**	**Excelent**
S6	1	1	1	1	1	1	1	**7**	**Excelent**
S21	1	1	1	0,5	1	0,5	1	**6**	**Very Good**
S8	1	1	1	1	1	0	1	**6**	**Very Good**
S11	1	1	1	1	0,5	0	1	**5,5**	**Very Good**
S14	1	0,5	0,5	1	1	0,5	1	**5,5**	**Very Good**
S15	1	1	1	0,5	0,5	0,5	1	**5,5**	**Very Good**
S7	1	1	0,5	0	1	1	1	**5,5**	**Very Good**
S9	1	0,5	1	0,5	1	0,5	1	**5,5**	**Very Good**
S12	1	1	1	0,5	1	1	0	**5,5**	**Very Good**
S16	1	0,5	0,5	0,5	1	0,5	1	**5**	**Good**
S10	1	1	0	0,5	1	0	1	**4,5**	**Good**
S17	1	1	1	0,5	0,5	0,5	0	**4,5**	**Good**
S2	1	0,5	1	1	1	0	0	**4,5**	**Good**
S20	1	1	1	0,5	0	0	1	**4,5**	**Good**
S22	1	1	1	0	0,5	0	1	**4,5**	**Good**
S23	1	1	1	0	0,5	0	1	**4,5**	**Good**
S25	1	1	1	0	0,5	0,5	0,5	**4,5**	**Good**
S4	0,5	1	1	0,5	0,5	0,5	0	**4**	**Average**
S5	1	0	1	1	1	0	0	**4**	**Average**
S18	1	0,5	1	0	0	0	1	**3,5**	**Average**
S1	1	0	0,5	0,5	0,5	0,5	0	**3**	**Fair**
S3	1	0	1	0,5	0,5	0	0	**3**	**Fair**

Scientific methodologies were also evaluated. Figure 5 shows that more than a half of the studies (14 studies - 56%) performed case studies as the empirical evaluation technique. Among them, only one study (4%) performed a case study using a real system [32], in which the French Early Warning System (SAIP) was evaluated. The other studies had a more exploratory nature by adopting models, architectures (proposed or implemented), or prototypes rather than a real SoIS. A total of three studies did not adopt a methodology. Evaluation in simulated or controlled scenarios were not found, which reveals an early stage of maturity that should be advanced.

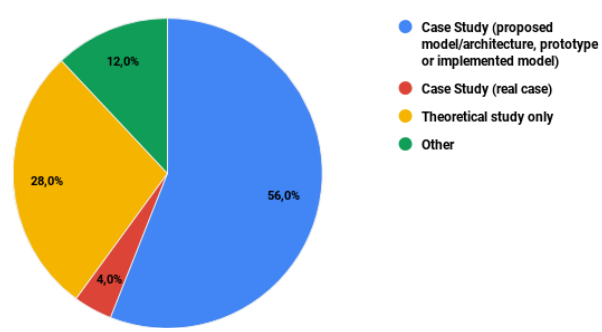

Fig. 5. Methodology type.

[11]https://www.w3.org/OWL/
[12]https://www.w3.org/wiki/SIOC/
[13]http://www.fob-project.org/
[14]http://www.bibliontology.com/

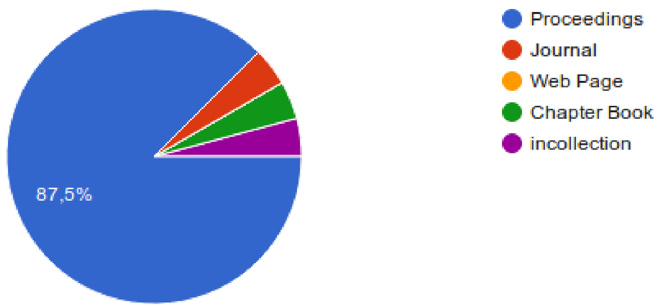

Fig. 6. Publications type.

The venues were also analyzed[15] The vast majority of the studies were published in conference and workshop papers. Only one study [S19] was published in a journal (Behaviour & Information Technology), which is a strong indication that more research on SoIS is needed.

IV. Discussion

There is still much work to be performed. As observed, several relevant studies did not present architectural definitions, models, specific characteristics or a taxonomy. For the most part, they simply relied on the well-known definitions of SoS. We discuss and summarize the main points below.

SoIS definition. After analyzing so many definitions, the authors agree on and suggest the following common definition: *A System-of-Information Systems (SoIS) is a specific class of SoS oriented to business processes in which constituent systems include information systems that interoperate between themselves and belong to different organizations* (adapted from S21, S13).

SoIS characteristics. There is no consensus yet about the SoIS characteristics, which poses an effort to be addressed in the forthcoming years. When considering the characteristics and quality attributes associated with SoIS, we observed many gaps to be explored, particularly (i) important attributes were also mentioned but not fully addressed in any of the included studies. For instance, security, consistency, and performance, which have a remarkable potential of damage on business constituent systems that are part of a SoIS, were not mentioned. Those quality attributes are particularly relevant to SoIS domain, since they are related to the reliability delivered by the SoIS while supporting business data exchange (financial transactions, purchase orders etc.) between constituent systems in a SoIS, and (ii) the attributes that were not covered yet, including safety, for example.

SoIS languages, models, and tools. The low number of studies dealing with languages, techniques and tools for modeling SoIS architectures point to an important area of study to be observed in future work. The potential of using already established languages and notations, such as BPMN and SPEM (Software Process Engineering Metamodel) for modeling activities in SoIS was observed in few studies [S21, S24]. There is a convergence (and need) for the proposition, adaption and/or adoption of sequence-driven languages, such as BPMN, SPEM and UML (sequence diagram), since none of the included studies focus on the definition of languages for the specificities of SoIS, which remains as an unsolved gap.

Demographic analysis. We also analyzed the leading research groups on SoIS. Most of the studies were developed in France [S6, S7, S8, S9, S10, S11, S14, S15, S16, S18, S19, S22, S23] and Brazil [S12, S13, S17, S21, S24, S25]. The first group has focused on SoIS for specific domains based on a self-authored approach named MEMORAe [42]. They prototyped and modeled a SoIS, followed by other studies using MEMORAe in specific solutions, such as learning ecosystem [29] and a brainstorming platform [23]. The second group presents different contributions to the topic, such as SoIS Ecosystems (EcoSoIS) [S13], and a requirements conceptual model for a language for specification of SoIS goals [S24].

Threats to validity were identified and involve (i) search string elaboration, (ii) missing of important primary studies, (iii) selection reliability, and (iv) data extraction. In order to reduce the impact of the first one, we systematically followed the PICOC principle. Threat (i) leads to threat (ii), since relevant studies might have not been recovered because we used the term SoIS (and not other related terms). However, since our focus was to cover the studies that have understood the set of interoperable IS as a SoIS and used eight search bases besides forward and backward snowballing, this threat is alleviated (even studies with correlated names would also be examined via snowballing, if they had been inspiration for the included studies). Furthermore, a future work is precisely to add the synonymous terms and make a search even more comprehensive. Aimed at ensuring an unbiased selection process, we defined research questions and derived inclusion and exclusion criteria. We believe that the questions and criteria are detailed enough to provide an assessment of how reliable is the final set of included primary studies, reducing the impact of selection reliability threat. Regarding data extraction, we conducted consensus meetings until full agreements. We also cross-checked our extractions for each included studies, increasing the reliability of the data extraction as well.

V. Final Remarks

This paper presented a systematic mapping (SM) on Systems-of-Information Systems (SoIS). Findings and contributions of this work include a compilation of definitions, set of attributes and characteristics used in the identification of SoIS in literature, information about the domains currently explored in this topic, as well as a mapping of techniques, tools and methodologies that have been used in this context, as well as future directions. As future work, we point out the need for exploring quality attributes in SoIS. Comparisons with other architectures, such as SOA, for example, should also be investigated. We observed that a specific modeling language

[15]Table with details of venues was suppressed due to space restrictions. A forthcoming and extended version of this paper shall bring those details.

supporting all the particularities of a SoIS architecture is still needed. We hope that this work can serve as reference for SoIS research in the forthcoming years.

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