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SURVEY

On the Concept of Transparency: A Systematic Literature Review

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ABSTRACT Over a decade since transparency was introduced as a first-class concept in computing, transparency is still an emerging concept that is quite poorly understood. Also, despite existing research contributions, transparency is yet to be incorporated into the software engineering practice, and the promise it holds remains unfulfilled. Although there is evidence of increasing stakeholders' demand for software and process transparency, the realization of such demand is yet to be fully witnessed within the software engineering practice. There is a need to uncover transparency and how it has so far been conceptualized, operationalized, and challenges faced. We applied a systematic literature review method in search of articles published between January 2006 and March 2022. This study reports a systematic review of the explicit conceptualization and application of transparency in 18 articles out of a total of 162 selected for review. Our study found that transparency remains an under-researched non-functional quality requirement concept, especially as it impacts information and software systems development. Of the 18 articles reviewed, only three studies representing 16.67% conceptualized transparency in software development and focused on the transparency of software artifacts. The remaining 83.33% of studies conceptualized transparency in information systems, focusing on general information and fully functional information systems. Transparency is yet to be fully explored from a theoretical gathering point of view and as a non-functional indicator of software quality hence its slow adoption and incorporation into mainstream software practice. Apart from providing a catalog of transparency factors that stakeholders can use to evaluate transparency achievement, the paper proposed a roadmap to enhance transparency implementation and also provides future research directions.

INDEX TERMS Transparency, software transparency, information transparency, process transparency, transparency requirements, transparency factors, transparency evaluation.

I. INTRODUCTION

Though a term that has been long-established in other older disciplines, transparency remains an emerging concept that different software project stakeholders must consider. Transparency is a multifaceted concept that is commonly used to refer to the act of "being open." Its use and interpretation depend on the context. For instance, transparency in governments, societies, and public organizations implies open business processes and the availability of information [1], [2], [3]. In computing, and from the business information systems point of view, process and information transparency refer to process disclosure and information disclosure, respectively [4], [5]. In software engineering, transparency relates to the extent to which stakeholders within a software project can answer their questions about the software system under development [6], [7]. Transparency of software or software transparency also refers to fully disclosing all functions of the software to its users [8].

In other computing sub-disciplines, the notion of transparency offers varying meanings depending on the context. For instance, in networking and distributed systems, transparency is a descriptive heuristic (i.e., a mental short-cut to solving problems) that is used to explain the representation of high levels of abstractions, such as the invisibility of network interactions and seamless remote use of resources by users [9], [10]. In these examples, transparency itself is not explained. This study is not concerned with definitions and studies that only use transparency as a descriptive heuristic to describe or explain some form of anomalies like the

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definitions in [10], [11], [12], and [13], even more so as they are not considered from a theoretical standpoint.

The research on transparency as a concept started over a decade ago by the Software Transparency research group [14] led by Professor Julio Cesar Sampaio do Prado Leite of Departamento de Informática, PUC-Rio, Brazil. Since its inception, it is instructive to assume that several studies about the concept of transparency would have been reported in the literature, especially in computing and its sub-disciplines. However, to the best of our knowledge, no study chronicled and comprehensively aggregated existing studies on transparency to provide a valuable body of knowledge that would further advance the concept of transparency and its practical application. The current study attempts to fill the vacuum.

Moreover, several years after its introduction, the promise transparency hold is yet to be fully explored and fulfilled. As an emerging concept, stakeholders, especially researchers and developers in the industry need to know the scientific and practical significance of transparency. Thus, introducing a concept such as transparency should not be an end, but a means to an end—transparency in engineering software. Concept and theory development are investments that remain crucial to software development success, even more so as computing and its various sub-disciplines lag behind other long-established disciplines in theory building. These two perspectives are, therefore, part of the motivation for this study.

The community, especially software project managers, developers, and requirements engineers, needs to explicitly implement and measure transparency during the software engineering process. In addition, they need to understand and know when transparency can be implicitly achieved based on their choices in information systems or software design and development approaches. Providing such knowledge in one study helps to raise awareness and stimulate further research efforts. Software practitioners can also benefit from such knowledge since it may help them create a transparency improvement program.

The current study investigates how transparency has been conceptualized and its extent of use from a conceptual perspective. We performed a systematic literature review (SLR) [15], starting with 1,362 potential peer-reviewed papers, and ultimately focused on 18 publications that studied transparency and evaluated its achievement based on its defining factors and variables. We deem our SLR to be a helpful guide for two audiences, including transparency researchers who propose, apply, and evaluate transparency achievement and all software industry stakeholders who are interested in implementing a transparency improvement initiative that adds value to software artifacts, software, and processes. Both audiences may want to use our review for the following reasons.

— *A reference guide*. We have compiled a list of transparency factors available in the literature. Researchers can see where authors of the factors further discussed and applied them.
— *Providing a roadmap for conceptualizations and evaluation*. The study proposes a conceptual blueprint or template that can be used to identify transparency objectively and understand how transparency may be achieved. It also identifies state-of-the-art conceptualizations that may help researchers view how their future proposals fit into the overall concept of transparency and its evaluation.
— *Source of inspiration and Call for further research*. The review can act as a guideline to help inspire and encourage a new way of thinking about transparency conceptualization, operationalization, and evaluation. Based on the provided insights, researchers may explore the possibility of transforming transparency from a concept to a theory. Additionally, our findings may help reinvigorate new discussions and research.

The rest of the paper is structured as follows: Section II provides background on transparency. Related work is presented in Section III. Section IV presents the method adopted for the review. In section V, we provide the results of the review. Section VI discusses the review results, a blueprint for evaluating transparency achievement, and opportunities for further research. Finally, Section VII presents a conclusion of the study.

II. BACKGROUND

In this section, we present a background on transparency. Transparency has been conceptualized in terms of information disclosure or process disclosure [16]. From the point of view of software, information transparency means making the information the software deals with transparent [5]. Process transparency, on the other hand, means the software can reveal how it works, what it does, and how it does it [5]. Apart from software, an ''automated process,'' other general organizational or business processes that are not automated may be required to be transparent. Since transparency deals with information and processes, it becomes a quality attribute of software and other organizational or business processes. Transparency, therefore, is considered a requirement of the stakeholders of software and processes.

Fig. 1 provides a pictorial overview of the dimensions of conceptualizations and operationalizations of transparency. A conceptualization is the formation of a concept [17], [18]. On the other hand, operationalization refers to implementing and measuring a concept using its measurable factors [17]. The operationalization of a concept helps to provide evidence of the practical significance of a concept in a real-world situation. Transparency may be measured by different factors that help its achievement.

Based on Fig. 1, transparency is the main quality that transparency factors can measure. Stakeholders would need to agree on what constitutes a transparency requirement that would require fulfillment via a suitable transparency factor. An established transparency requirements catalog will then be the target for transparency measurement by their respective

factors. Through the operationalization of a transparency factor, software, software artifacts, and processes can be evaluated for transparency achievement. In the case of software development life cycle (SDLC) processes, the end goal of such an evaluation could be to have transparent processes that produce transparent software artifacts and deployable software.

Given the multifaceted and complex nature of transparency and how it has been achieved, we identified two dimensions (process and information) of conceptualization and operationalization (see Fig. 1). In this SLR, the process transparency (PT) dimension refers to the conceptualization and operationalization of transparency that focuses on automated (i.e., software) and unautomated (i.e., other organizational or business processes) processes. On the other hand, the information transparency (IT) dimension refers to the conceptualization and operationalization that focuses on software, especially the information it deals with, and software artifacts such as requirements documents, design documents, and code. Fig. 1 partly hints at a blueprint for transparency achievement, which will be provided later in the paper.

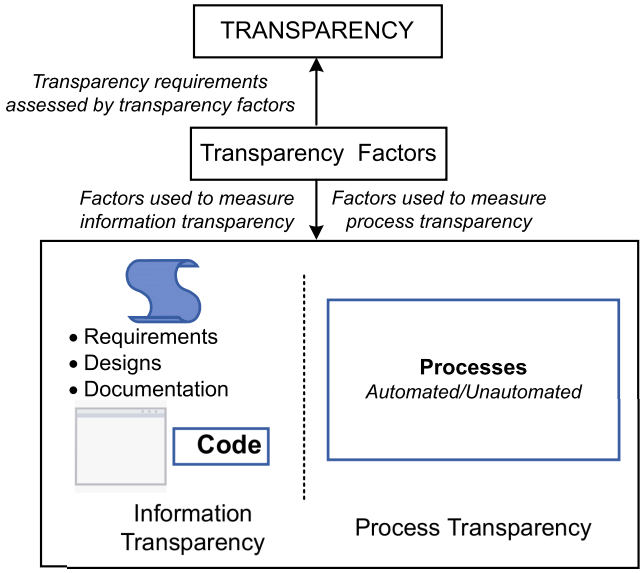

FIGURE 1. Overview of transparency conceptualizations and operationalizations.

A. DEMAND FOR SOFTWARE TRANSPARENCY AND GENERAL DEMAND FOR TRANSPARENCY IN SOFTWARE ENGINEERING

There is a global demand for transparency in various human endeavors, whether government, private or social enterprises [1]. The Volkswagen carbon emission scandal [19] and Boeing's 737 Max plane crashes [20] are some incidents that have reiterated the call for more transparency in software. To answer whether there is a demand for software transparency, Portugal *et al*. [21] relied on the data about bills proposed to the Brazilian Congress to identify the demand for transparency. They argued that there is a "real future demand for software transparency." Several studies [6], [8], [16], [22], [23], [24] have addressed the need for software transparency. Transparency has been considered a key driving force for open-source software development. According to Dabbish *et al*. [23], transparency, as it concerns software engineering promises to be an enabler of collaboration and coordination. However, in the software engineering process, the demand has not received much attention except as the reported works by Tu *et al*. [6], [7] indicate.

In [16], the demand for transparency is categorized as stakeholders' demand for the internal transparency of software, software processes, and the mediators of software and the information produced by software systems. Tu *et al*. [6], [7] opined that transparency could benefit other SDLC stages apart from the requirements engineering phase. Furthermore, the studies in [4] and [25] emphasized the benefits of introducing transparency as a requirement from the process and information points of view. Moreover, as the prevalence of code over models persist due to the adoption of social coding platforms such as GitHub and Agile methodologies, Leite [26] argued that this trend might be mitigated with transparency.

B. TRANSPARENCY AS A PRIMARY CONCEPT

The multifaceted and complex nature of transparency makes transparency a concept that is seldom approached as a primary concept like other well-established concepts [13], [27], [28], [29]. Transparency as a primary or first-class concept means considering transparency as a monolithic and independent concept explained by well-defined factors. Some studies [27], [28], [29] conceptualized transparency as a second-class concept in union with other antagonizing (i.e., concepts that negate the principle of openness, which signifies transparency) concepts such as privacy and security. Since transparency positively connotes the act of making a given process or software open to stakeholders, it is qualified by equally positive factors (e.g., availability, accessibility) that helps to explain and achieve it. The studies reported in [6], [16], [24], [30], [31], and [32] conceptualized transparency as a primary concept.

C. TRANSPARENCY AS A SECONDARY CONCEPT

Several studies [22], [27], [28], [29], [33], [34], [35], [36], [37], [38] considered transparency as a secondary concept but in union with other major concepts. For instance, transparency is conceptualized as a secondary concept under another primary concept, such as accountability, privacy, and security. Addressing the challenge of antagonizing concepts such as privacy and security is deemed a significant investment since these concepts, by their rights, contribute to transparency. By this, we mean that stakeholders' transparency requirements that border on privacy, for example, must also be addressed while at the same time trying to achieve transparency.

As previously explained, though transparency is positively understood to mean being open, antagonizing transparency measurement factors on the face of it may appear to negate

the typical idea of openness, but they yet help the fulfillment of transparency concerns that border on the preservation of privacy and security of information. A transparency achievement initiative would, therefore, aim to achieve typical transparency requirements and antagonizing transparency requirements as provided in [39].

III. RELATED WORK

Chazette [40] reported an SLR of 13 papers, which partly aimed to provide evidence on how transparency has been approached in requirements engineering. First, the author grouped the existing approaches under six themes: modeling, requirements analysis; requirements elicitation; concept models; trust and privacy, and trust and transparency. Then based on the SLR strategy, and as part of a proposed future study, the author proposed three research questions regarding the challenges towards realizing transparency in requirements engineering. However, apart from Chazette, to the best of our knowledge, we did not find any prior secondary study that provided a systematic compilation of transparency-related studies as our SLR aims to deliver.

IV. RESEARCH METHODOLOGY

This section presents the methodology adopted in the current systematic literature review (SLR) study. The SLR study follows the guidelines proposed by Kitchenham *et al.* [15]. The guidelines have established themselves as a popular and widely accepted standard for conducting literature reviews in software engineering (SE). The SLR process (see Fig. 2) consists of several activities that can be grouped into three major phases: design, conducting, and reporting the review findings.

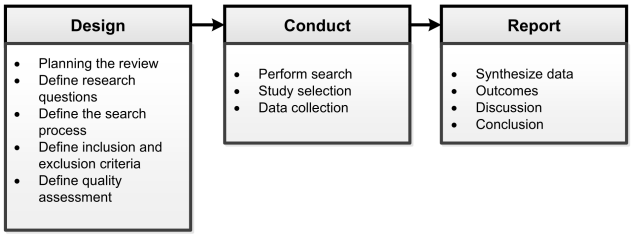

FIGURE 2. Systematic literature review process.

A. RESEARCH QUESTIONS

This study aims to investigate the existing conceptualizations of transparency and the extent of its operationalization. We, therefore, sought to retrieve and analyze relevant and credible studies that relate to transparency. The research questions and their motivations are as follows:

1) RQ1

How has transparency been conceptualized in information systems and software engineering?

- *RQ1.1*—What are the existing definitions of transparency?
- *RQ1.2*—What are the existing factors of transparency, their relationships, and means of representation?
- *RQ1.3*—What are the reference disciplines of transparency factors?
- *RQ1.4*—What are the main research approaches used in conceptualizing transparency and the dimensions of conceptualization?
- *RQ1.5*—What are the methods used to evaluate transparency?

a: RATIONALE

Transparency is a concept that is rarely approached from a theoretical point of view [41], [42]. As previously mentioned, the common use of transparency as a descriptive heuristic lacks any theoretical underpinnings that explain and support transparency. The consequence is that stakeholders find it difficult to identify what represents transparency and how it can be achieved. This indication partly motivated RQ1. Though the findings from the studies mentioned above are outside the computing field, they are relevant to our study because transparency is multidisciplinary, complex, and multifaceted. Also, since the above findings cannot be generalized to computing and its sub-disciplines, it also motivates the current SLR as it aims to x-ray the information and software systems landscape to arrive at findings that reflect the current state of affairs of transparency conceptualization.

In order to better address RQ1, we provided sub-research questions RQ1.1 to RQ1.5. We aimed to identify existing definitions of transparency and investigate factors that help explain transparency. Stakeholders need to understand and ascertain the factors that can be used to define and measure transparency. When software project stakeholders become aware of these transparency-describing factors, they may consider their actual operationalization. If factors of transparency are investigated, it is reasonable to consider the research approach and context of transparency conceptualizations and the methods used to evaluate transparency.

2) RQ2

What are the existing operationalizations of transparency?

a: RATIONALE

The purpose of RQ2 is to investigate the practical examples of transparency operationalizations (i.e., the implementations and measurement of transparency achievement) and analyze the extent of the operationalization of transparency. As an emerging concept, stakeholders need to know in practical terms how information or software systems development, for instance, can ultimately benefit from transparency to deliver software projects more successfully.

3) RQ3

What are the challenges with operationalizing transparency?

a: RATIONALE

RQ3 is motivated by the need to investigate existing challenges in implementing transparency. As an emerging and multifaceted concept, stakeholders need to know the challenges that accompany the implementation and

TABLE 1. Targeted sources.

ID	Digital Library	URL
ID1	ACM Digital Library	https://dl.acm.org/dl.cfm
ID2	Science Direct	https://www.sciencedirect.com
ID3	IEEE Xplore	https://ieeexplore.ieee.org/Xplore
ID4	Springer	http://www.springerlink.com
ID5	Google Scholar	https://www.scholar.google.com
ID6	Scopus	https://www.scopus.com
ID7	Web of Science	https://apps.webofknowledge.com

measurement of transparency and how such challenges may be mitigated.

B. SEARCH PROCESS

The search was carried out via the conventional manual process as provided by the search engines. Table 1 provides a list of digital library sources searched. The first author performed the search of articles in the order listed in Table 1 from February 2, 2022, to March 7, 2022. The second and third author supervised the search process and its outcome. These database sources were considered to be among the reputable leaders in digital collections. Databases such as Google Scholar, Web of Science and Scopus provide broad access to electronic papers and have the capacity to return a high search result on the execution of a search query than other smaller and more focused sources. We also provide a flow chart representing the search process in Fig. 3. The papers identified during the paper identification stage include journal articles, book chapters, and conference papers. The resulting papers are, therefore, papers that meet the established inclusion criteria. Though Fig. 3 presents the general search process flowchart, Fig. 4 (see Section IV-C3) complements it as it further captures a detailed paper identification and study selection process following well-established guidelines provided in [43].

As part of an SLR protocol development, Kitchenham and Charters [15] suggested a model for framing SLR research questions. This model is known as PICOC (Population, Intervention, Comparison, Outcome, Context) and was initially proposed by Hunt [44]. We next present how we adopted the model.

1) POPULATION

The current study considers peer-reviewed journal articles, conference papers, book chapters and workshops that report the conceptualizations and operationalizations of transparency in software engineering and information systems.

2) INTERVENTION

The intervention's objective was to collect theoretical (theory or concept formulation) and empirical evidence related to the various factors of transparency, conceptualization approaches, operationalization areas, and challenges with implementing transparency.

3) COMPARISON

The comparison criterion does not apply to the current study.

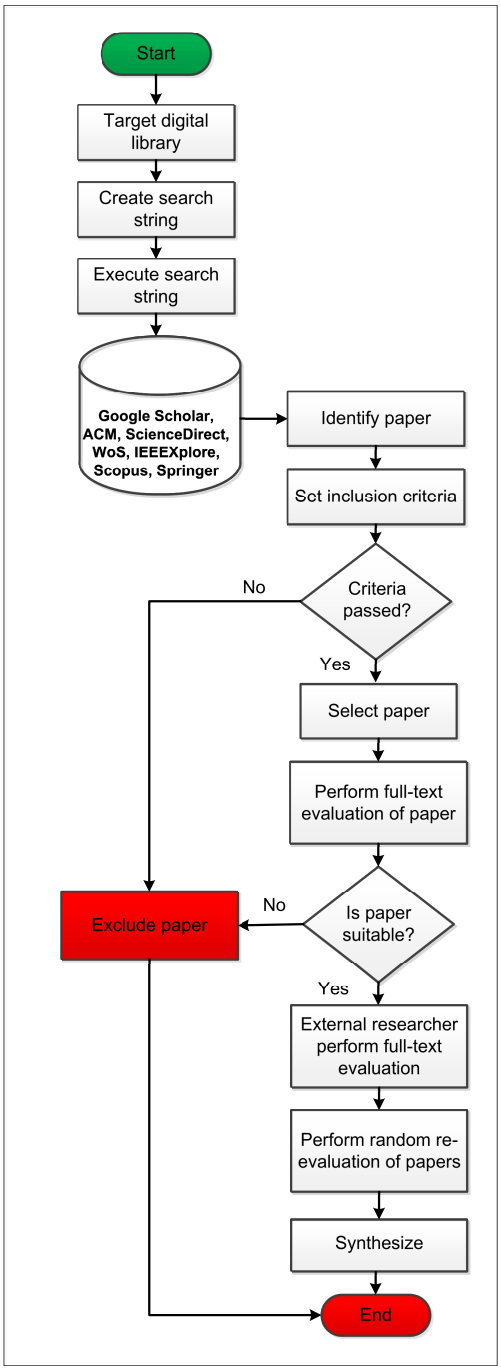

FIGURE 3. The search process.

4) OUTCOME

Expected outcomes include a catalog of transparency factors that stakeholders may use to implement, assess and improve transparency. Also included are approaches that may further be used to conceptualize transparency, the operationalizations of transparency, and the current challenges of dealing with transparency.

5) CONTEXT

Review of studies that treat transparency as a primary concept within software engineering and information systems subdisciplines.

The first author constructed several search strings based on the research questions and the use of synonyms. Initial search strings were constructed and used to perform a pilot search. The search strings were refined, and more strings that fit the purpose were constructed, considering the pilot search outcome. The following two queries were used to search relevant databases based on titles, keywords, and abstracts.

String one—*"transparency impact" OR "software transparency" OR "transparency requirements" OR "information transparency" OR "process transparency" OR "transparency modeling" OR "transparency evaluation" OR "metrics for transparency" OR "process disclosure" OR "information disclosure" OR "process openness" OR "information openness" OR "transparency notions" OR "transparency attributes" OR "transparency concept" OR "transparency factors" OR "transparency models" OR "transparency challenges" OR "transparency applications" OR "transparency approaches" OR "transparency context" OR "transparency in open-source software development"*

String two—*"transparency impact" OR "software transparency" OR "transparency requirements" OR "process transparency" OR "transparency modeling" OR "transparency evaluation" OR "metrics for transparency" OR "transparency in open source software development"*

The second query was used to search for papers in the ScienceDirect database due to the restriction set by ScienceDirect on the number (8) of Boolean variables and words supported for searching.

6) STOPPING HEURISTIC PROCEDURE

Since reviewing all the results is not feasible in some cases, especially when the returned results are running in hundreds of thousands, we applied a stopping heuristic [45] as follows:

1) For the first search query, execute the search on all six digital sources.
2) Rank the results by relevance.
3) Assess the search results until reaching ten consecutive, irrelevant results.
4) Otherwise, continue to the next 10 results (as in step 3).

C. REVIEW PROCESS

In this section, the paper presents aspects of the review protocol necessary for conducting the SLR. Before proceeding, the paper provides a background on how it identified the concept of transparency in the literature.

1) IDENTIFICATION OF THE CONCEPT OF TRANSPARENCY

It is important to emphasize that a transparency conceptualization demonstrates scientific significance. In this paper, scientific significance implies evidence of other related concepts, hypotheses, and theories that may have been generated to support transparency. Hypotheses bordering transparency may have been empirically (or otherwise) validated to support transparency. This rationale informed the need also to consider studies that reported any experiment or any other evaluation of transparency. On the other hand, the practical significance of transparency demonstrates transparency operationalizations.

In order to identify and describe the concept of transparency, this paper borrowed some of the structural components of theory employed in identifying and describing theories from [46], [47]. The structural components include the means via which a theory is represented, the specified constructs of the theory, and the specified relationships between the constructs. It is noted that constructs and their relationship constitute the essential parts of a theory or a concept. Though the SLR aims to identify the concept of transparency, using the structural components and descriptions for theories is instructive since concepts also require a means of representation, constructs, and relationships.

Furthermore, towards identifying the concept of transparency, the SLR considered factors and their corresponding relationships together with the variables and associations that represent them. Therefore, this paper uses "factor" to refer to the attributes or constructs or factors or softgoals that help describe or explain the concept of transparency. It should be noted that the use of notion, attribute, factor, or construct is interchangeable in the literature. However, the paper will mostly use the term factor for consistency.

2) INCLUSION AND EXCLUSION CRITERIA

This section presents the criteria for including or excluding a primary study. The criteria are partly explained in Section IV-C4 and fully in Section IV-C5. Table 2 presents the inclusion and exclusion criteria. We considered all papers published between Jan 2006 and March 2022. This time frame is because transparency as a concept appeared to have been introduced in 2007. The paper also considered that a 16-years span is an extended period, sufficient to consider a compilation of studies and the aggregation of the body of knowledge regarding transparency.

TABLE 2. Inclusion and exclusion criteria.

Inclusion ID	Inclusion Criteria
IC1	All peer-reviewed studies including journal articles, book chapters and conference proceedings published between January 2006 and March 2022.
IC2	Studies that provide an appropriate definition or explanation of transparency.
IC3	Studies in software engineering and information systems sub-disciplines of computing.
Exclusion ID	**Exclusion Criteria**
EC1	All studies not written in the English Language.
EC2	Studies that do not consider transparency as a primary concept.
EC3	All studies that do not focus on conceptualizing transparency by clearly providing softgoals, notions or attributes or factors or constructs of transparency.

3) STUDY SELECTION

This section discusses the study selection procedures.

a: FIRST STAGE: TITLES, ABSTRACTS, AND KEYWORDS

The first author performed the search for papers based on titles and keywords using the search queries. We aimed to be as inclusive as possible since abstracts were not read during this stage. The first stage produced the data presented in Table 3. The ''Total Results'' column in Table 3 represents the search engine's self-reported total number of results upon executing the query. The ''Reviewed Results'' column is the outcome of executing the heuristic procedure outlined in Section IV-B6. The inclusion and exclusion criteria applied are IC1, and EC1, respectively. Of the 33,656 papers returned by the search engines, 1,362 papers were examined. Of the 1,362 papers, 493 duplicates were removed by the first author resulting in 869 papers that were included for screening by the authors. Based on title, abstract, and keywords, the first author included 162 papers for full-text review. The second and third author further reviewed the included papers. Where there were disagreements, the authors decided on a consensus.

b: SECOND STAGE: FULL TEXTS

This stage involves a full review and deciding on the full text of each 162 titles retained in the first stage. Full-text consideration was guided by the inclusion and exclusion criteria which, at this stage, were applied fully. The first author selected potential papers for full-text review based on the inclusion criteria (IC2, IC3) and exclusion criteria (EC2, EC3). The second and third author reviewed the papers included by the first author. An external researcher was also engaged during this stage to evaluate the included and excluded papers by the authors to avoid bias. The evaluation outcome by the external research returned in favor of the authors' papers already selected.

The first author further performed a random re-evaluation of papers to ensure that the inclusion and exclusion criteria were followed. During this stage, any disagreement that arose was resolved through a consensus between the authors and the external researcher.

Finally, in this stage, of the 162 sources, the researchers agreed on 18 full texts, and 144 were excluded from further review. This final selection did not include sources from ACM and Web of Science databases. ACM did not have papers that were suitable for full-text review. Web of Science had ten papers that were eligible for full-text review but were considered duplicates or overlaps of papers already selected from their primary sources and therefore not included. Duplicates from Google Scholar and Scopus were similarly removed.

Summarily, the authors searched a population of over thirty thousand sources, examined 1,362 titles, and selected 162 titles based on their relevance to our research objective. Of the 162 relevant titles, the authors then used the full text of the 162 papers to decide on 18 papers reported in the SLR.

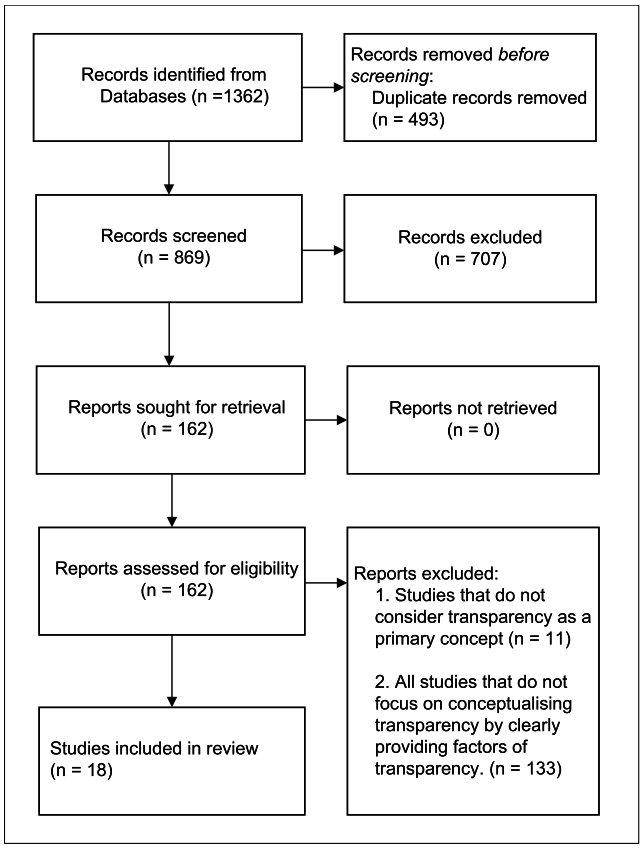

FIGURE 4. Summary of quantitative results of primary studies.

As part of the study selection process, this paper applied the ''PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies'' reported in [43]. The application of PRISMA guidelines resulted in Fig. 4. Fig.4 indicates the number of papers obtained from each targeted database and the statistics on the number of papers included and excluded in each stage of the selection process.

4) QUALITY ASSESSMENT CRITERIA

As part of the SLR process, primary studies that have been obtained must be assessed to determine their actual relevance [15]. In the current SLR, 18 primary studies were obtained and included in the SLR. The paper defined five quality assessment questions to assess the quality of the primary studies retained. Table 4 presents a summary of the quality assessment questions.

a: JUSTIFICATION FOR QUALITY ASSESSMENT CRITERIA

The data extraction guidelines this paper adopted from Hannay *et al*. [46] and Gregor [47] informed the development of the quality questions. The rationale for also basing the quality assessment on these five criteria stems from the fact that Stakeholders need to know what helps explain transparency in terms of factors. Primary studies should explain transparency using factors that are clearly defined. Because transparency is a concept, the studies on transparency may

TABLE 3. Database engines, and results for the first stage.

Search String	Index/Search Engine	Total Results	Reviewed Results	Overlapping Papers	Unique Papers	Researcher
String 1	IEEExplore	10153	327	-	327	First author
String 1	Springer	1786	239	-	239	First author
String 2	ScienceDirect	213	190	-	190	First author
String 1	ACM	1240	111	-	111	First author
String 1	Scopus	5615	157	157	-	First author
String 1	Google Scholar	14500	237	235	2	First author
String 1	Web of Science	149	101	101	-	First author
	Total	33,656	1,362	493	869	

TABLE 4. Quality assessment questions.

ID	Criteria	Type of Response
QA1	Are the notions of transparency well defined?	Yes (Y) = 1, Partly (P)= 0.5 or No (N) = 0
QA2	Are the relationships between notions well described?	Yes (Y) = 1, Partly (P)= 0.5 or No (N) = 0
QA3	Is there any experiment or evidence to show the application of transparency conceptualisation?	"
QA4	Are the research limitations well documented?	"
QA5	Are there well documented challenges of measuring transparency?	"

define the relationships between factors of transparency and how the factors help measure transparency. This expectation is usually a requirement for conceptualization and theory formulation Hannay *et al*. [46] and Gregor [47]. The scoring was performed as follows: Yes (Y) = 1; Partly (P) = 0.5; No (N) = 0; The reason for providing quality assessment questions is, therefore, to avoid bias in the conduct of the review, in addition to auditing both the internal and external review validation process.

5) DATA COLLECTION

This section describes the type of data identified and collected based on our research questions and the overall objective of our SLR.

a: DATA EXTRACTION OF TRANSPARENCY CONCEPTS

To extract transparency concepts, we look out for explicit statements in the literature related to factors of transparency and their definitions. Additionally, to also identify and include the concept and definition of transparency in our review, we relied on some of the data extraction criteria provided in [46] and [47] as previously mentioned. Because transparency is an emerging concept in information systems and software engineering, some data extraction attributes for theories such as theory's structural representations and theory's role were not considered in this SLR. Table 5 provides a summary of data attributes for the extraction of transparency concepts from the reviewed papers. We next describe the procedure for extracting data attributes that may not be self-explanatory.

b: METADATA

Concept *names* and *references* are obtained from the reviewed articles, where possible. Though the commonly used name for the concept under investigation is *transparency*, this study envisages that some articles may use other synonyms such as *openness* or *disclosure* to refer to the same concept. *Reference* records the source of the transparency conceptualization. Since transparency is characterized as a complex and multifaceted concept, the *Reference Discipline* attribute records the sources of the factors used to describe and achieve transparency.

c: STRUCTURAL COMPONENTS

The *Means of Representation* attribute is used to indicate how the concept of transparency is presented typographically. The *Factors and Relationships* attribute values are determined based on the understanding provided in Section IV-C1. When possible, this paper records only what is perceived to be factors and relationships based on the reviewed article. The data collected from each primary study would enable us to address the SLR's research questions.

6) DATA SYNTHESIS

Because the SLR aimed to investigate the concept of transparency and the extent it has been conceptualized and operationalized, we deemed it appropriate to adopt a qualitative method to synthesize the data that will be obtained from each included primary study. A qualitative synthesis relies on a narrative and textual approach to summarize, analyze, and assess the data needed to answer the review questions.

V. RESULTS AND ANALYSIS

Our study selection process resulted in 18 studies (see Appendix) that met the inclusion criteria. Data from the studies were extracted following the data extraction criteria described in Section IV-C5. Before presenting the results and analysis of each research question, we provide an overview of the studies' general characteristics and depict the quality assessment outcome.

TABLE 5. Data attributes for extracting the concept of transparency (***Data Extraction Form***) [Adapted from [46], [47].

Data Attribute	Description
Metadata	Adapted from [46]
- *Name*	Name given for the concept by the author(s) of the reviewed article or by the researcher if no explicit name was given *(RQ1)*.
- *Reference*	Literary reference given for the concept of transparency *(RQ1)*.
- *Terminology*	Indicates explicit use of the term in describing transparency *(notion, model, attribute, facet, property, dimension, characteristic, softgoal, concept, factor or quality attribute, quality goal, construct or none)*.
- *Reference discipline*	The discipline(s) of a paper's literature sources to transparency notions. *(RQ1)*.
- *Definition of transparency*	An explicit definition of the concept of transparency *(RQ1)*
Structural notions	Generic (Adapted from [47])
- *Means of representation*	Indicates how the concept is presented (e.g., words, diagrams). *(RQ1)*
- *Notions and relationships*	Examples of main constructs or attributes or notions and relationships present in the concept.*(RQ1)*
- *Research approach*	Records approach(s) used to conceptualise transparency and the context of conceptualisation (RQ1).
- *Transparency evaluation method*	Records the method(s) used to evaluate transparency achievement. *(RQ1)*
- *operationalization of transparency*	Records any implementation of transparency concept. *(RQ2)*
- *Challenges with implementing transparency*	Records any challenge(s) with transparency implementation. *(RQ3)*

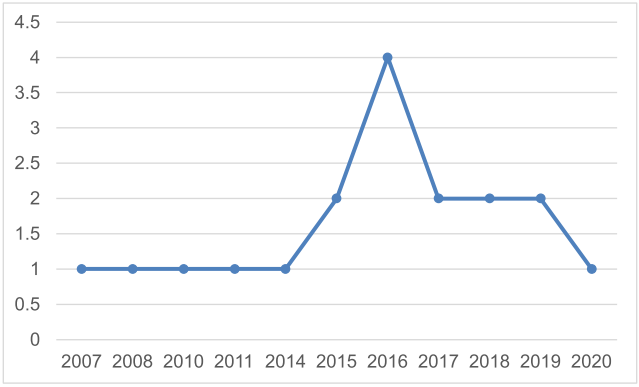

FIGURE 5. Temporal view of studies.

A. CHARACTERISTICS OF STUDIES

The selected studies were published between 2006 and 2022. Fig. 5 presents the number of studies according to the year of publication. We observed an increasing number of publications from 2015 and declining, then stable in 2017, then dropping in 2019. The years 2017, 2018, and 2020 recorded single publications, respectively. The highest number of publications was in 2016. Despite the importance of transparency, it no longer appears to trend as a topic for research hence the papers' motivation. Based on the temporal view analysis, it is reasonable to conclude that the number of studies about transparency conceptualization and applications appeared trim through the years.

Our finding corroborates an earlier observation that transparency is rarely approached from a theoretical perspective. The limited number of studies also confirms the view of Hosseini *et al*. [PS4, PS6]. Most of the papers we excluded from the review only used transparency as a descriptive heuristic, lacking the required theoretical underpinnings a concept should reflect. The outcome also indicates the paucity of transparency-related studies, as Hosseini *et al*. [30] also observed.

TABLE 6. Paper distribution.

Database	Total	# of Overlap Papers	# of Unique Papers	% of Unique Papers
Springer	10	-	10	58.56
IEEEXplore	4	-	4	22.22
GoogleScholar	17	15	2	11.11
ScienceDirect	2	-	2	11.11
Total	33	15	18	100

The types of publications included in this study are conferences, book chapters, workshops, and journals. Many of the studies are conference papers (9 studies; 50.00%), followed by journal articles (6 studies; 33.33%), book chapter publications (2 studies; 11.11%), and one (1) workshop publication (5.56%).

Table 6 presents a summary of the papers from each electronic database in terms of the distribution of the included papers. The Total column represents the total number of studies included in the corresponding database; the Overlapping column captures the number of papers that overlap from other databases; the Unique column represents unique papers that originally appeared in the corresponding database. The % of Unique Papers shows the percentage of unique papers from the database. A majority (58.56%) of the included papers were obtained from the Springer database. This is followed by IEEEXplore, which recorded four (22.22%) papers. GoogleScholar and ScienceDirect recorded two articles each, respectively, representing 11.11% in each case.

Based on the included primary studies, pioneering work on transparency conceptualization can be traced to Leite and Cappelli of the Software Transparency research group (Departamento de Informática, PUC-Rio, Brazil). The other three significant transparency research contributors include Tu *et al*. (University of Auckland, New Zealand), Hosseini *et al*. (University of Bournemouth, United Kingdom), and Spaguelo *et al*. (University of Luxembourg, Luxembourg). A more recent entrant is Alsaedi *et al*. (University of Bournemouth, United Kingdom). More details about the included primary studies are provided in Appendix.

B. QUALITY ASSESSMENT RESULT

Table 7 indicates the scores awarded to each primary study (PS) under each corresponding quality question based on the five quality assessment questions presented in Section IV-C4. The first author performed the assessment under the supervision of the second and third author. All disagreements that ensued were resolved via consensus.

The **%Total Score** (obtained by Total/Total Score * 100) row indicates the points in percentage (over the highest score of 5) obtained by the selected studies for the overall quality assessment questions. As an example, %TotalScore for **QA3** is computed as: (6.5/64.5) * 100).

Assuming that each selected study recorded the maximum score of one (1), **%MaxQA** is obtained by dividing the total maximum scores for all studies under a QA question by the total points (i.e., Total row) recorded for all studies under the same QA question and multiplying the outcome by 100. As an example, %MaxQA for QA2 is computed as (6/12) *100).

The **Total Score** column presents the total score recorded for each primary study across all QAs. The percentages reported here are, therefore, maximum percentages recorded against each study and for all QAs. For example, only two studies [PS2, PS3] scored 4.5, representing 90% of the maximum score of five (5) a PS may obtain. Next in the ranking are studies [PS4, PS10, PS17, PS18], scoring four (4) and representing approximately 80% of the maximum score. This is followed by PS5, PS7, PS11, PS12, PS13, PS14 and PS16, all of which scored 3.5, representing 70% of the maximum score. Finally, primary studies [PS1, PS6, PS8, PS9, and PS15] all scored 3, representing 60% of the maximum score. The results generally indicated that the studies recorded scores above average (50%). The results also give confidence that the papers have good quality and can be used for the SLR.

The **%MaxQA** indicates the points in percentage obtained from the scores recorded by each quality assessment question over the highest score attained. A percentage of 100 means the paper has good quality and will contribute positively to the SLR outcomes. Papers with a 50% score and above will be considered of good quality. It is important to note that though different papers may score any point between 0 and 1 for a given QA, they all contribute to the overall score (i.e., %MaxQA), which is then interpreted as provided above. The evaluation of each PS based on each of the quality assessment questions in Table 6 is as follows:

—*For quality criterion **QA1** (well-defined transparency factors.)* A 100% score was obtained for all primary studies.

—*For **QA2** (well-described relationships between factors).* The result obtained for all primary studies is 50%. This is an average result in our view. It indicates that the relationships between transparency describing factors are yet to be well conceptualized, especially in SE, as observed in [PS2, PS3]. Establishing and understanding the relationships between the factors of a phenomenon is one of the theory formulation requirements [48], [49], [50]. The studies [e.g., PS4, PS5, PS7, PS10, PS13, PS18] from IS perspective provided more details about the relationships between transparency factors. The IS studies contributed largely to the overall score because they are more than the SE studies. However, their descriptions (e.g., goal modeling as provided in PS10) of relationships between transparency factors do not fulfill the requirement of theory formulation.

—*For **QA3** (experiment or evidence showing an operationalization of transparency conceptualization).* The result obtained is 77%, which is well above the average of 50%. Only PS2 and PS3 reported an experiment as they formulated hypotheses that required empirical testing. The other studies, which are IS-based, reported evaluation of a process in one case and the information produced by information systems.

Based on the reviewed studies, the view of transparency as information and process improving concept, operationalized in some context, implies that controlled experiments may not be necessary as a validation method. However, in an information context that focuses on the transparency of software artifacts, a controlled experiment has proved useful as a means of validation. Some of the reviewed studies [e.g., PS1, PS4, PS5, PS13, PS14, PS16] scored either zero or low for QA3 because they did not provide any evaluation. This lack of assessment may be that the studies were in their preliminary stages, or evaluation was provided later in another related study.

—*For **QA4** (research limitations documented).* 79% was obtained. We find this result positive (above average) for all the primary studies. Therefore, this result is equally positive.

—*Concerning **QA5** (challenges of measuring transparency documented).* The result obtained was 71%, which is also positive. However, of all the primary studies evaluated, only QA2 yielded an average result because some reviewed studies did not provide concrete descriptions of the relationships between transparency factors.

Overall, the quality assessment is considered positive, and we can be confident about the studies retained and the outcome of the SLR study.

C. THREATS TO VALIDITY

In this section, we analyze the threats to the validity of our SLR study. In identifying and analyzing the threats, we applied Wohlin *et al*.'s [51] 4-points categorization of threats, including construct, internal, external, and conclusion validity threats.

TABLE 7. Quality assessment criteria result.

ID	QA1	QA2	QA3	QA4	QA5	Total Score	% by Max S
PS1	1	0.5	0	1	0.5	3	60.0
PS2	1	0.5	1	1	1	4.5	90.0
PS3	1	0.5	1	1	1	4.5	90.0
PS4	1	0.5	0.5	1	1	4	80.0
PS5	1	0.5	0	1	1	3.5	70.0
PS6	1	0.5	0	0.5	1	3	60.0
PS7	1	0.5	0	1	1	3.5	70.0
PS8	1	1	0	0.5	0.5	3	60.0
PS9	1	1	0	0.5	0.5	3	60.0
PS10	1	1	0	1	1	4	80.0
PS11	1	1	1	0	0.5	3.5	70.0
PS12	1	0.5	0.5	1	0.5	3.5	70.0
PS13	1	0.5	0	1	1	3.5	70.0
PS14	1	0.5	0	1	1	3.5	70.0
PS15	1	0.5	0.5	0.5	0.5	3	60.0
PS16	1	0.5	0	1	1	3.5	70.0
PS17	1	1	1	0.5	0.5	4	80.0
PS18	1	1	1	0.5	0.5	4	80.0
Total	18	12	6.5	14	14	64.5	
%Total Score	28	19	10	22	22		
%Max QA	100	50	77	79	71		

1) CONSTRUCT VALIDITY

According to Wohlin *et al.*, construct validity is related to generalizing the research outcome to the construct, concept, or theory that motivated the study. To minimize the effect of this threat, we followed the same approach in [52] by utilizing several synonyms representing the primary constructs of transparency in our SLR search string and the whole study. In addition, we normalized the term researchers used to present and describe transparency during the data synthesis phase. We further used the most common terms in our report and sometimes interchangeably. Finally, given that transparency is complex, we established two primary contexts of transparency conceptualization and application: information and process transparency. This delineation enabled us to retrieve studies about transparency.

2) INTERNAL VALIDITY

This threat concerns arriving at a wrong conclusion when investigating causal relationships [51]. An SLR's conduct aims to minimize internal validity threats in the research [12], [57]. We implemented a study selection approach to mitigate internal validity threats that reduced personal biases by enlisting an external researcher's opinion and random evaluation of selected primary studies.

The quality assessment of selected primary studies also helped to minimize internal threats to validity. Sequential and sometimes iterative conduct of the study selection process also helped to mitigate this threat. We searched seven major digital libraries covering computing and its related subdisciplines. This is also in addition to manually searching the related work sections of the studies we selected based on the abstract.

3) EXTERNAL VALIDITY

This validity seeks to establish a generalization of the SLR findings [52]. It is related to the extent to which the included primary studies are representative of the topic and goal of the review. In the context of an SLR study, the assessment of external validity will depend on the selected primary studies to the extent that, if an included primary study is not externally valid, neither is the synthesis of its content [53]. To minimize this threat, we opted not to include papers from the grey literature—this formed part of our paper inclusion criteria. We arrived at our search process after an initial investigation and several rounds of pilot searches. In addition, we included studies that considered transparency as a first-class concept from January 2006 to March 2022. The exclusion of studies that did not treat transparency as a first-class concept may affect the SLR result's generalizability.

4) CONCLUSION VALIDITY

This validity aims to show and ensure that an SLR study's procedures can be repeated and the same results produced [54]. Our SLR was conducted following Kitchenham and Charters' guidelines [15], which helped mitigate conclusion validity threats. However, there is already an assumption by the guidelines to the effect that not all relevant existing primary studies can be identified in the literature. To reduce this threat, an SLR protocol was defined and validated for use in the actual conduct of the SLR. The validation helped reduce the risk and exclude irrelevant papers while keeping with the SLR study's goal. This effort is in addition to utilizing various synonyms that fit the description of the notion of transparency. We also conducted a manual search by searching the related work section of the included studies based on abstracts

D. RQ1. HOW HAS TRANSPARENCY BEEN CONCEPTUALIZED IN INFORMATION SYSTEMS AND SOFTWARE ENGINEERING?

This main research question aims at ascertaining the extent to which transparency in IS and SE has been conceptualized.

To effectively answer RQ1, sub-research questions RQ1.1 to RQ1.5 were identified. The answers to the sub-research questions are provided next.

TABLE 8. Definitions of transparency.

Definitions of transparency	Reference
"Enables stakeholders to answer their questions about the software system during its software life cycle."	PS1
"Open flow of information amongst stakeholders."	PS4
" A set of interrelated softgoals (non-functional requirements)."	PS8
"Ex-ante transparency enables the patient to anticipate what will happen to his/her medical and personal data. Ex-post transparency enables the patient to be informed or get informed about what happened to his/her medical and personal data."	PS12
"Open flow of information amongst stakeholders."	PS15
"The use of online spaces by individuals and groups to communicate their own information on a voluntary basis to support positive work ethics such as building organisational trust, maintaining organisational ethics, reducing misdeeds and increasing employees' engagement and motivation."	PS16

1) RQ1.1—WHAT ARE THE EXISTING DEFINITIONS OF TRANSPARENCY?

RQ1.1 aims to compile appropriate definitions of transparency from the reviewed articles. Since the SLR views transparency as a concept to be explained via the process of conceptualization, it is important to identify definitions that align with this view. Based on the articles reviewed, only studies by Tu *et al*. [PS1], Alsaedi *et al*. [PS16], and Spagnuelo *et al*. [PS12] provided an explicit definition of transparency. Table 8 indicates the definitions of transparency. Other reviewed studies [PS4, PS15] provided appropriate definitions of transparency adopted from the same referenced source.

2) RQ1.2—WHAT ARE THE EXISTING FACTORS OF TRANSPARENCY AND THEIR STRUCTURAL RELATIONSHIPS?

This question aims to identify and analyze the factors proposed to measure transparency. Table 9 presents the various factors of transparency and their corresponding definitions. The *Proposed Application* indicates the context in the factor may be operationalized. The factors that do not have definitions are left blank because the primary study did not provide a definition. Since the concept of transparency and its factors are described using various terminologies in different studies, our SLR aims to normalize these standard terms and use them consistently in the paper. Therefore, we use *factors* to refer to attributes, notions, or softgoals of transparency.

It is important to note that Table 9 does not indicate relationships between factors, and all factors are at the same level of abstraction. We show relationships between factors and their levels of abstraction in the later part of this section. Also, factors were extracted from all included primary studies. Therefore, some factors could be semantically equivalent to other factors because different authors similarly proposed them. Therefore, Table 9 should be considered a general catalog of transparency describing factors.

Furthermore, it is worth noting that not all primary studies may be included as part of the overall result. For instance, studies that did not propose any transparency factor but only applied it based on another study would not be referenced. In addition, based on our data extraction criteria and categorization (see Table 5), studies may be included in more than one category.

The factors in Table 9 are partly a direct response to RQ1.2. The factors were extracted based on the data extraction criteria previously presented in Table 5. The factors of transparency provided by primary studies [PS9, PS10] appear to be repetitive in some papers. We, therefore, captured such factors once. We also applied the same criteria to other primary studies that have repeated factors. The repetition of some of the factors arose because they and their corresponding relationships are a product of several decomposition, aggregations, and refinements during the research. Some of the factors are common to the non-functional requirements framework reported in [55] since they were mapped to the framework. The authors conceptualized transparency based on the framework. We consider some factors (e.g., understandability, portability) as non-functional software quality factors [56]. As provided by the authors in [PS4, PS6, PS7], the factors of transparency did consider the information and process transparency requirements and the channel of communication.

The authors in [PS13] also proposed factors, some of which are common to the other reported studies. The reference sources of the factors are part of the general references for the SLR provided in the references section. Table 10 further provides commonly proposed factors of transparency and notion that are unique to the reviewed paper. For readers, especially those interested in implementing transparency, Table 10 can serve as a reference for widely applied factors that can also be used to evaluate related stakeholders' transparency requirements they desire to achieve.

a: NAME OF TRANSPARENCY CONCEPTS AND REFERENCE

The SLR also aimed compile the names of transparency concepts provided in the reviewed article and their reference sources. Based on the reviewed articles, transparency appeared to be the most common name used by researchers when conceptualizing transparency. We did not encounter any other terms such as openness or disclosure that have commonly referred to as transparency.

b: TERMINOLOGIES USED

Depending on some approaches (e.g., goal modeling, IEEE metric methodology) used to conceptualize transparency, transparency researchers have introduced several terminologies, all of which appear to refer to the same properties or characteristics of transparency. Concerning the terminologies used, the reviewed articles presented various conceptualizations and descriptions of transparency using terms such as

''concept'' and ''softgoals'' [PS10], ''notion'' and attributes [PS1], ''facets,'' and ''reference models'' [PS4], ''factor,'' ''sub-factor,'' ''metric'' [PS14]. For example, in [PS10], transparency is described as a ''soft concept'' that consists of interrelated softgoals that help its achievement. Softgoals are non-functional requirements that can also be considered attributes or factors such as accessibility and usability, all of which contribute to transparency. In primary studies [P1, PS3], transparency is presented as a concept with describing properties termed factors.

The primary study [PS5] described transparency as a concept and used the term ''facets'' and ''properties'' to refer to the four main dimensions of transparency that may be achieved. Each facet consists of several sub-dimensions of transparency that should be fulfilled while evaluating transparency. Based on the four facets (transparency usefulness, transparency meaningfulness, transparency stakeholders, and information quality) of transparency proposed in [PS5], the authors further used the term ''reference models'' to refer to and also define various conceptual models of transparency in [PS4]. Four reference models were proposed – each reference model corresponding to each transparency facet. A reference model is an abstract framework for understanding essential relationships amongst the entities of a particular phenomenon, property, or system [57].

We observed that, though the sub-dimensions of each transparency facet could be regarded as factors of transparency based on their names and definitions, the authors used the term ''steps'' to refer to each factor and the order to evaluate it in the case of *Transparency Usefulness* property. It is also worth noting that the Transparency Stakeholders facet and its accompanying dimensions are not provided in Table 9 because it does not appear to be at the level of other transparency factors. The transparency stakeholders facet only serves to identify stakeholders and entities involved in transparency implementation. This explanation is also applicable to *Transparency Recipients* in [PS16].

In [PS16], transparency is presented as a concept that may be assessed through several factors. Though Transparency Recipients is not a property of transparency, its sub-dimensions are in the form of questions (e.g., ''Do the recipients depend on information providers?) that appear under transparency factors (e.g., information dependability, value, consistency) and, therefore, considered as such. As earlier provided in our criteria, the concept of transparency may be defined based on well-defined properties that enable its evaluation. By adopting the term *factor*, we have normalized the various terms used by researchers to conceptualize and measure transparency.

c: MEANS OF REPRESENTATION

Concerning the means of representation, the concept of transparency and its describing factors was generally represented as diagrams with texts. The primary studies reviewed provided various means of representation. For example, PS10 represented their concept of transparency as an extensive Softgoals Inter-dependency Graph (SIG) with texts. In [PS17], a model was used to represent transparency with texts. In [PS4], reference models were used to define and represent various forms of transparency, whereas the authors in [PS2] used only textual representation. In [PS5], a chart diagram was used to categorize different facets of transparency with textual descriptions. The authors in [PS12] represented transparency via a cloud diagram indicating the various attributes of transparency.

Furthermore, PS14 defined and modeled several metrics for assessing transparency via its various describing factors. Finally, the authors in [PS15] used text to describe a proposed framework for achieving transparency. Since some of the primary studies are later publications of the same authors, there was no need to multi-count the number of studies that indicated a means of representation. Furthermore, the indication of a means of representation in one primary study may not be captured in the authors' later publications, and such representations do not necessarily need to be captured. This also applies to other cases.

d: TRANSPARENCY FACTORS AND STRUCTURAL RELATIONSHIPS

We relied on the framework provided in Table 5 to present the factors of transparency. Structural relationships refer to how the factors of transparency are defined and how they relate structurally with each other to offer meaning to transparency.We consider the number of factors that can be identified for a given concept of transparency to indicate the transparency concept's clear presentation.

Primary studies [PS2, PS5, PS10, PS14, PS17] provided several transparency primary factors together with their sub-factors in most cases. These sub-factors were grouped in a manner that indicates a proposed relationship, and together they help assess transparency via their respective primary factors. The factors and relationships we have identified are provided in Table 11. As Table 11 further indicates, transparency can be assessed by one or more main factors. These primary factors are further evaluated by sub-factors that can directly be measured.

3) RQ1.3—WHAT ARE THE REFERENCE DISCIPLINES OF TRANSPARENCY FACTORS?

The purpose of this sub-research question is to identify and analyze the various reference disciplines (i.e., the origins of transparency factors) where transparency factors were initially proposed.

Besides the structural factors of transparency, Table 11 also provides the reference disciplines for the various factors of transparency. Based on the paper's indications, we determined the reference disciplines (i.e., origins of the transparency factors). The transparency factors have been derived from computing disciplines such as IS, SE, and HCI. Other non-computing fields include business management (Bus Mgt.), business and information management

TABLE 9. Existing factors of transparency.

S/No.	Factors	Definition of Factors	Proposed Application	Reference
1	Accessibility	"The quality of being easy to meet deal with"	Process/Information	PS10
2	Portability	"The quality of being light enough to be carried"	Process/Information	"
3	Visibility	-	"	"
4	Disponibility	-	"	"
5	Operability	"The quality of being treated by surgical operation"	"	"
6	Performability	"The ability to give a good performance"	"	"
7	Informativeness	"The quality of providing or conveying information"	"	"
8	Clarity	"The ability to be free from obscurity and easy to understand"	"	"
9	Completeness	"The quality of being complete and entire; having everything that is needed"	"	"
10	Correctness	"The quality of being conform to fact or truth"	"	"
11	Compositivity	-	"	"
12	Current	"The quality of occurring in or belonging to the present time"	"	"
13	Extensibility	"The quality of being protruded or stretched or opened out"	"	"
14	Integrity	"The quality of being undivided or unbroken completeness, or totality with nothing wanting"	"	"
15	Divisibility	-	"	"
16	Accuracy	"The quality of being near to the true value"	"	"
17	Dependability	"The quality of being dependable or reliable"	"	"
18	Comparable	"The ability to be compared"	"	"
19	Consistency	"The ability to express logical coherence and accordance with the facts"	"	"
20	Conciseness	"The ability to express a great deal in just a few words"	"	"
21	Auditability	"The ability to examine carefully for accuracy with the intent of verification"	"	"
22	Decomposability	"The ability to separate into constituent elements or parts"	"	"
23	Extensibility	"The quality of being protruded or stretched or opened out"	"	"
24	Explicative	-	"	"
25	Validity	"The quality of being valid and rigorous"	"	"
26	Controllability	"The ability to be certain of something"	"	"
27	Verifiability	"The quality of being tested (verified or falsified) by experiment or observation"	"	"
28	Traceability	"The quality of following, discovering, or ascertaining the course of development of something"	"	"
29	Availability	"The quality of being at hand when needed"	"	"
30	Spread out	-	"	"
31	Usability	"The quality of being able to provide good service"	"	"
32	Uniformity	"The quality of lacking diversity or variation"	"	"

TABLE 9. *(Continued.)* **Existing factors of transparency.**

S/No	Factors	Definition of Factors	Proposed Application	Reference
33	Simplicity	"The quality of being free from difficulty or hardship or effort"	"	"
34	Intuitiveness	-	"	"
35	Comprehensibility	-	"	"
36	User-friendliness	-	"	"
37	Understandability	"The quality of comprehensible language or thought"	"	"
38	Composability	"The ability to put together out of existing material"	"	"
39	Adaptability	"The ability to change (or be changed) to fit changed circumstances"	"	"
40	Accountability	"The quality of being explained; made something plain or intelligible"	"	"
41	Publicity	"The quality of being open to public view"	"	"
42	Transparency Usefulness	"Enables stakeholders to make decisions based on provided information and act upon them"	Information	PS4
43	Information Availability	"Information provider must disclose information for the use of the information receivers"	Information	PS4
44	Information Interpretation	"Interpretation of information in a way that can be understood easily by information receivers"	Information	"
45	Information Accessibility	"Degree to which information can be easily located by information receivers"	"	"
46	Information Perception	"Information receivers' perception of the transparency provided by the information"	"	"
47	Information Understandability	"Perceived information should also be understood and comprehended by information receivers"	"	"
48	Information Acceptance	"Information receivers' perception of information matches their beliefs"	"	"
49	Information Actionability	"Provided information to information receivers enables them to act upon it"	"	"
50	Information Quality	-	"	"
51	Sound Information	"Represents the quality of the information supplied by the information provider"	"	"
52	Dependable Information	"Represents the quality of the service in providing information by the information Provider."	"	"
53	Useful Information	"Represents the meeting/exceeding of the information receiver's expectations in the supplied information quality."	"	"
54	Usable Information	"Represents the meeting/exceeding of the information receiver's expectations in information provision service."	"	"
55	Transparency Meaningfulness	"Stakeholders must know the actions and reasons behind the provided information. "	"	"
56	Data Transparency	"Answers the question of what information is needed and who are the stakeholders in the context of transparency"	"	"

TABLE 9. *(Continued.)* **Existing factors of transparency.**

S/No	Factors	Definition of Factors	Proposed Application	Reference
57	Process Transparency	"Answers the question of how something is performed in the context of transparency"	Process	"
58	Free of error	"The extent to which information is accurate and dependable."	"	"
59	Concise representation	"The extent to which information is compactly represented."	"	"
60	Completeness	"The extent to which information is not missing and is of sufficient breadth and depth for the task at hand."	"	"
61	Consistent representation	"The extent to which information is presented in the same layout."	"	"
62	Appropriate amount	"The extent to which the volume of information is suitable for the task at hand."	"	"
63	Objectivity	"The extent to which information is unbiased, unprejudiced, and impartial."	"	"
64	Relevancy	"The extent to which information is applicable and helpful for the task at hand."	"	"
65	Understandability	"The extent to which information is easily comprehended."	"	"
66	Interpretability	"The extent to which information is in appropriate languages, symbols, and units, and the definitions are clear."	"	"
67	Believability	"The extent to which information is considered as true and credible."	"	"
68	Accessibility	"The extent to which information is available, or easily and quickly retrievable."	"	"
69	Ease of manipulation	"The extent to which information is easy to manipulate and apply to different tasks."	"	"
70	Reputation	"The extent to which information is highly regarded in terms of its source or content."	"	"
71	Value-added	"The extent to which information is beneficial and provides advantages from its use."	"	"
72	Security	"The extent to which access to information is restricted appropriately to maintain its security."	"	"
73	Timeliness	"The extent to which information is sufficiently up-to-date for the task at hand."	"	"
74	Policy Transparency	"Answers the question of why an action is performed in the context of transparency"	"	"
75	Accessibility	"Degree to which stakeholders can obtain information that they believe is likely to answer their questions easily"	Information	PS1
76	Understandability	"Degree to which the information obtained by stakeholders can be comprehended with prior knowledge"	Information	"
77	Relevance	"Degree to which the information obtained by stakeholders answers their questions"	Information	"
78	Accountability	"Enables the patient to monitor the use of his/her medical and personal data, and to hold a person accountable in case of its misuse	"	PS12

TABLE 9. *(Continued.)* **Existing factors of transparency.**

S/No	Factors	Definition of Factors	Proposed Application	Reference
79	Availability	"Enables the patient to obtain and use information related to his/her medical and personal data when needed"	"	"
80	Informativeness	"ability to convey a good quality of information, and helps to understand the excellence of information provided	"	PS13
81	Validity	-	"	"
82	Verifiability /Auditability	"Enables the patient to verify what happened to his/her medical and personal data"	"	"
83	Accessibility	"Being easy to obtain"	"	"
84	Understandability	"Being precise and producing the correct result"	"	"
85	Readability	"How easy it is for a user to read and understand text"	"	PS14
86	Accuracy	"How much the information matches the real process of the system"	"	"
87	Detailing	"Whether the information is detailed enough for the general understanding of the subject"	"	"
88	Conciseness	"How straightforward is the information.	"	"
89	Reachability	"How easy it is for a user to reach the information"	"	
90	Portability	"How easy it is to transfer and use information in the different systems."	"	"
91	Currentness	"How timely is the information"	"	"
92	Transparency content	-	"	PS16
93	Presentation of information	-	"	"
94	Timeliness of information	"information communicated is timed in a way that enables the recipients to bring about a positive outcome."	"	"
95	Dependency on information providers,	"Do the recipients depend on the information providers?"	"	"
96	Valuable information	"Is the information valuable for the recipient?"	"	"
97	Consistent information	"Is the information consistent with the recipient's work?"	"	"
98	Availability of information	"Is the information available?"	"	"
99	Relevant information	"Is the information relevant?"	"	"
100	Accessible information	"Is the information accessible?"	"	"
101	Interpretable information,	"Is the information interpretable for the recipient?"	"	"
102	Easy to understand	"Is the information easy to understand?"	"	"
103	Compatible format	"Is the format of the information compatible with the recipient's preferences?"	"	"
104	Provide information (before or during or after),	"Must the information be provided (before, during, after) the activity?"	"	"
105	Real-time information,	"Must the information be provided in real-time?"	"	"
106	Frequency of information provision	"Do recipients need a specific frequency of providing the information?"	"	"

(Bus & Info Mgt.), philosophy, law, business administration (Bus Admin), health information systems (HIS), government and organizational behavior. This array of disciplines shows that transparency is a global concept that permeates different disciplines. These contributing disciplines also indicate that transparency is a multidisciplinary concept and equally multifaceted.

We observed that the complexity of the concept implies that when adopted, it will require new argumentation to fit the peculiarities of the domain and context it is applied. For

TABLE 10. Common and distinct factors of transparency.

S/No.	Common Factors	Primary Study	Distinct Factors	
1	Accessibility	[PS1,PS4, PS10,PS12,PS16]	Publicity [PS10]	Frequency of information provision [P16]
2	Portability	"	Adaptability [PS10]	Provide information (before or during or after)[PS4]
3	Informativeness	"	Composability [PS10]	Compatible format
4	Correctness	"	Intuitiveness [PS10]	Dependency on information providers [PS16]
5	Current	"	Uniformity [PS10]	Presentation of information [PS16]
6	Accuracy	"	Simplicity [PS10]	Transparency content [PS16]
7	Dependability	"	Spread out [PS10]	Real-time information [PS16]
8	Consistency	"	Comprehensibility [PS10]	Detailing [PS14]
9	Conciseness	"	Controllability [PS10]	Reachability [PS14]
10	Auditability	"	Explicative [PS10]	Readability [PS14]
11	Validity	"	Extensibility [PS10]	Information perception [PS4]
12	Verifiability	"	Decomposability [PS10]	Information actionability [PS4]
13	Availability	"	Comparable [PS10]	Information acceptance [PS4]
14	Usability	"	Divisibility [PS10]	Information quality [PS4]
15	Uniformity	"	Compositivity [PS10]	Sound information [PS4]
16	Simplicity	"	Performability [PS10]	Transparency meaningfulness [PS4]
17	User-friendliness	"	Disponability [PS10]	Data transparency [PS4]
18	Understandability	"	User friendliness [PS10]	Process transparency [PS4]
19	Accountability	"	Visibility [PS10]	Free of error [PS4]
20	Information interpretation	"	Traceability [PS10]	Believability [PS4]
21	Relevance	"	Operability [PS10]	Ease of manipulation [PS4]
			Objectivity [PS4]	Reputation [PS4]
			Appropriate amount [PS4]	Security [PS4]

instance, in IS, PS10 conceptualized transparency and provided operationalizations for factors such as accessibility and usability. In SE [PS3], the factors of accessibility, understandability, and relevance were operationalized. However, the factors of transparency that may be used to evaluate transparency at the process level may not be used for assessing transparency at the product level. For example, the transparency metrics proposed in [PS13] cannot be generalized to SE. This difference in operationalizations explains why there are different conceptual argumentation and operationalizations of transparency.

4) RQ1.4—WHAT ARE THE MAIN RESEARCH APPROACHES USED IN CONCEPTUALIZING TRANSPARENCY AND THE CONTEXT OF CONCEPTUALIZATION?

For RQ1.4, Table 11 also shows the two primary contexts in which transparency has been conceptualized and the main research approaches used. The contexts are information and process transparency contexts. The approaches are either qualitative, quantitative, or both.

a: RESEARCH APPROACHES

Two notable approaches found in the primary studies reviewed are qualitative and quantitative. Primary studies [PS4, PS5, PS7, PS8, PS10] used the former approach, which incorporated modeling and survey. Primary study PS13 followed a quantitative approach by defining metrics to evaluate the transparency of information produced by an information system. Their approach also employed modeling. Primary study PS3 adopted a quantitative approach that incorporated experiment and survey. Very few primary studies adopted a quantitative research approach to conceptualizing transparency.

b: DIMENSIONS OF CONCEPTUALIZATION

Based on the reviewed papers, there are two main dimensions in which transparency has been conceptualized: information (information transparency) and process (process transparency) contexts. Most of the conceptualizations reported in the primary studies (e.g., PS10, PS4) have focused on achieving information transparency using a qualitative research approach. Such conceptualizations appeared outside the information or software systems development process. Also, primary studies PS3 and PS13 followed a quantitative research approach in conceptualizing transparency from the context of information transparency.

Concerning the achievement of transparency during software development, only one primary study [PS3] conceptualized transparency in an information context by evaluating the effectiveness of software requirements specifications. Therefore, the operationalization and the approach adopted, therefore, emphasizes the transparency of software artifacts. Furthermore, it further distinguishes the focus of SE transparency conceptualization from IS conceptualizations that have so far been reported in the literature.

5) RQ1.5—WHAT ARE THE METHODS USED TO EVALUATE TRANSPARENCY?

This sub-research question aims to identify and analyze the methods used in evaluating transparency after its conceptualization. If transparency factors are investigated, it is reasonable to consider how such factors are evaluated. In other

TABLE 11. Structural factors of transparency and their relationships.

Article	Factors and Relationships	Context	Research Approach	Evaluation Method	Reference Discipline
PS10	*Accessibility* [portability, availability, publicity] *Informativeness* [clarity, completeness, correctness, current, accuracy, integrity, consistency, Comparable] *Understandability* [dependability, extensibility, composability, decomposability, Conciseness] *Auditability* [traceability, validity, controllability, verifiability, accountability] *Usability* [uniformity, adaptability, simplicity, operability, performability, user-friendliness, Intuitiveness]	Information/Process	Qualitative	Case study, Survey, framework	IS/SE/Bus Mgt.
PS1	*Accessibility* *Understandability* *Relevance*	Information	Quantitative	Experiment, Survey	IS/HCI/SE
PS4	*Transparency Usefulness* [information availability, information interpretation, information accessibility, information perception, information understandability, information acceptance, information actionability] *Information Quality* [Sound Information (free of error, concise representation, completeness, consistent representation), Dependable Information(timeliness, security), Useful Information(appropriate amount, objectivity, relevancy, understandability,interpretability), Usable Information(believability, accessibility, ease of manipulation, reputation, value added)] *Transparency Meaningfulness* [data transparency, process transparency, policy transparency]	Information	Qualitative	Case study, Survey, framework	IS/Bus Mgt./Law/Bus Admin. Info. Mgt.
PS13	*Informativeness* [accuracy, currentness] *Understandability* [conciseness, detailing, readability] *Accessibility* [availability, portability] *Validity* [effectiveness]	Information	Quantitative	Case study	IS/SE/HIS
PS16	*Transparency recipient* [Dependency on information providers, Valuable information, consistent information] *Transparency content* [Availability of information Relevant information, Accessible information] *Presentation of information* [Interpretable information, Easy to understand, Compatible format] *Timeliness of information* [Provide information (before or during or after), Real-time information, Frequency of information provision]	Information	Qualitative	Case study, Survey	IS
PS15	Adopted from (PS4, PS5)	Information	Qualitative		IS

words, the method used to evaluate the implementation of each transparency factor. For instance, factors such as accessibility, relevance, understandability can be evaluated through a survey or experiment. Existing studies on transparency may report different methods to assess transparency achievement.

All the 18 primary studies were assessed for any form of evidence that demonstrates transparency achievement evaluation. Primary studies that did not provide any assessments are not included as part of this category.

a: EXPERIMENTS WITH TRANSPARENCY

In this study, we systematically reviewed the conceptualization and operationalization of transparency. In this vein, retrieving and assessing primary studies that reported experiments using transparency formed part of our research questions (RQ1.5) in addition to other studies that reported other forms of evidence outside experiments.

In order to identify what constitutes an experiment, we borrowed the definition and view provided in [58], [59], and [60]. According to Sjøberg *et al*. [60], ''controlled'' experiments are undertaken by either individuals or a group of individuals by conducting tasks to compare treatments in terms of varying processes, populations, and methods, for instance. As explained in Cook *et al*. [61], we also considered randomized and quasi-experiments since they are also used in SE.

All included primary studies were assessed for experiments. However, only two primary studies [PS2, PS3] from the same authors reported a controlled experiment. Primary study PS2 is a conference paper that was later extended and published as an article [PS3] in the Empirical Software Engineering journal.

b: CASE STUDY, SURVEY, AND FRAMEWORK

To not be biased in our review, we also included studies that employed other methods for evaluating transparency. We understand that since transparency is multifaceted, evaluating its achievement need not necessarily involve performing controlled experiments, as is often the case when concepts or theories are formulated. Primary studies [PS10, PS4] evaluated transparency using various case studies together with surveys. In [PS13], the authors' defined metrics were used to evaluate transparency achievement in their case study. In [PS7], a framework that combines a transparency modeling language was proposed, and an evaluation was performed using a case study. In [PS15], the researchers also presented a framework to evaluate transparency, but the actual evaluation was yet to be reported.

E. RQ2—WHAT ARE THE EXISTING OPERATIONALIZATIONS OF TRANSPARENCY?

Previously in Section V-D, we provided the existing factors of transparency. This section presents various operationalizations of transparency based on the proposed factors. As previously explained in Section II, operationalization involves the actual use of the factors of a concept in measuring the achievement of the concept. An operationalization, therefore, provides evidence of the practical significance of the concept that is being examined in a real-world scenario. It also analyses the extent of the use of the transparency concept. Thus, transparency remains a valuable concept. All the articles reviewed in this study demonstrated the usefulness of transparency.

c: OPERATIONALIZATIONS

Table 12 presents a summary of the implementations and measurement of transparency. It also indicates whether the operationalization was within an information or process transparency dimension. Transparency has been proven useful in improving business processes, as reported in Leite and Cappelli [PS10]. Transparency has also been applied in analyzing election systems with security and e-government websites [PS10]. Transparency has also proven useful in evaluating software requirements documents' effectiveness in [PS2, PS3]. Hosseini *et al*. [PS4] used the concept of transparency to analyse the UK's information act. Spagnuelo and Lenz [PS18] demonstrated that transparency could be achieved in an online health information management system. These operationalizations are fulfilling the demand for transparency by stakeholders at various levels and dimensions. Transparency has also been applied to intelligent environments [PS15] and social platforms [PS17].

d: EXTENT OF OPERATIONALIZATION

Concerning the extent of the operationalization of transparency, we considered primary studies that adopted existing concepts of transparency to further research on transparency by applying it to other domains or providing new conceptual argumentation. As an emerging concept, we found the extent of the operationalization of transparency to be minimal. For example, in SEP, only studies by Tu *et al*. [PS2, PS3], to the best of our knowledge, have attempted to consider the achievement and evaluation of transparency in the SDLC requirements engineering phase. We did not encounter any primary study that used the conceptualization by Tu *et al*. to further research transparency. For instance, the primary study PS15 applied the transparency conceptualization provided in [PS4, PS5].

Though other studies (e.g., PS4, PS5, PS10) from the information systems point of view focused on managing transparency requirements in information transparency and process transparency contexts, Tu *et al*. instead focused on achieving transparency requirements in an IT context but considering the transparency of software artifacts. Their work shows that transparency can also be realized in the way functional requirements of a system are represented as requirements and design documents by choosing requirements or a design development paradigm that encourages transparency.

F. RQ3—WHAT ARE THE CHALLENGES WITH OPERATIONALIZING TRANSPARENCY?

One of the key challenges in applying transparency is inherent in the concept itself. It is a complex concept with varying ambiguities [PS10, PS4, PS13]. For instance, the demand and provision of transparency should not antagonize security and confidentiality requirements [39], [62]. This aspect is beyond the scope of our study. However, Serrano *et al*. [62] provided how transparency might be achieved without compromising the security and confidentiality of information.

Out of the 18 primary studies reviewed, four primary studies [PS3, PS10, PS4, PS13] provided clear challenges with implementing transparency. For example, Leite and Cappelli [PS10] outlined the challenges of incorporating transparency in the SEP. These challenges include trust in requirements that are intended to provide transparency, the cost of incorporating transparency in SEP without increasing overall development cost, performance in terms of the assurance of trust without interference with the performance of the system itself and lastly, how to deal with the public as ''customers.'' According to the authors, the last challenge stems from the fact that software engineers appear not to be too familiar with dealing with people in the real sense of a ''customer'', which requires different strategies.

According to the authors in [PS4], the challenge with achieving transparency lies in the financial cost of implementation, coupled with the required time to realize the implementation. Their position on monetary cost aligns with the position in [PS10]. To reduce the burden of implementing transparency, the authors suggested developing software tools and techniques that would enable the achievement of transparency. The incorporation of these tools and techniques would potentially encourage stakeholders to participate in the transparency initiative. Besides the challenges in terms of time and money, Hosseini *et al*. [PS6] highlighted other challenges, including the complexity of specifying accurate stakeholders' transparency requirements and agreeable transparency requirements by all competing interests within and outside the organization.

In [PS13], the authors opined that the design and implementation of transparency could result in risk exposure since information systems and their information are made transparent to stakeholders. There is, therefore, a need to have technically skilled people who can understand and deal appropriately with the information. The authors also suggested using tools that can aid stakeholders in this regard.

As it concerns software engineering, transparency appears to be in its formative stage. The challenge with achieving it is providing appropriate transparency requirements and measures that the stakeholders can utilize during information or software system development. The authors in [PS2, PS3] have explicitly called for transparency measures to be provided in this regard.

VI. DISCUSSION

In this section, we discuss the SLR findings and the limitations of the review and provide future research directions.

A. DISCUSSION ON HOW TRANSPARENCY HAS BEEN CONCEPTUALIZED IN INFORMATION SYSTEMS AND SOFTWARE ENGINEERING (RQ1)

In order to investigate how transparency has so far been conceptualized in IS and SE sub-disciplines of computing, it was reasonable to compile the existing definitions of transparency (RQ1.1); identify the current factors of transparency, and their relationships (RQ1.2); the origins or reference disciplines of the constructs (RQ1.3); identify fundamental research approaches used in conceptualizing transparency and the context of conceptualization (RQ1.4), and the methods used to evaluate transparency achievement (RQ1.5). The answers to these questions have already been provided in the previous section.

The primary studies we have reviewed in this SLR have conceived transparency as a non-functional requirement (NFR) and a new quality of information or software systems and processes they support. Transparency, therefore, stands as an additional quality concept to be considered among other NFRs provided in [55]. The SLR, thus, explores transparency from the point of view of concepts and then highlights the need for theories that support transparency. The studies in [41] and [42] have further shown why transparency should be approached from a conceptual and theoretical point of view. Adopting such an approach enabled us to identify the concept of transparency in terms of its describing factors, means of representation, structural components, and relationships between factors.

Early research on transparency argued that transparency is a concept that is best approached as a requirements engineering (RE) activity. All the reviewed studies appeared to agree with the approach. This approach is motivated because requirements engineering is the first and crucial phase of software or information systems development. During this phase, we believe that stakeholders' transparency requirements can be elicited and analyzed by a transparency implementation and evaluation team (TIET) that would need to be set up within an organization. Therefore, we envisage that an organization serious about incorporating transparency in its software development or organizational process would need to establish TIET for that purpose.

Furthermore, it is essential to note that transparency requirements can sometimes be related to the functional and non-functional requirements of a software or information system. After an elicitation activity, the TIET would have to identify appropriate transparency factors and sub-factors that may be used to evaluate the transparency and the evaluation method. The current SLR catalogs existing factors of transparency that will be useful in this regard. Since the catalog may not address all transparency requirements in all domains and contexts of interest, additional factors would have to be developed.

TABLE 12. Operationalizations of transparency.

Factors	Application	Context	Reference
- Transparency usefulness - Information quality - Transparency meaningfulness	Evaluation of transparency in the UK Information Act.	IT	PS4
- Accessibility - Usability - Informativeness - Auditability	•Evaluation of transparency in an online patient's health information system	IT	PS10
	•Evaluation of the transparency of a software acquisition process	PT	
	•Evaluation of the transparency of government website	IT	
- Accessibility - Usability - Relevance	Empirically evaluated the transparency of text-based SRS and use case model-based SRS in terms of effective communication.	IT	PS3
- Informativeness - Understandability - Accessibility - Validity	Evaluation of transparency in an online patient's health information system.	IT	PS18

B. DISCUSSION ON EXISTING TRANSPARENCY OPERATIONALIZATIONS (RQ2)

Transparency's complex and multifaceted nature presents different opportunities for its operationalization during information or software systems development. An operationalization of transparency involves an actual implementation of any of the factors of transparency in a specific domain of interest and context. Stakeholders, especially developers, may utilize the factors of transparency we have cataloged in this paper when transparency achievement is being considered. The catalog, therefore, serves as a reference point for transparency operationalization.

Based on the reviewed studies, there are very few operationalizations of transparency. The reason may be that transparency is still yet to be supported by theories that enhance its understanding, thereby making it more useful. Operationalizations that followed a conceptual or theoretical point of view appeared very limited. Apart from the few previously highlighted examples of transparency operationalizations, other aspects of the information or software development process, including organizational processes, can also benefit from transparency operationalization.

C. DISCUSSION ON THE CHALLENGES WITH OPERATIONALIZING TRANSPARENCY (RQ3)

The complex characteristics of transparency require that when operationalized by TIET, it must be adapted to address the concerns of the domain and context in which it is being operationalized. This expectation is even more as there is an abundance of factors that helps the operationalization of transparency, as the catalog of factors indicates. The challenge concerning the cost of incorporating transparency into the general information or software systems development implies that any initiative that aims to introduce transparency must factor in the cost concerning the budget earmarked for the whole software development project. Apart from the financial cost, a transparency initiative should be such that it does not affect the project's delivery time.

There is also a need to address the problem of trust on the part of clients when stakeholders' transparency requirements are introduced and the reorientation of software developers to handle clients as customers. Since transparency operationalization and evaluation will be conducted based on stakeholders' transparency requirements, stakeholders must agree on a set of transparency requirements that should be evaluated and how the assessment could be achieved. This approach helps to overcome some of the challenges. The SE-based primary studies have shown a need to provide a measurement for transparency during software development. Providing a measurement in this regard will involve adopting a quantitative research approach and conducting experiments to ascertain the level of transparency achievement.

D. RESEARCH LIMITATION

In order to identify the concept of transparency and its various conceptualizations and operationalizations, this study relied on well-established guidelines for identifying theories and concepts [46], [47]. The data extraction criteria were also motivated by the same guidelines and the research questions. The SLR identified transparency as a concept in terms of describing factors and relationships between the factors. The SLR did not accommodate studies on transparency that do not consider it a concept. It is also important to emphasize that several studies that did not consider transparency as a first-class concept were also not included in the SLR. Studies that treated transparency in union with antagonizing concepts such as security and privacy were not considered in the current SLR. We hope to embark on another SLR that would accommodate such studies.

E. PROPOSED ROADMAP FOR TRANSPARENCY CONCEPTUALIZATION AND EVALUATION

The findings from the SLR make it imperative to provide a plan or template that will not only enable the evaluation of transparency achievement but stimulate further research on transparency conceptualization. Since the SLR did not find a clear plan to understand and evaluate transparency, this finding motivated and informed the roadmap to

inspire and stimulate more interest in transparency research. The proposed roadmap is presented in Fig. 6. It captures a sequence of steps and essential constructs necessary to achieve a transparency conceptualization and the evaluation of transparency achievement. These steps, including the valuable constructs involved, are briefly explained as follows.

1) INITIAL CONCEPTION

Our approach to achieving transparency in software engineering aligns with the view that it should be conceived as a requirements engineering activity. This approach is inspired by Professor John Mylopoulos, who opined in [5] that "transparency is an interesting quality because it makes it necessary to attach requirements models to software." Since transparency is a requirement of the stakeholders of an information or software system or process, it is reasonable to initiate its implementation and measurement during the requirements engineering phase of the software engineering process. During the requirements engineering phase, transparency requirements analysts can elicit stakeholders' transparency requirements and other normal requirements demanded of the software artifacts and software itself.

Though the SLR identified several existing definitions of transparency, the findings from this study and our belief in approaching transparency achievement from a transparency requirements engineering activity inspire us to provide a new definition to help our understanding and operationalization of transparency further. In this study, transparency refers to the degree to which information about a process or software/software artifact is made open to the stakeholders of a software engineering project. The process, as used here, includes automated or unautomated business or organizational processes such as software life cycle processes. As a caveat, a successful operationalization of the proposed definition will depend on establishing stakeholders' transparency requirements as a prerequisite to transparency operationalization. It is the fulfillment of the transparency requirements that would ensure the openness of information to stakeholders.

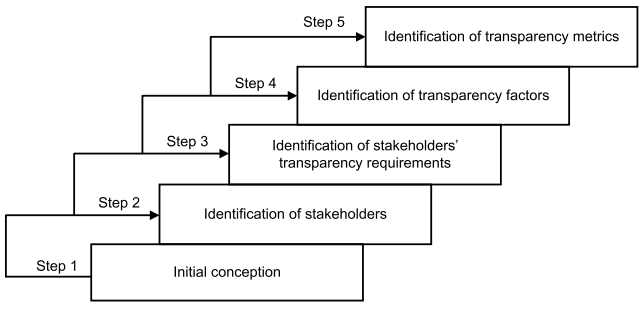

FIGURE 6. A roadmap for transparency evaluation.

2) IDENTIFICATION OF STAKEHOLDERS

In this step, it is important to identify all stakeholders of the software system or the organizational process who may express various concerns regarding transparency. Transparency may not be achieved if all stakeholders who demand transparency are not involved in the transparency implementation and evaluation process.

3) TRANSPARENCY REQUIREMENTS

From a transparency requirements engineering point of view, for software processes and software/software artifacts to be made open to stakeholders, a set of stakeholders' transparency requirements will have to be established. Software processes and software/software artifacts would be deemed transparent or open to stakeholders if the set of pre-established stakeholders' transparency requirements is fulfilled. Therefore, in this step, it is necessary to collect all stakeholders' transparency requirements related to either the software that is being developed or any other business process (e.g., software life cycle processes) that may not be automated. To this end, it is the achievement of these transparency requirements that would be evaluated.

4) IDENTIFICATION OF TRANSPARENCY FACTORS

This step is concerned with identifying transparency factors that can be used to evaluate the achievement of the requirements provided in the preceding step. Successful identification and collection of transparency factors mean that operationalizations that demonstrate the usefulness of each factor in assessing transparency requirements can be considered. Since operationalization is the empirical measurement of a concept such as transparency, it would indicate the practical significance of each transparency-defining factor.

5) TRANSPARENCY METRICS

This step focuses on identifying measures and metrics that, in turn, assess the transparency factors identified in step 5. This step involves the actual operationalization of each factor of transparency towards the fulfillment of a targeted stakeholders' transparency requirement. The benefits of transparency conceptualization and operationalization will be incomplete if the transparency metrics are not used to improve stakeholders' transparency. For example, a poor transparency evaluation outcome would mean that the transparency of the evaluated software/software artifact or process will need to be improved upon. These identified critical elements of the proposed roadmap feed into a conceptual framework currently being developed as part of the first author's PhD work.

Summarily, the proposed roadmap serves as an early blueprint or steps that can be followed to evaluate transparency. Opportunities for further transparency research are provided in the next section.

F. OPPORTUNITIES FOR FURTHER RESEARCH

One of the significant findings of this study is that transparency has been majorly conceptualized as a non-functional requirement. It is also a non-functional requirement that is

seldom approached from theory and empirical points of view. We also found from the reviewed studies that transparency is under-researched and under-applied, at least from the standpoint of our SLR study. This outcome lends credence to similar findings reported in [41] and [42] but in another domain outside computing. In this vein, our SLR may serve as evidence and a reference for transparency conceptualization in SE and IS.

More than a decade after its initial conceptualization, transparency appears not to have progressed in academia and the industry from our research perspective. This outcome is evident from the limited number of primary studies we found to have conceptualized and applied transparency in various contexts and disciplines, especially in IS and SE. The limited number of primary studies also appears to suggest a lack of interest in transparency research.

The current study also found that the operationalizations of transparency are limited. As most of the primary studies reported, the applications we encountered mostly served as proofs-of-concept. Beyond these applications, transparency is yet to be fully recognized and incorporated as a requirement that improves an organization's software development process, software artifacts, and the software itself. There is, therefore, a need to establish a recognizable and valuable transparency improvement model or standard that organizations can adapt to any existing software engineering process improvement program.

1) NEED FOR TAILORED CONCEPTUALIZATIONS AND OPERATIONALIZATIONS

The study identified several factors of transparency, including their proposed relationships. Given the numerous factors we have cataloged, achieving all stakeholders' transparency requirements is impossible without overburdening the software engineering process. To reduce the burden, there is a need for research that provides tailored argumentation of transparency in the software engineering context. Also, because transparency is complex and multifaceted, a transparency solution is hardly a one-size-fits-all solution; hence tailored transparency conceptualizations and operationalizations are needed for software, software artifacts, and processes (including other organizational processes) that give birth to them.

2) NEED TO EXPLORE OTHER PHASES OF INFORMATION OR SOFTWARE SYSTEMS DEVELOPMENT

Only one primary study conceptualized transparency in an information transparency context and within the requirements engineering phase. Therefore, the study results cannot be generalized to the other phases of the software development process. A transparency realization initiative within the software development process should consider the various phases of development in software engineering. The benefit of achieving transparency during software development is yet to be fully explored as other phases of development remain unexplored. The reviewed primary study evaluated the transparency of software requirements specifications. Further studies can investigate how other software artifacts such as design documents and code and their corresponding process models could benefit from transparency.

3) NEED FOR MORE EXPERIMENTS AND FORMALIZATION OF TRANSPARENCY

In SE, transparency has witnessed limited research and application, unlike IS, with more published studies and applications of transparency. However, we still considered the IS studies to be few, given the period of our SLR coverage. Based on our results, only two primary studies reported an experiment on transparency evaluation by stakeholders in SEP. A single experiment is not sufficient for providing scientific evidence that supports the usefulness of transparency in software development.

In software development, providing scientific and practical evidence (formalization) that supports transparency would make transparency interesting to the research community and valuable in the industry. Also, such evidence can potentially serve as a pathway to the development of a standard or model for a transparency implementation and improvement program that complements the software engineering process capability maturity model that is in use by most software companies. Our proposed roadmap lays a foundation for our quest to formalize and create a standard for a transparency improvement initiative.

VII. CONCLUSION

In this study, we conducted a systematic literature review of the conceptualization and operationalization of transparency. Our findings revealed that transparency had been conceived as a non-functional quality of the stakeholders of software or processes. Based on the reviewed studies, most researchers opined that the best approach to achieving transparency is to consider it a requirements engineering activity. In SE and IS, transparency is yet an emerging concept, which remains rarely approached from a theoretical and empirical standpoint. It also revealed that research on transparency and its practical applications is limited, especially in SE. The paucity of papers could suggest that transparency no longer trends as a concept of research in computing.

Most of the articles we reviewed have conceptualized transparency in an information context. Only three SE studies focused on conceptualizing and applying transparency to the software engineering process as they focused on the transparency of software artifacts. We did not find any study that altogether provided empirical evidence showing cause-effect relationships between the structural factors from a theory point of view. The lack of empirical studies presents a challenge, especially when considering the transparency of software and software artifacts. There is a need for further research on transparency, especially its formalization. We hope the current study will help stimulate further research and reawaken interest in transparency research.

APPENDIX

TABLE A1. Reviewed Primary Studies

ID	Reference	Institution	Citation Count	Reference Identifier
PS1	Tu, Y.-C., Thomborson, C., and Tempero, E., "Illusions and perceptions of transparency in software engineering," in 18th Asia-Pacific Software Engineering Conference, Ho Chi Minh, Vietnam, 2011: IEEE, pp. 365-372.	University of Auckland, New Zealand	11	[1]
PS2	Tu, Y.-C., Tempero, E., Thomborson, C.: 'Evaluating presentation of requirements documents: Results of an experiment'. In: Requirements Engineering. (Springer,2014. pp. 120–134)	"	2	[2]
PS3	Tu, Y.-C., Tempero, E., & Thomborson, C. (2016). An experiment on the impact of transparency on the effectiveness of requirements documents. Empirical Software Engineering, 21, 1035–1066.	"	21	[3]
PS4	Hosseini, M., Shahri, A., Phalp, K., and Ali, R., "Four reference models for transparency requirements in information systems," Requirements Engineering, 2018.	University of Bournemouth, United Kingdom	70	[4]
PS5	Hosseini, M., Shahri, A., Phalp, K., and Ali, R., "Foundations for transparency requirements engineering," in Proceedings of the 22nd International Working Conference on Requirements Engineering: Foundation for Software Quality, Gothenburg, Sweden, 2016, vol. 9619: Springer-Verlag,	"	24	[5]
PS6	Hosseini, M., Shahri, A., Phalp, K., and Ali, R., "Towards engineering transparency as a requirement in socio-technical systems," in 2015 IEEE 23rd International Requirements Engineering Conference (RE), 2015, pp. 268-273.	"	16	[6]
PS7	Hosseini, M., Shahri, A., Phalp, K., and Ali, R., "Engineering transparency requirements: A modelling and analysis framework," Information Systems, 2018.	"	14	[7]
PS8	Cappeli, C., Leite, J. C. S. d. P., and Oliveira, A. d. P. A., "Exploring Business Process Transparency Concepts," in 15th IEEE International Requirements Engineering Conference (RE 2007), 2007, pp. 389-390.	PUC-Rio, Brazil	35	[8]
PS9	Leite, J. C. S. d. P. and Cappeli, C., "Exploring i* Characteristics that Support Software Transparency," in CEUR Workshop Proceedings, Recife, Pernambuco, Brazil, 2008, pp. 51-54.	"	36	[9]
PS10	Leite, J. C. S. d. P. and Cappelli, C., "Software Transparency," Business & Information Systems Engineering, 2010	"	145	[10]
PS11	Hosseini, M., Shahri, A., Phalp, K., & Ali, R. (2016). A modelling language for transparency requirements in business information systems. Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 9694. -5_15	University of Bournemouth, United Kingdom	31	[11]
PS12	Spagnuelo, D. and Lenzini, G., "Transparent Medical Data Systems," J. Med. Syst., vol. 41, no. 1, pp. 1-12, Spagnuelo2017a 2017.	University of Luxembourg, Luxembourg	18	[12]
PS13	Spagnuelo, D., Bartolini, C., and Lenzini, G., "Metrics for Transparency," Cham, 2016: Springer International Publishing, pp. 3-18.	"	10	[13]
PS14	Spagnuelo, D., Bartolini, C., and Lenzini, G., "Modelling Metrics for Transparency in Medical Systems," Cham, 2017: Springer International Publishing, pp. 81-95.	"	6	[14]

TABLE A1. *(Continued).* **Reviewed Primary Studies**

ID	Reference	Institution	Citation Count	Reference Identifier
PS15	Amiribesheli, M., Hosseini, M., & Bouchachia, H. (2016). A principle-based transparency framework for intelligent environments. Proceedings of the 30th International BCS Human Computer Interaction Conference, HCI 2016, 2016-July.	University of Bournemouth, United Kingdom	4	[15]
PS16	Alsaedi, T., Stefanidis, A., Phalp, K., & Ali, R. (2019). Social Transparency in Enterprise Information Systems: Peculiarities and Assessment Factors. BESC 2019 - 6th International Conference on Behavioral, Economic and Socio-Cultural Computing, Proceedings.	University of Bournemouth, United Kingdom	3	[16]
PS17	Alsaedi, T., Phalp, K., & Ali, R. (2019). Towards an assessment method for social transparency in enterprise information systems. Proceedings - IEEE International Enterprise Distributed Object Computing Workshop, EDOCW, 2019-October.	"	2	[17]
PS18	Spagnuelo, D., Bartolini, C., & Lenzini, G. (2020). Qualifying and measuring transparency: A medical data system case study. Computers & Security, 91, 101717.	University of Luxembourg, Luxembourg	5	[18]

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REFERENCES

[1] R. E. Oliver, *What is transparency?* New York, NY, USA: McGraw-Hill, 2004.
[2] G. Rowe and L. J. Frewer, "Public participation methods: A framework for evaluation," *Sci. Technol. Hum. Values*, vol. 25, no. 1, pp. 3–29, Jan. 2000.
[3] B. Holzner and L. Holzner, *Transparency in Global Change: The Vanguard of the Open Society*. Pittsburgh, PA, USA: Univ. of Pittsburgh Press, 2006.
[4] C. Cappelli, J. C. S. D. P. Leite, and A. D. P. A. Oliveira, "Exploring business process transparency concepts," in *Proc. 15th IEEE Int. Requirements Eng. Conf. (RE)*, Delhi, India, Oct. 2007, pp. 389–390.
[5] J. C. S. D. P. Leite and C. Cappelli, "Exploring i* characteristics that support software transparency," in *Proc. CEUR Workshop*, Recife, Brazil, Feb. 2008, pp. 51–54.
[6] Y.-C. Tu, E. Tempero, and C. Thomborson, "An experiment on the impact of transparency on the effectiveness of requirements documents," *Empirical Softw. Eng.*, vol. 21, no. 3, pp. 1035–1066, Jun. 2016.
[7] Y.-C. Tu, C. Thomborson, and E. Tempero, "Illusions and perceptions of transparency in software engineering," in *Proc. 18th Asia–Pacific Softw. Eng. Conf.*, Ho Chi Minh City, Vietnam, Dec. 2011, pp. 365–372.
[8] P. Meunier, "Software transparency and purity," *Commun. ACM*, vol. 51, no. 2, p. 104, Feb. 2008.
[9] D. Ince, *A Dictionary of the Internet*. New York, NY, USA: Oxford Univ. Press, 2017.
[10] J. E. Mercado, M. A. Rupp, J. Y. C. Chen, M. J. Barnes, D. Barber, and K. Procci, "Intelligent agent transparency in human–agent teaming for multi-UxV management," *Hum. Factors, J. Hum. Factors Ergonom. Soc.*, vol. 58, no. 3, pp. 401–415, May 2016.
[11] A. Dhananjayan and K. T. Seow, "A formal transparency framework for validation of real-time discrete-event control requirements modeled by timed transition graphs," *IEEE Trans. Human-Mach. Syst.*, vol. 45, no. 3, pp. 350–361, Jun. 2015.
[12] M. Eiband, H. Schneider, M. Bilandzic, J. Fazekas-Con, M. Haug, and H. Hussmann, "Bringing transparency design into practice," in *Proc. 23rd Int. Conf. Intell. User Interfaces*, Tokyo, Japan, 2018, pp. 211–223.
[13] J. Ahn and S. Hur, "Improving adaptability and transparency of dynamically changing mobile agent runtime environments," in *Proc. Pacific Rim Int. Workshop Multi-Agents*. Guilin, China: Springer, 2006, pp. 754–759.
[14] Departamento de Informática PUC-Rio. *Software Transparency*. Accessed: Jun. 25, 2019. [Online]. Available: http://transparencia.inf.puc-rio.br/english/eng_index.html
[15] B. Kitchenham and S. Charters, "Guidelines for performing systematic literature reviews in software engineering version 2.3," Keele Univ., Keele, U.K., Tech. Rep. 1595933751, 2007.
[16] J. C. S. D. P. Leite and C. Cappelli, "Software transparency," *Bus. Inf. Syst. Eng.*, vol. 2, no. 3, pp. 127–139, Jun. 2010.
[17] M. DeCarlo, *Scientific Inquiry in Social Work*. USA: Open Social Work Education, 2018.
[18] C. W. Mueller, "Conceptualization, operationalization, and measurement," *Encyclopedia Social Sci. Res. Methods*, vol. 1, no. 163, pp. 1–8, 2004.
[19] B. Blackwelder, K. Coleman, S. Colunga-Santoyo, J. S. Harrison, and D. Wozniak, "The Volkswagen scandal. Case study," Robins School Bus., Univ. Richmond, 2016.
[20] P. Johnston and R. Harris, "The Boeing 737 MAX saga: Lessons for software organizations," *Softw. Qual. Prof.*, vol. 21, no. 3, pp. 4–12, Jun. 2019.
[21] R. L. Q. Portugal, P. Engiel, H. Roque, and J. C. S. do Prado Leite, "Is there a demand of software transparency?" in *Proc. 31st Brazilian Symp. Softw. Eng. (SBES)*, Fortaleza, Brazil, 2017, pp. 204–213.
[22] R. T. Mercuri, "Trusting in transparency," *Commun. ACM*, vol. 48, no. 5, pp. 15–19, May 2005.
[23] L. Dabbish, C. Stuart, J. Tsay, and J. Herbsleb, "Leveraging transparency," *IEEE Softw.*, vol. 30, no. 1, pp. 37–43, Jan. 2013.

[24] M. Hosseini, A. Shahri, K. Phalp, and R. Ali, "Towards engineering transparency as a requirement in socio-technical systems," in *Proc. IEEE 23rd Int. RequirementS Eng. Conf. (RE)*, Ottawa, ON, Canada, Aug. 2015, pp. 268–273.
[25] C. Cappeli, "An approach for business processes transparency using aspects," Ph.D. dissertation, Dept. Informática, PUC-Rio, Rio de Janeiro, Brazil, 2009.
[26] J. C. S. D. P. Leite, "The prevalence of code over models: Turning it around with transparency," in *Proc. IEEE 8th Int. Model-Driven Requirements Eng. Workshop (MoDRE)*, Aug. 2018, pp. 56–57.
[27] S. Berthold, S. Fischer-Hübner, L. Martucci, and T. Pulls, "Crime and punishment in the cloud: Accountability, transparency, and privacy," in *Proc. DIMACS/BIC/A4Cloud/CSA Int. Workshop Trustworthiness, Accountability Forensics Cloud (TAFC)*, Malaga, Spain, Apr. 2013, pp. 1–8.
[28] K. Brennan-Marquez and D. Susser, "Obstacles to transparency in privacy engineering," in *Proc. IEEE Secur. Privacy Workshops (SPW)*. San Jose, CA, USA: IEEE, May 2016, pp. 49–52.
[29] O. Zinovatna and L. M. Cysneiros, "Reusing knowledge on delivering privacy and transparency together," in *Proc. IEEE 5th Int. Workshop Requirements Patterns (RePa)*. Ottawa, ON, Canada: IEEE, Aug. 2015, pp. 17–24.
[30] M. Hosseini, A. Shahri, K. Phalp, and R. Ali, "Four reference models for transparency requirements in information systems," *Requirements Eng.*, vol. 23, no. 2, pp. 251–275, Jun. 2018.
[31] D. Spagnuelo, C. Bartolini, and G. Lenzini, "Qualifying and measuring transparency: A medical data system case study," *Comput. Secur.*, vol. 91, Apr. 2020, Art. no. 101717.
[32] Y.-C. Tu, E. Tempero, and C. Thomborson, "Evaluating presentation of requirements documents: Results of an experiment," in *Requirements Engineering*. Auckland, New Zealand: Springer, 2014, pp. 120–134.
[33] L. Chazette and K. Schneider, "Explainability as a non-functional requirement: Challenges and recommendations," *Requirements Eng.*, vol. 25, no. 4, pp. 493–514, Dec. 2020.
[34] C. Fernández-Gago and D. Nuñez, "Metrics for accountability in the cloud," in *Summer School Accountability Security Cloud*. Malaga, Spain: Springer, Jun. 2014, pp. 129–153.
[35] D. Nunez, C. Fernandez-Gago, S. Pearson, and M. Felici, "A metamodel for measuring accountability attributes in the cloud," in *Proc. IEEE 5th Int. Conf. Cloud Comput. Technol. Sci.*, vol. 1. Marrakesh, Morocco: IEEE, Dec. 2013, pp. 355–362.
[36] D. Antoni, A. Bidar, M. I. Herdiansyah, and M. Akbar, "Critical factors of transparency and trust for evaluating e-government services for the poor," in *Proc. 2nd Int. Conf. Informat. Comput. (ICIC)*. Papua, Indonesia: IEEE, Nov. 2017, pp. 1–6.
[37] L. M. Cysneiros, M. Raffi, and J. C. S. D. P. Leite, "Software transparency as a key requirement for self-driving cars," in *Proc. IEEE 26th Int. Requirements Eng. Conf. (RE)*. Banff, AB, Canada: IEEE, Aug. 2018, pp. 382–387.
[38] M. Amiribesheli, M. Hosseini, and H. Bouchachia, "A principle-based transparency framework for intelligent environments," in *Proc. Electron. Workshops Comput.* Poole, U.K.: Bournemouth Univ., Jul. 2016, pp. 1–6.
[39] C. Cappelli, H. Cunha, B. Gonzalez-Baixauli, and J. Cesar, "Transparency versus security: Early analysis of antagonistic requirements," in *Proc. ACM Symp. Appl. Comput. (SAC)*, Sierre, Switzerland, 2010, pp. 298–305.
[40] L. Chazette, "Mitigating challenges in the elicitation and analysis of transparency requirements," in *Proc. IEEE 27th Int. Requirements Eng. Conf. (RE)*, Jeju Island, South Korea, Sep. 2019, pp. 470–475.
[41] G. Michener and K. Bersch, "Identifying transparency," *Inf. Polity*, vol. 18, no. 3, pp. 233–242, Oct. 2013.
[42] K. Bersch and Greg Michener, "Conceptualizing the quality of transparency," in *Proc. 1st Global Conf. Transparency*. Newark, NJ, USA: Rutgers Univ., 2011.
[43] M. J. Page, J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, L. Shamseer, J. M. Tetzlaff, E. A. Akl, S. E. Brennan, and R. Chou, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *Syst. Rev.*, vol. 10, no. 1, Dec. 2021, Art. no. 105906.
[44] M. Hunt, *How Science Takes Stock: The Story of Meta-Analysis*. Newbury Park, CA, USA: Sage, 1997.
[45] A. Meneely, B. Smith, and L. Williams, "Validating software metrics: A spectrum of philosophies," *ACM Trans. Softw. Eng. Methodol.*, vol. 21, no. 4, p. 24, 2012.
[46] J. E. Hannay, D. I. K. Sjoberg, and T. Dyba, "A systematic review of theory use in software engineering experiments," *IEEE Trans. Softw. Eng.*, vol. 33, no. 2, pp. 87–107, Feb. 2007.
[47] S. Gregor, "The nature of theory in information systems," *MIS Quart.*, vol. 30, no. 3, pp. 611–642, Sep. 2006.
[48] K. O. Solomon, D. L. Medin, and E. Lynch, "Concepts do more than categorize," *Trends Cogn. Sci.*, vol. 3, no. 3, pp. 99–105, Mar. 1999.
[49] D. I. Sjøberg, T. Dybå, B. C. Anda, and J. E. Hannay, "Building theories in software engineering," in *Guide to Advanced Empirical Software Engineering*. London, U.K.: Springer, 2008, pp. 312–336.
[50] D. A. Whetten, "What constitutes a theoretical contribution?" *Acad. Manage. Rev.*, vol. 14, no. 4, pp. 490–495, Oct. 1989.
[51] C. Wohlin, P. Runeson, M. Höst, M. C. Ohlsson, B. Regnell, and A. Wesslén, *Experimentation Software Engineering*. New York, NY, USA: Springer, 2012.
[52] J. Vilela, J. Castro, L. E. G. Martins, and T. Gorschek, "Integration between requirements engineering and safety analysis: A systematic literature review," *J. Syst. Softw.*, vol. 125, pp. 68–92, Mar. 2017.
[53] M. Gasparic and A. Janes, "What recommendation systems for software engineering recommend: A systematic literature review," *J. Syst. Softw.*, vol. 113, pp. 101–113, Mar. 2016.
[54] X. Zhou, Y. Jin, H. Zhang, S. Li, and X. Huang, "A map of threats to validity of systematic literature reviews in software engineering," in *Proc. 23rd Asia–Pacific Softw. Eng. Conf. (APSEC)*. Hamilton, New Zealand: IEEE, 2016, pp. 153–160.
[55] L. Chung, B. Nixon, E. Yu, and J. Mylopoulous, *Non-Functional Requirements in Software Engineering*. Boston, MA, USA: Kluwer, 2000.
[56] *Systems and Software Engineering: Systems and Software Quality Requirements and Evaluation (SQuaRE): Measurement of System and Software Product Quality*, ISO, Geneva, Switzerland, 2016.
[57] C. M. MacKenzie, K. Laskey, F. McCabe, P. F. Brown, R. Metz, and B. A. Hamilton, "Reference model for service oriented architecture 1.0," *OASIS Standard*, vol. 12, no. S18, pp. 1–31, Aug. 2006.
[58] T. A. Kroeger, N. J. Davidson, and S. C. Cook, "Understanding the characteristics of quality for software engineering processes: A grounded theory investigation," *Inf. Softw. Technol.*, vol. 56, no. 2, pp. 252–271, Feb. 2014.
[59] D. T. Campbell and J. C. Stanley, *Experimental and Quasi-Experimental Designs for Research*. Burlington, MA, USA: Ravenio Books, 2015.
[60] D. I. K. Sjoeberg, "A survey of controlled experiments in software engineering," *IEEE Trans. Softw. Eng.*, vol. 31, no. 9, pp. 733–753, Sep. 2005.
[61] T. D. Cook, D. T. Campbell, and W. Shadish, *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*. Boston, MA, USA: Houghton Mifflin, 2002.
[62] M. Serrano and J. C. S. D. P. Leite, "Capturing transparency-related requirements patterns through argumentation," in *Proc. 1st Int. Workshop Requirements Patterns*, Trento, Italy, Aug. 2011, pp. 1–10.

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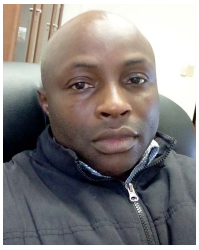

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