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STATE OF THE ART

Self-reporting Limitations in Information Systems Design Science Research

Typology and Guidelines

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Abstract Besides increasing transparency and demonstrating awareness of the author, self-reported limitations enable other researchers to effectively learn from, build on, validate, and extend the original work. However, this topic is understudied in information systems design science research (IS DSR). The study has assessed 243 IS DSR papers published in the period 2013–2022 and built a typology of the 19 most relevant limitations, organized into four categories: (1) Input Knowledge and Technology, (2) Research Process, (3) Resulting Artifact, and (4) Design Knowledge. Further, the contribution suggests actions to mitigate each type of limitation throughout the entire IS DSR project lifecycle. The authors have also created guidelines to report the limitations in a useful way for knowledge accumulation. The proposed typology and guidelines enable reviewers and editors to better frame self-reported limitations, assess rigor and relevance more systematically, and provide more precise feedback. Moreover, the contribution may help design researchers identify, mitigate, and effectively communicate the uncertainties inherent to all scientific advances.

Keywords Limitations · Design science research · Knowledge accumulation · Research methods · Reporting guidelines · Research uncertainty

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1 Introduction

Design science research (DSR) is of the foremost importance for the present and the future of impactful information systems (IS) (Baskerville et al. 2018). Having its foundations in the work of Simon (1996), DSR evolved in the theoretical strand of design and action (Gregor 2006) to study "*an artifact in a context*" (Wieringa 2014), revealing exceptional progress in IS journals (Palvia et al. 2015) and doctoral theses (Cater-Steel et al. 2019). Nevertheless, Gregor and Hevner (2013) also stated that "*DSR has yet to attain its full potential impact on the development and use of information systems due to gaps in the understanding and application of DSR concepts and methods.*" More recently, researchers pointed to the insufficient replication and cumulative knowledge obtained from extending and testing existing DSR theories (Vom Brocke et al. 2020; Olbrich et al. 2017; Schuster et al. 2018).

Authors have regularly enriched the information systems design science research (IS DSR) literature with guidelines for the creation of innovative artifacts (Hevner et al. 2004; Peffers et al. 2007; Wieringa 2014), production of acceptable contributions (Baskerville et al. 2018), recommendations for IS DSR evaluation using FEDS (Venable et al. 2016), and formulating research questions (Thuan et al. 2019). Other studies focused on the publication, for example, the influential work of Gregor and Hevner (2013) or that of Heinrich and Schwabe (2014), that uses a DSR approach to arrive at a specific structure to report design principles. Yet another example suggests a DSR publication schema (Dinter and Krawatzeck 2015). These authors argue that only general guidelines exist for reporting DSR and identified aspects to account for in the different sections proposed by Gregor and Hevner (2013). More recently, Vom Brocke and Maedche (2019) presented

six key dimensions that all DSR papers should address, namely: (1) problem description, (2) input knowledge, (3) research process, (4) key concepts, (5) solution description, and (6) output knowledge. Other authors concentrated on specific parts of DSR publications; for example, Shrestha et al. (2014) centered on the communication of DSR evaluation, while Storey et al. (2017) exemplified a visual abstract in the context of software engineering.

That said, regardless of the field of research, we can always rest assured that "*[e]very study, no matter how well it is conducted and constructed, has limitations*" (Simon and Goes 2013). So, on the one hand, identifying limitations is crucial for the quality of research; but, on the other hand, "*their prejudicious nature makes them a rather unique and vulnerable component of peer-reviewed articles* […and] *more specific directions are warranted in as to the reporting of limitations*" (Brutus and Duniewicz 2012). Furthermore, IS DSR "*should implement better reporting practices* [… and b]*eing open about the shortcomings and possible extensions of one's own work may encourage follow-up research*" (Schuster et al. 2018). Perhaps even more important, better reporting demonstrates that authors are aware of the limitations, improves transparency "*and* [works] *are likely to be cited because they have informed the design and conduct of future studies*" (Puhan et al. 2012). Other research fields – most notably, the medical and biomedical – have already recognized the importance of effectively reporting limitations. Moreover, there are already important frameworks available to address the related topics of generalizability (Wieringa and Daneva 2015) and validity (Wieringa 2014; Larsen et al. 2020), and there are at least two sections suitable for reporting DSR limitations: the discussion and the conclusions (Gregor and Hevner 2013). However, a study about how limitations have been reported in IS research in general (and in IS DSR in particular) is still absent from the literature. This paper addresses that gap by proposing a typology and guidelines for self-reporting of limitations in IS DSR.

Our contribution offers new insights for (1) assessing how IS researchers have reported limitations in recent DSR inquiries, (2) suggesting preventive measures to mitigate each one, and (3) proposing guidelines to report IS DSR limitations. This work is essential to advance IS DSR publications because, as Aguinis et al. (2020) identified, "*while some broad dimensions of methodological limitations seem to apply across fields*", the unique combination of methodological challenges in a specific field may reveal different concerns. Moreover, inspired by previous research addressing self-reported limitations and methodological challenges in other related fields (Brutus et al. 2010; Brutus and Duniewicz 2012; Aguinis et al. 2020), our work also aims to propose improvement recommendations.

The remainder of this paper is organized as follows. The following section provides key definitions and analyzes the related work on reporting limitations. Subsequently, we describe our research approach and then present our proposal for a typology of limitations in IS DSR and guidelines for self-reporting them. Finally, we discuss our contribution and then close the paper with a summary of the findings, implications, this study's own limitations, and opportunities for future work.

2 Key Definitions and Related Work

It is essential to understand that "limitations" and "delimitations" have different meanings (Price and Murnan 2004). Limitations are the potential weaknesses of the study that are intimately related to the research design (Simon and Goes 2013; Theofanidis and Fountouki 2018), such as "*an 'imposed' restriction which is therefore essentially out of the researcher's control"* (Theofanidis and Fountouki 2018) that can affect the results. Delimitations, however, are boundaries of the contribution decided and justified by the researcher. Thus, *"delimitations are mainly concerned with the study's theoretical background, objectives, research questions, variables under study and study sample*" (Theofanidis and Fountouki 2018) that "*arise from limitations in the scope of the study*" (Simon and Goes 2013).

Internal validity is concerned with rigor and control, namely "*the degree to which a study establishes a cause-and-effect relationship between the treatment and the observed outcome*." In contrast, external validity "*is addressed by delineating inclusion and exclusion criteria, describing subjects in terms of relevant variables, and assessing generalizability*" (Slack and Draugalis 2001). Nevertheless, design research theories are not restricted to *"causal explanations"* and, as explained by Wieringa and Daneva (2015), can also include "*middle-range theories that balance generality with practicality*" like models. In this paper, we adopt the definition of design theory proposed by Wieringa (2014), "*which is a theory of the properties of the artifact and its interaction with the problem context,*" because artifact and theory are indissociable in DSR (Baskerville et al. 2018). Moreover, validity in DSR has been largely inspired by other fields of research, and, according to Larsen et al. (2020), "[t]*here was little evidence of proposed validities intended to meet the specific needs of DSR to support claims about the "utility" of artifacts and other DSR contributions* […and], *the construct, method, and, design theory knowledge types are woefully underrepresented*" (Larsen et al. 2020).

Since we could not find studies discussing how limitations have been and should be reported in IS, we broadened

our search to understand how other research fields address the topic and found the literature presented in Table 1.

The above contributions in the related work are valuable but not devised for design-oriented research projects that are crucial to the development of the IS field. On the one hand, they confirm the need to study self-reported limitations in scientific publications and provide specific examples of limitations and how they are reported. On the other hand, they also highlight the differences in each field of knowledge and the enormous value for training researchers and promoting scientific advances. Consequently, it is important to research how IS DSR authors have reported and should report limitations.

3 Research Approach

We have employed design science research to build a typology of self-reported limitations in IS DSR based on recent publications (Denyer et al. 2008) and devise guidelines to assist design researchers in disclosing them. We have structured the process according to the DSR grid proposed by Vom Brocke and Maedche (2019) and evaluated it using the framework from Venable et al. (2016), caring for the balance between the resulting artifact and theory development (Baskerville et al. 2018), while aiming for an effective communication strategy (Vom Brocke and Maedche 2019, Vom Brocke et al. 2020).

We summarize the research problem and the fundamental concepts in Fig. 1. The research process started with a systematic literature review (SLR) on self-reporting IS DSR limitations. We followed the recommendations of Kitchenham (2004) to create a review protocol, carefully select studies indexed in relevant IS publications, and adopt guidelines for data synthesis. As per Webster and Watson (2002), we made a concept-centric analysis – association of papers and types of limitations and recommendations for ideal reviews. For example, the review should explain the contributions, key concepts, define boundaries, and develop improvements to future contributions.

We have decided to use the AIS Electronic Library (AISeL) as the initial source of the papers. The reasons for this delimitation are: First, AIS is the leading association for IS researchers and practitioners worldwide. Second, AISeL is one of the most relevant databases for the IS community and an essential link to business and information systems engineering (Buhl 2011), including top journals and conferences.

We sought to extract and build on relevant design knowledge from processes reported in the literature (March and Smith 1995; Denyer et al. 2008). Chandra Kruse et al. (2019) call this design archaeology. The SLR was essential to create valid input knowledge (Vom Brocke and Maedche 2019) because "[s]*ystematic literature reviews are primarily concerned with the problem of aggregating empirical evidence*" (Brereton et al. 2007) and "*can provide a powerful method* [to formulate design propositions]" (Denyer et al. 2008). To cope with SLR's challenges in "*synthesizing review results*" (Denyer et al. 2008), we have adapted the steps proposed by Brereton et al. (2007) and Van Aken and Romme (2012) to our context of evidence-based business and information systems research, namely by:

1. Delineating the research project and formulating a valid research question to address the need for information;
2. Identifying the best available evidence to answer the research question, including information about the context;
3. Assessing the evidence fitness for purpose, potential impact, and utility;
4. Integrating the critical evaluation with the expertise in the field and with stakeholders' characteristics, exploring alternative solutions;
5. "[E]*valuat*[ing] *the effectiveness and efficiency in executing steps 1–4 and seek*[ing] *ways to improve them"* (Brereton et al. 2007).

We followed a tailored SLR protocol, leading to 114 publications selected for content analysis (61 papers published in ten different IS journals and 53 papers published in conferences). The inclusion criteria were peer-reviewed articles (published between 01/01/2018 and 04/10/2020) focusing on developing an artifact or contributing to IS DSR advances. We included IS journals indexed in AISeL and papers published at the premier IS conference (ICIS). We excluded editorials and commentaries, short papers lacking limitations (at this stage, we looked for a separate limitation section or self-reported limitations in the conclusions), and all papers that only briefly mentioned the term. The content analysis included a keyword search (e.g., "*limit*,") and looked for limitations stated in different sections of each paper (e.g., conclusions, limitations section, discussion). The complete protocol of the SLR and the studies identified in the review are available in the online appendix (available via http://link.springer.com).

After the descriptive review synthesis (Kitchenham 2004), we have created a typology with main categories of self-reported limitations, complemented with preventive measures inspired by the related work presented in Sect. 2. The limitations were classified using a snowballing procedure. Each limitation found was added to a list (previously identified in the sample or already identified in related work) or, if new, generated a new type of IS DSR self-reported limitation. The typology building was incremental, coded in the Mendeley reference management

Table 1 Related work on *self-reported limitations*

Study	Domain	Contributions for reporting limitations
Wang et al. (2015)	Clinical practice	Limitations "*were rarely mentioned in the study abstracts or journal press releases, the content of which is associated with that of news stories, but were commonly "buried" in lengthy Discussion sections*"
Ross and Bibler Zaidi (2019)	Medical education	The proposal made by Ross and Bibler Zaidi (2019) calls for three main steps, namely to describe: (1) the limitation, (2) its implications, and (3) mitigating tactics. These authors also suggest that focusing on the study's specific limitations rather than general issues is essential. Moreover, the probability of getting a paper accepted in the field of medical education is higher if the authors adequately address the study limitations instead of leaving their identification to the responsibility of the reviewers and editors
Ioannidis (2007)	Clinical epidemiology	Failing to include an appropriate discussion of limitations and not using the instructions for authors and editorials to raise awareness of this problem may lead to "*an important loss of context for the scientific literature*"
Theofanidis and Fountouki (2018)	Nursing and biomedical	Researchers sometimes fail to deliver a reflection on limitations, compromising the quality of the research
Connelly (2013)	Nursing	Connelly (2013) presented specific examples of limitations, namely sample size and selection, lack of data, lack of research about the topic, data collection issues, failure to verify data from other sources, history of the intervention, or researcher bias (e.g., language or culture). This author identifies three distinct types of limitations, depending on the researcher's ability to control them: uncontrollable, minimizable, and those that emerge when the researcher tries to balance "*rigour and reality*." An example of the latter is using calibrated equipment to obtain exact measures (e.g., thermometers) when the clinical practice does not always use equipment so precise in their practice
Guyatt et al. (2011)	Observational studies	There are four main types of limitations in observational studies, namely: (1) the failure to develop and apply appropriate eligibility criteria (inclusion of control population), (2) flawed measurement of both exposure and outcome (comparable to the evaluation step in DSR), (3) failure to adequately control confounding, and (4) incomplete follow-up
Aguinis and Lawal (2012)	Experiments	The authors found that 33% of limitations focus on external validity issues (e.g., not generalizable, selective sample, missing data or responses), while internal validity issues account for 37% (e.g., lacking measurement of a critical variable, confidence in causality). Other types of limitations found by these authors include statistical and construct validity (e.g., participant bias or placebo effect)
Weyns et al. (2012)	Engineering	The authors conclude that a section on limitations and assumptions is essential in conference papers and that reviewers should address the case of trade-offs. These authors found that the most common limitations were technological, the complexity of the self-adapting system, model versus implementation (eventual mismatch), and changes required to use the system. In the 34% of papers that did discuss limitations, the themes included: (1) solutions restricted to a specific domain/ application, (2) simplified versions of real situations, (3) performance issues, (4) requirements for use, (5) insufficient evaluation of the artifact, (6) lack of accuracy, and (7) lack of proof that the artifact works as expected, for example, concerning reliability or safety of the system
Yavchitz et al. (2014)	Systematic reviews	Limitations can be included in abstracts, as suggested by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), having no apparent effect on the readers' interpretation of the findings
Beller et al. (2013)	Systematic reviews	PRISMA acknowledges five main types of limitations, namely: (1) the risk of bias (e.g., data unavailability), (2) inconsistency of effect or association (e.g., high heterogeneity), (3) imprecisions (e.g., a small number of events or sample), (4) indirectness of the evidence (e.g., obtained via an intermediate or a short-term conclusion), and (5) possibility of publication bias (e.g., incomplete data)
Brutus et al. (2013)	Management	Proposed six guidelines, based on a review of the literature between 1982 and 2007: (1) ensure that discussing limitations is a priority and is included in every study, (2) separate the limitations section (mandatory), (3) ask the reviewers to explicitly list the limitations, (4) focus on the most crucial limitations, (5) state the implications of the limitations for the study, (6) describe the limitations while avoiding justifications. The authors also stated that 38% of the papers they analyzed did not present limitations. The most prevalent types of limitations were internal and external validity (reported in nearly half of the studies), followed by construct validity, statistical conclusion validity, and theoretical issues in a minority of the cases
Brutus et al. (2010)	Management	The authors observed that reported limitations change over time, requiring a continuous evaluation in each field of knowledge

Table 1 continued

Study	Domain	Contributions for reporting limitations
Brutus and Duniewicz (2012)	Management	When studying the limitations of leadership research, the authors observed that the majority were related to external validity, and although "*a focus on generalizability is common to all applied social sciences, LQ* [Leadership Quarterly] *authors appear particularly sensitive to the contextual specificity of their work and its lack of generalizability*" (Brutus and Duniewicz 2012). In this case, the authors found that only 11,5% of the articles did not report any type of limitations, much lower than the 38% found in other management publications (e.g., Academy of Management Journal or Strategic Management Journal) in the period of 1982–2007
Aguinis et al. (2020)	Management	Restricting the scope to a single journal in international business research, Aguinis et al. (2020) found that deficient measures (73%), the particularities of sample or context (62.2%), research design (62.2%), and evidence about causal relations (8.1%) are the most prevailing challenges, revealing differences from the work of Brutus et al. (2013)

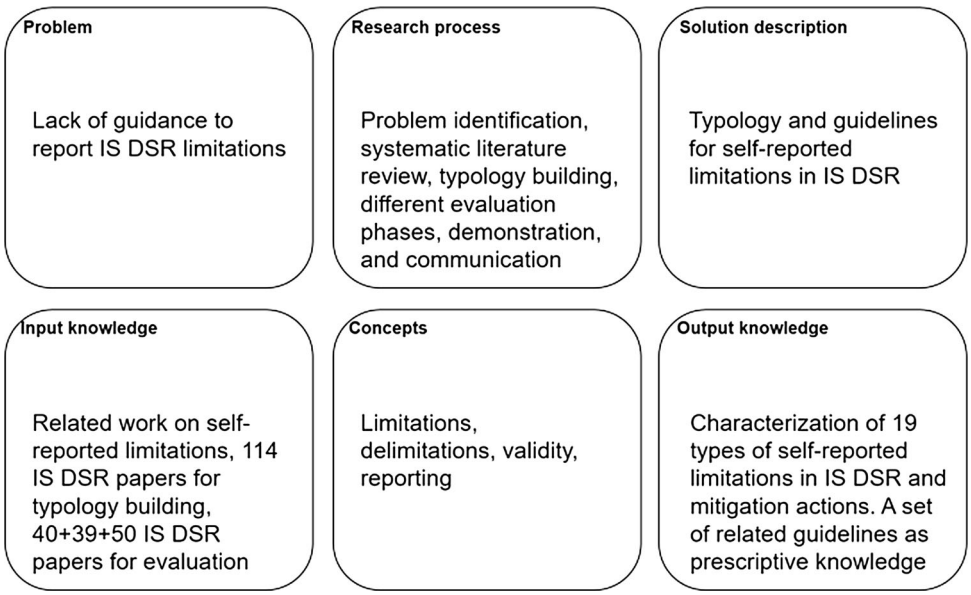

Fig. 1 Research presentation according to the DSR grid (Vom Brocke and Maedche 2019)

system, based on a comprehensive sample of relevant IS DSR publications.

Having created the typology and guidelines, we then needed to evaluate its completeness and utility (Venable et al. 2016). To that end, we have procured a new and distinct sample of DSR papers with which to test.

In the First Evaluation Phase, we used 40 AISeL publications in key IS conferences (AMCIS, ECIS, and PACIS since 2019) and HICSS 2018 proceedings. In addition, we have also added journals from the AIS Senior Scholars' Basket of Journals (basket of eight) not accessible via AISeL (restricted to the period 2018–2020).

In the Second Evaluation Phase, we used an additional set of 39 papers (27 journal publications selected among 67 results and 12 full papers selected among 46 published in ICIS between 04/10/2020 and 04/03/2021), aiming to test the typology and guidelines with more recent publications.

In the Third Evaluation Phase, we focused solely on papers published in journals included in the AIS Senior Scholars' Basket of Journals (basket of eight) since it is highly influential in the AIS community. We executed our search via Scopus, in July 2022, using the expression "design science research" in the title, abstract, and keywords, and we obtained 74 papers published since 2013. The distribution was as follows: 26 papers from the European Journal of Information Systems, 24 from the Journal of AIS, 7 from the Information Systems Journal, 6 from the Journal of MIS, 4 from Management Information Systems Quarterly, 4 from the Journal of Information Technology, 2 from Information Systems Research, and 1 from the Journal of Strategic Information Systems. We decided to keep the papers already retrieved in the previous Evaluation Phases – for example, Chanson et al. (2019) – to check if the team consistently identified the same types of limitations after learning from the process. After removing articles that did not include self-reported limitations (e.g., opinion papers or commentaries), we retained 50 manuscripts for analysis.

The final stage of our research evolved in cycles of reflection (e.g., "*does this limitation fit any of the types we*

have identified?"; "*even if it fits, can it provide added value as example to include in the paper?*"; or even "*are we properly addressing limitations in our own paper and, if not, can we improve the guidelines to assist future researchers?*").

4 Theory Building: Unfolding the Nature of Limitations in IS DSR

Section 4.1 provides a synthesis of how IS DSR publications report the study's limitations. The following section synthesizes the limitations in nineteen relevant types, presents mitigation actions, and devises guidelines for IS DSR self-reported limitations.

4.1 Input Knowledge: Content Analysis of the 114 Publications

We started our analysis of the IS DSR papers discovered in the SLR by identifying the references used more often to support their research process. We present the breakdown in Fig. 2.

The chart in Fig. 2 reveals six influential references (on the left). Three of them are key readings on DSR foundations and principles (Hevner et al. 2004; Peffers et al. 2007; Gregor and Hevner 2013), one proposes the action design research variant (Sein et al. 2011), another presents evaluation guidelines (Venable et al. 2016), and, finally, there is methodological guidance by Vaishnavi and Kuechler (2015). The image on the right shows the authors representing 18% of the publications. We have counted the references used by the authors of the selected sample of papers when introducing the research approach or explaining the steps and guidelines used for conducting or discussing research (e.g., "*Following the design science research (DSR) methodology [REF]*" or "*and definition of solution objectives (as suggested by [REF]*"). We tagged each paper in Mendeley and computed the sum of occurrences at the end. Some authors in our sample provide a comprehensive review of fundamental DSR literature and a detailed description of the DSR approach, for example, Chanson et al. (2019).

Almost 60% of the papers identified in the SLR exhibited two or three main types of limitations (e.g., single case, prototype, and the scope for the artifact use). The averages of the number of self-reported limitations per paper in AIS journals and the ICIS conference were 2.48 and 2.58, respectively. The papers that did not clearly identify limitations were under 10%. Many of these were short papers. These findings are similar to the 11.5% of papers not mentioning limitations and the 2,3 average limitations per paper found in the field of leadership research (Brutus and Duniewicz 2012). They compare favorably to the 1.66 average limitations per paper in industrial and organizational psychology (Brutus et al. 2010), to the 1.27 average limitations per paper found in Brutus et al. (2013), and to the case of 60% + conference papers on self-adaptive

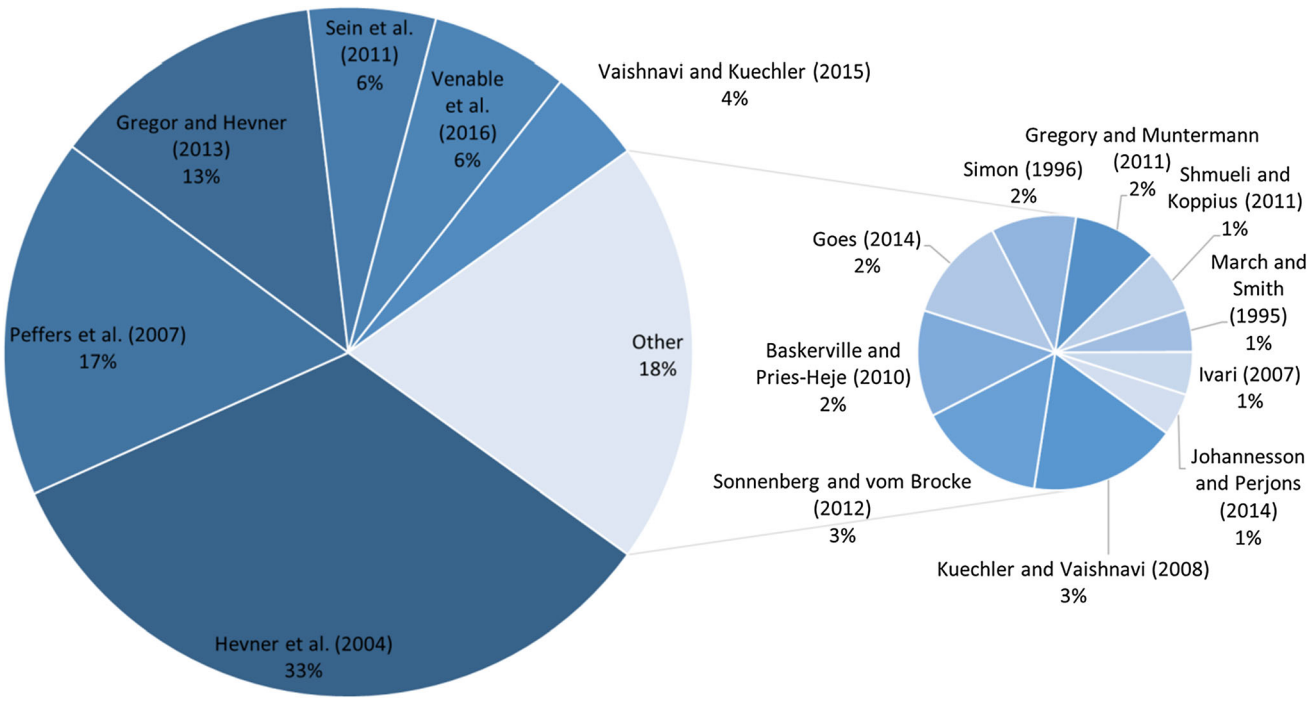

Fig. 2 Breakdown of the references used to support DSR in the sample of 114 papers

systems in software engineering not describing any limitations (Weyns et al. 2012). However, we need to read these numbers carefully because we are contrasting very recent literature with samples obtained in the early stages of this century, and "*trends indicate that researchers have clearly increased the number of self-reported limitations and directions for future research over time*" (Brutus et al. 2013). Moreover, the granularity level of treating limitations varies, and DSR has particularities, such as the intersection of artifact developments and the social and organizational aspects involved.

The majority of IS DSR publications do not include a separate section for limitations, despite some authors arguing that it would be the preferable way of reporting them (Connelly 2013). Leadership research, for example, has moved significantly towards this recommendation, with papers including a separate section on limitations growing from 18.5% in 1990–1995 to 56.6% in 2001–2007. We have also found that many IS DSR papers do not clearly indicate where to find the limitations. For example, the inclusion of sentences such as "[Section X] *summarizing key results, discussing implications and limitations, and pointing to directions for future research*" (Linhart et al. 2020) could assist the reader in finding them, even in the absence of a specific heading. Linhart et al. (2020) is a good example of this practice, signaling the location of limitations and providing a good reflection when discussing the artifact and in the conclusions.

We have highlighted eight inspiring examples of addressing limitations in IS DSR (four published on BISE, one on MISQ, two on JAIS, and one on JITTA). Most of them include a separate section, although it does not seem mandatory. For example, Zhang et al. (2019) present very detailed reflections about the limitations in their approaches, artifacts, or data-related issues. The authors also address repeatability concerns and examine limitations in the evaluation and discussion sections. Other examples presented by Linhart et al. (2020) extensively introduce their limitations in the evaluation section and assist the reader in finding their location (e.g., Sects. 5, 6), while the work of Miah et al. (2019) provides a rich discussion of the limitations, including generalizability in ADR. We agree that using a single section for limitations in extensive artifact evaluation can be difficult in some cases, and the options of these authors seem appropriate. Others discuss limitations in particular sections or sub-sections. For example, Morana et al. (2019) use almost one page to present five fundamental limitations, Wu et al. (2019) provide an interesting association with future research opportunities, Nalchigar and Yu (2020) deliver one of the most profound analyses of potential limitations spread through different parts of the paper, Del-Río-Ortega et al. (2019) present a comprehensive analysis of the artifact and its use (often missing in the DSR research papers). Finally, Niemöller et al. (2019) also describe the limitations in the technology used to create the artifacts (smart glass). Regarding ICIS, Hobert (2019) clearly states where the limitations can be found and provides a good reflection on them. This manuscript was a runner-up for Best Paper, proving that openly discussing this issue did not hinder recognition. The other good examples presented three to four limitations, usually pointing to their location and reflecting on and explaining the research process (Neville et al. 2018; Schoormann et al. 2018; Feine et al. 2019; Kammler et al. 2019; Diederich et al. 2020). The set included a short paper (Köster et al. 2018), a laudable exception since they typically did not discuss limitations, despite the importance of reflecting on the present and potential weaknesses in research in progress. Naturally, the selection above is subjective and based on the researchers' perceptions when comparing the set to other published DSR studies. Other good examples exist in this sample.

4.2 A Guide to Self-Reporting of Limitations in Design Science Research

Limitations are usually described after the fact and depend on two sources: (1) the delimitations explicitly decided by the authors that may cause or avert limitations by restricting the problem or the solution space, and (2) uncontrollable aspects. Both raise weaknesses that have an impact on the research outcomes. Some may enclose future work opportunities, but the authors must carefully evaluate this association. On the one hand, it can blur the limitations into future intentions. On the other hand, it may limit the authors' reflection on future avenues. Examples of questions beyond space of limitations are: "*how can the artifact inspire research in other areas?*" or "*what aspects originally out of scope (consequently out of the limitations space) can be explored in the future?*".

The futures space is unlimited; the limitations depend on the selection of the authors' delimitations and their transparent and rigorous reporting. If the authors discuss potential limitations at the beginning of the project, they can consider mitigating actions. This risk-based approach is not a definitive solution because there will still be other types of limitations, but it can help prevent a few. Table 2 presents the typology of limitations derived from the sample of 114 papers.

The mitigating actions included in the typology highlight key procedures extracted from foundational DSR studies and related work in self-reporting limitations. Formative and summative validity, or internal and external correction in research, has notable references in IS and software engineering whose detail is beyond the scope of this work. For further reading, we suggest Lee and Hubona

Table 2 Typology of DSR limitations and mitigating actions

A Typology of IS DSR Limitations			
Category*	Type of limitation	Examples	Mitigating actions
Input knowledge and technology	Limitation 1 (L1). Data sources/Foundations	The authors collected limited data, or its quality is poor	Adopt triangulation techniques (Van Aken and Romme 2012) and restrict the problem space to enable the collection of trustworthy data (Legner et al. 2020)
	L2. Insufficient number of previous studies	The topic is under development, limiting the possibility of comparing the results or accumulating knowledge	Search for similar problems in other areas. Compare to similar cases to clarify the space. Much more needs to be done if the research is insufficient, but that does not necessarily constitute uncertainty for the research outcome (Connelly 2013). According to Popper, scientific theories are temporary, and the advances emerge from the rejection of less satisfying theories and their replacement by better ones, not by accumulating observations (Popper 1982)
	L3. Sample size	The authors collected information from particular experts or from a reduced number of interviewees to prepare the process	Similar to L1. This type of limitation is common in different research fields (Connelly 2013). However, selecting the wrong participants is not an actual limitation but a research design mistake to avoid
	L4. Novelty/ Shortcomings of the technology	The authors used technology that may create problems for the use of the artifact	Design the artifact for future reuse (like an IT solution to be integrated with other modules) (Vom Brocke et al. 2020). Clearly explain in the discussion why the artifact is valuable even with the limitations of the current technology and what it adds to the body of knowledge (Baskerville et al. 2018)
Research process	L5. Setting	Single organization	Ensure that the uniqueness of the organization is important to a specific space (assists in the delimitation and in formulating the correct research questions (Thuan et al. 2019))
	L6. Participants	Researchers or students are the main participants in the design and development	Try to include different participants in the evaluation and justify the selection (Aguinis and Solarino 2019) in the methodology section. Explain the selection bias (Wieringa 2014) and provide alternatives (e.g., a guide to using the artifact)
	L7. Method	Evaluation is not completed. Missing steps in the DSR process	Ensure the correct use of DSR (Vom Brocke and Maedche 2019), and select an evaluation framework (Venable et al. 2016). If using a DSR adaptation, explain what it consists of and the rationale. Implement mitigating actions and state them in the discussion section (focus on actual limitations, not minor issues of the process and the artifact (Brutus et al. 2013)
	L8. Difficulties – out of the authors' control	The authors do not control aspects (e.g., company decisions, funding) that condition the unfolding of the project	Present the difficulties in the discussion and explain mitigation actions. If there are uncertainties, state them in the limitations section and point to more details in the discussion (Brutus and Duniewicz 2012; Brutus et al. 2013)

Table 2 continued

A Typology of IS DSR Limitations			
Category*	Type of limitation	Examples	Mitigating actions
Resulting artifact	L9. Simplifications	The artifact only solves a part of the complex problem	Explain the simplification advantages (e.g., minimum viable product, easier to test before large-scale adoption) and evolutions needed in future work (not in the limitations section). Differentiate those recommendations from the weaknesses – that derive only from the current version of the artifact
	L10. Evaluator's bias/ Measurement bias	The evaluation was made exclusively by the participants. Subjectivity	Try to include experts in the early stages of design and development. Explain the impact for knowledge accumulation in future cycles (Vom Brocke et al. 2020). Present warnings regarding the use of the artifact and the context of use (Larsen et al. 2020) (e.g., a medicine tested in a limited cohort may pose severe risks for a broader population; similar reasoning applies to a DSR artifact). Evaluate the possibility of the Hawthorn effect (French 1953)
	L11. Not real users/ Controlled experiment	Laboratorial or academic deployment	Explain why the context was selected and why it is adequate for the problem/solution space. Explain how to use the artifact in future DSR cycles/requirements for the involvement of real users
	L12. Real situation/ Prototype	The artifact was not used in a real situation. The artifact representation is still under development	Support the outcome in the research projectability (Baskerville and Pries-Heje 2019). A prototype may be relevant for both practice and new DSR cycles. Include cautious statements and clear limitations of the outcomes (Ioannidis 2007) – prototypes may fail in many situations due to social and technical issues. Present a risk assessment
	L13. Limited performance	The artifact is slow or inefficient under certain conditions. Does not discriminate all the variables needed to support a decision	A new artifact's poor performance will compromise its utility (Hevner et al. 2004) (like a new medicine that does not help or causes side effects). However, design contributions are not strictly related to the artifact's performance (Baskerville et al. 2018). Explain how future research can address that issue and the important aspects of the research besides the performance issues
	L14. Requirements to use the artifact	Large amounts of data are needed to use the artifact in practice. Specific training. User preparation	Identify the real users' needs (problem definition). The solution space may require the creation of a user manual. Reporting this type of limitation is mandatory because it is hard to identify by the audience. It increases the value of the contribution (Ross and Bibler Zaidi 2019)
Design knowledge	L15. Uncertainty in future events/Time-related constraints/ Risks	The development of artifacts for emerging situations. Possibility of using the artifact for the wrong reasons. Risks while using the artifact (e.g., wrong decisions, societal impacts)	Identify scenarios and implications for futures. There are multiple future studies techniques (Gray and Hovav 2011; Hovav 2014; Hovorka and Peter 2019). The uncertainties of futures will still exist, but authors can explore how the artifact will be helpful (or need changes) in better futures
	L16. DSR outcome not compared to alternatives	The outcome improves the problematic situation but was not compared with alternatives that address the same problem	Clearly explain the shortcomings of alternative approaches or competing artifacts (Hevner et al. 2004) in the early stages of the DSR process

Table 2 continued

A Typology of IS DSR Limitations			
Category*	Type of limitation	Examples	Mitigating actions
	L17. Scope of DSR application	The artifact is only available in particular situations	Adequately address it in the DSR plan, so it is a delimitation and an opportunity for future work in the solution space (Vom Brocke and Maedche 2019)
	L18. Other theoretical limitations	Limited balance between artifact and theory	Provide guidance from key DSR literature (Baskerville et al. 2018). Use previous DSR studies to support the choices. Previous design knowledge can be replicated and tested in the selected problem/solution space (Vom Brocke et al. 2020)
	L19. Generalizability and transferability	Usually presented as a general limitation (to avoid), requires details	Clearly define the problem and solution spaces (Vom Brocke and Maedche 2019). DSR researchers should aim to prove value and then accumulate knowledge to the proof of use (Briggs et al. 2011). Employ well-established strategies for generalizing theory (Wieringa and Daneva 2015). Evaluate the importance of projectability in DSR (Baskerville and Pries-Heje 2019)

*Adapted from Vom Brocke et al. (2020)

(2009), Wieringa (2014), Mingers and Standing (2020), and the framework proposed by Larsen et al. (2020) that addresses the (1) design antecedents, (2) development and use, and (3) outcome.

Three main aspects make IS DSR unique, namely, the role of the artifact (Baskerville et al. 2018), the publication guidelines (Gregor and Hevner 2013), and the specific lifecycle of the research (Hevner et al. 2004; Peffers et al. 2007; Gregor and Hevner 2013). According to De Leoz and Petter (2018), IS DSR "*is a distinct research paradigm in the information systems*" embedded in specific contexts, creating artifacts with social and technical impacts. Their paper presents an example of contributing guidelines to assist IS DSR researchers, not to impose norms but as a suggestion for improving the quality of our research outcomes. There are also exemplary suggestions of guidelines for self-reported limitations in other fields "*to maximize the value of limitations and directions for future research so that they can serve as true catalysts for further scientific progress*" (Brutus et al. 2013). Therefore, specific guidelines are necessary to help IS DSR researchers in reporting limitations because "*It is difficult to over-emphasize the significance of design work and design knowledge in Information Systems (IS) for both research and practice*" (Gregor and Jones 2007). Aligned with earlier contributions in industrial and organizational psychology (Brutus et al. 2010), we do not recommend inflexible rules for self-reported limitations. However, we believe that the following guidelines will be helpful to IS DSR researchers: Guideline 1, based on Brutus and Duniewicz (2012) and Brutus et al. (2013), is common to different research fields. Guideline 2 aims to prevent the conflation of the discussion of limitations and future work, potentially hindering both. The remaining guidelines are more specific to IS DSR publications and emerge from the authors' reflection in light of the related work, the sound examples found in the literature, and the uniqueness of IS DSR (Hevner et al. 2004; Wieringa 2014; Baskerville et al. 2018; Vom Brocke and Maedche 2019).

4.2.1 Guideline 1: Identify and Clearly State Limitations

Although a section about limitations is interesting (Brutus et al. 2013), we do not suggest that it should be mandatory if (1) the authors' state where they located their artifact-related discussion and (2) use headings or other mechanisms to indicate the discussion of limitations. Authors should address three elements: the limitation, its causes, and how to address them (Brutus et al. 2013; Ross and Bibler Zaidi 2019). Authors should avoid justification (Brutus et al. 2013) or minimization; for example, "*this is the limitation… but we think that it is not so important*".

4.2.2 Guideline 2: Separate Limitations and Future Work

We recognize that limitations are reasonable starting points for future research but are not the only avenues. This recommendation aims to free the authors' minds to

consider future scenarios that they may otherwise not even consider in the present. Limiting future work to merely solving research limitations is a narrow perspective.

4.2.3 Guideline 3: Avoid Trying to Create Infallible Artifacts

In fact, "*infallibility is not compatible with scientific thinking*" (Ioannidis 2007). It can be frustrating to read a scientific publication that ends with long paragraphs explaining why the artifact is superior to all the other alternatives but does not point out any limitations. Infallible design knowledge is not knowledge: it is belief. Moreover, belief is the unscientific exclusion of alternatives.

4.2.4 Guideline 4: Reflect on Limitations During the DSR Lifecycle

Design science research has specific concerns of validity for both the process, and the product of research, within the lifecycle of (1) theoretical foundations and requirements, (2) development and use of artifacts, and (3) outcome and utility (Hevner et al. 2004; Wieringa and Daneva 2015; Larsen et al. 2020). For example, implementing measures to reduce design theory indeterminacy and make design knowledge more relevant to practitioners (Lukyanenko and Parsons 2020). Therefore, due to the particularities of DSR, the continuous reflection must start in the early stages of the problem formulation, following the recommendations included in Table 2, and end with a transparent report of weaknesses that raise uncertainties.

4.2.5 Guideline 5: Use Delimitations as the First Step for Framing DSR Limitations

The authors' decision about the problem and the solution spaces is the first step toward more contextualized and impactful IS research contributions (Briggs et al. 2011; Vom Brocke et al. 2020). Limitations that pertain to the DSR time and space journeys are the most important to report. Therefore, authors should carefully reflect on how they delimit their work. A significant DSR limitation is an uncertainty in the DSR space that influences the outcome and deserves attention in future research.

4.2.6 Guideline 6: Acknowledge the Centrality of the Artifact to DSR and to the Limitations

Reporting artifact limitations is mandatory to avoid inflating results or interpretations (Ioannidis 2008). Theory and artifacts are intertwined in DSR (Baskerville et al. 2018; Gregor and Hevner 2013), but it is easy to separate them when discussing limitations. Artifact weaknesses and uncertainties may be more detailed and specific (e.g., included in the evaluation or discussion sections) according to the social and technical context of use (Wieringa 2014). The main limitations can be presented in the abstract, the conclusions, or a separate section, for example, with subsections for artifact and design theory. Authors may use the typology (L9–L14) presented in Table 2 as a starting point to select the most relevant artifact-related limitations for present and future use.

After describing the limitations, the authors should check whether they addressed the problem and solution space. The causes of the uncertainties (content) identified in a particular section (visibility) must balance artifact and theory, following a specific research process (DSR adherence). First, the paper should identify causes and describe limitations in the problem/solution space, pointing to solutions. Second, it is necessary to evaluate uncertainties within the lifecycle of DSR for both artifact (inputs, design, use, or possible uses) and theory-specific limitations.

4.3 Evaluation of Our Proposal

Our evaluation process includes two perspectives: the researchers' and the practitioners'. We chose to address both because we need to (1) check if self-reported limitations in the set of IS DSR papers used for evaluation fit the categories and types of Table 2, and (2) assess if the typology and guidelines are useful. We executed the evaluation in four phases. The initial three used distinct samples of papers in distinct moments to consolidate the findings. The fourth phase illustrates the application of the typology to our own work. We describe them in more detail below.

4.3.1 Phase 1

In the dataset of 40 papers selected for this evaluation phase, most manuscripts show one, two, or three limitations (20%, 22%, and 24%, respectively). Fewer report four (7%) or five limitations (5%). About 14% of the papers are unclear about their weaknesses, and some address uncertainties merely with cautious sentences.

Following the protocol presented in the online appendix (Sect. A1.2.), we could classify all the self-reported limitations using the types proposed in Table 2 and did not encounter new ones. Examples include "*considered a short time frame* [for data collection]" presented in Table 2 as type L1 – Data sources/ Foundations, "*a new topic lacking solid background, requiring an exploratory approach*" type L2, "*the technology X has not reached a level that enables* [some requirement]" or "*one limitation is the current state of digitalization in sector* X" type L4, "*only a*

single case company (…)" type L5, "*the work* X *is a first step with a limited number of participants* (…)" type L6, "*strengthening the evaluation by* [explain solutions to improve evaluation]" type L11, or "*regulatory, technological, or standardization challenges in location X*" type L14.

However, we have identified different examples of each type and strategies to deal with the delimitations. For example, the work of Rose et al. (2019) states that they do not make theoretical propositions "*but rather* [*to*] *ensure that artefact development has a traceable theoretical component*" (see L18 in Table 2) and Grotherr et al. (2018) mention that "*the sociotechnical artifact fell back on a purely technical artifact*" nevertheless, generating design knowledge with a real implementation. Kolkowska et al. (2017) serves as an example of various types of limitations across the four categories of Table 2. For example, data quality (*Input Knowledge and Technology*), the intervention of participants and the researchers (*Research Process*), artifact representation uncertainties, and transferability of the findings. We could also confirm that the technology's novelty is a prevalent limitation in blockchain-related studies (e.g., Wickboldt (2019)).

4.3.2 Phase 2

We collected an additional set of 39 papers for the evaluation process in February 2021. Since DSR standards change over time (Venable 2015), accounting for the more recent literature is vital.

Once again, the typology proposed in Table 2 proved robust, as it could account for all the types of limitations identified in the new sample. For example, "*the evaluation of our artifact is based on a sample size of* X, *but could be strengthened* (…)" type L3, "*cases used in the experiments pertained to* [specific setting]" type L5, "*we measured* X *with a single item but multiitem could improve the results*" type L10, "*contrasting to [real setting], our system did not include information about* [artifact limitation]" type L11, "*our results rely on a prototype* (…) *it is questionable if* X *holds up in the field*" type L12, "*since the results of the artifact* [shortcoming presented], *a new method is necessary to* [explain what can be done]" type L13, or "X *government's law and regulation are different from* Y, *which poses a limitation to the requirements and development* [of the artifact]" type L17, or "*we reflect on the theorization methodology* [identifying issues], *therefore* [suggesting solution]" type L18.

A paper by Zschech et al. (2020) constitutes a nice exemplar, as it explicitly states in the abstract that the authors are "[f]*ollowing a design science research approach*", locates the discussion of limitations, and considers different techniques to improve validity, delimiting the artifact development and possible bias. Furthermore, the authors present a separate section on limitations, extensively discussing aspects such as the availability of real-world data (L2), artifact simplification (L7), data inputs and artifact performance (L13), real-world implementation issues (L15,) artifact users (L17), and generalizability (L19).

4.3.3 Phase 3

The typology's robustness was again confirmed using an extended sample of papers published in journals included in the basket of eight. In this sample, we identified an average of three limitations, covering 15 out of 19 types presented in Table 2.

The number of self-reported limitations remained stable over time in this sample (period 2013–2022). We highlight the comprehensive example of Meth et al. (2015), evaluating particular design limitations in the discussion and presenting uncertainties in the conclusions related to the student sample, the theory used, and the method. Also, Piel et al. (2017), discuss two main limitations related to the lack of data and participants in a specific section and an additional (minor) four that are artifact-related.

Some authors preferred to detail fewer limitations (the most relevant), like Chatterjee et al. (2018) pointing to the small number of cases or Coenen et al. (2018) discussing the state of artifact development. The work of Huber et al. (2019), concerned with designing a domain-specific modeling language, presents a good example of how artifact limitations can open relevant opportunities for future work. More recent studies like the case of Dincelli and Chengalur-Smith (2020) opt for a separate section and cover different types of limitations related to the artifact, scope, performance (as it evolves and over time), and risks.

Artifact-related limitations (L11 and L12) and context particularities (L5) are the most frequent (nearly 50% of the papers report some form of limitation in the artifact outcome or research setting), followed by theoretical limitations (L18), which are expectable in high-quality journals. We also found evaluation issues in 20% of the papers. Less usual ones include insufficient data (L1) or requirements to use the artifact (L14).

4.3.4 Phase 4

To conclude the evaluation of our proposal, we have applied it to this paper. Regarding *Input Knowledge and Technology*, the papers we used are restricted to the IS field, leading to a discussion in our limitations section (L1). However, we overcame the lack of previous work on IS DSR limitations (L2) by searching in other fields. We have compared our sample with related work (L3) and explained

the need and utility of our contribution to IS DSR (L4). The *Research Process* does not evolve in a single setting (L5); however, the authors being the only participants in the research and the process used for content analysis can raise potential uncertainties that must be stated (L6, L7). We did not face adverse events that influenced our outcomes (L8). Our *Resulting Artifact* is a simplified (L9) form of presenting limitations, but it was our decision to delimit the objectives and the research approach. However, the evaluation made exclusively by the research team is an evident limitation (L10). The guide is ready to be used by other researchers (L11), and we have tested it with a publication (L12), evidencing a good coverage of the limitations in the selected studies (L13). Moreover, a reflection on the typology performance (L13) suggests caution because other unidentified limitations may exist in DSR, justifying specific recommendations for its use (L14). Finally, the *Design Knowledge* produced may be valuable to increase DSR impact (L15), was inspired by and contrasted to related work (L16), explains its proper use in DSR (L17), and we developed a theory-engrained typology of self-reported limitations (L18). However, the accumulation of knowledge rests with the IS DSR community recognizing the typology and guidelines (L19). The DSR evaluation section may be a good location for other IS DSR authors to explain how they used our contribution to help them reflect and identify limitations to discuss.

5 Discussion

Our findings confirm that many DSR projects suffer from the "*single case condition*", "*aiming at deriving DK* [Design Knowledge] *within this project* [… with a] *monolithic structure* […missing] *the opportunity to compose DK contributions*" (Vom Brocke et al. 2020). This situation, visible in DSR studies' limitations, raises one of the major obstacles to knowledge accumulation with this popular approach in the IS field. However, following some principles can improve this situation (Vom Brocke et al. 2020). The first is the correct delimitation (and relation) of the problem and the solution spaces, starting with a complete definition of the context, the criteria for suitable solutions, and the solution. The subsequent principles presented by Vom Brocke et al. (2020) are the grounding on prior knowledge, transparency about the process, and the advances made to the selected research spaces. Nevertheless, although it is possible to find the single case condition at design-time (e.g., "*the project was conducted in a single organization*") or at evaluation-time (e.g., "*evaluation with a single case, missing a longitudinal analysis of the results*"), the design knowledge and research impact are not necessarily diminished. In fact, according to Karl Popper's Critical Rationalism, scientific progress does not stem from an accumulation of observations, namely successive acritical confirmations, but from carefully formulated attempts to disprove existing theories. Validity is always considered provisional to the context of the problem and the solution, and researchers should experiment with variations of that context to find out how the provisional "trues" hold (Popper 1982).

We see delimitations and limitations as crucial elements in this frame of reference. First, an adequate delimitation of the research, which includes a well-formulated research question/objective, will help the authors identify the most critical limitations in the problem–solution space. Thuan et al. (2019) provide guidance on constructing DSR research questions. Second, the evolution of the process and the artifact are two sources of potential limitations to the production of design knowledge. Third, the research outcome and how it answers the design spaces' challenges is another source of uncertainty. Suggestions for improving the study delimitation include presenting details of the research boundaries in the case presentation or, at a later stage, strengthening particular aspects of the artifact evaluation. For example, "*the advantage of the approach X is limited to the tasks of Y and Z*".

The uncertainties related to the phase of knowledge accumulation will tend to look for (1) the future of the DSR process in a "*single case*" that will surely need more DSR cycles to evolve or (2) the future of the artifact and its impact in more evolved stages of design knowledge accumulation (Vom Brocke et al. 2020; Schuster et al. 2018).

A "*cautious statement*" is acceptable if the authors also reflect on the limitations, but replacing them with mere warnings is discouraged. It creates the perception that the author did not put enough effort into reflecting and communicating the actual limitations and their implications. Regarding generalizability and transferability concerns, we suggest the inspiring reading of the last research mile by Briggs et al. (2011) and the differentiation of transferring to a similar class of problems or a different one.

Immersing limitations in the discussion section without previously identifying their location, or merging them with future work (e.g., "*future work can include the approaches A,B,C that we could not test for reason X, Y*") does not help in the identification of the uncertainties that are so crucial in the publication process. However, in line with our content analysis, we do not suggest that a separate section for limitations in DSR should be mandatory, as in other research fields (Brutus et al. 2013). Moreover, influential research in DSR already considers the possibility of including limitations in the discussion section (Gregor and Hevner 2013), not only in the conclusions. The rationale for our stance is three-pronged: (1) the majority of recent

DSR authors are aware of the need to state limitations, (2) producing design theories and theory-engrained artifacts raises many more possibilities for weaknesses, particularly artifact-related, that authors may better describe in the discussion section, and (3) we have found outstanding examples of papers with profound reflections about limitations that used a dual strategy: artifact-related limitations extensively presented in the discussion, and theory-related limitations clearly stated in the conclusions. Artifact-related limitations can make the DSR evaluation more profound, guiding the authors' reflection. However, we consider relevant the identification of the section(s) where the discussion of limitations takes place by using the word in section headings and a brief sentence in the introduction. We also suggest separating limitations and opportunities for future work – the accumulation of knowledge is not restricted to weaknesses in findings but should include the opportunities they will create for the future(s).

Scientific validity is a decisive dimension when discussing the limitations of DSR projects (Wieringa 2014; Larsen et al. 2020). Van Aken et al. (2016) have put forward a simple set of criteria based on pragmatic validity and practical relevance concepts. The former expresses the evidence that the design will produce the desired results, and the latter describes how the design will make valuable contributions to the field. In a more explicit effort to reconcile paradigms, Mingers and Standing (2020) propose a whole model to assess the truth and correctness of scholarly research. They instantiate it for a wide range of paradigmatic concerns. This model discriminates between internal correctness (formative), external correctness (summative), and truth. For the specific case of DSR and action research, they propose that internal correctness encompasses the issues (or limitations) of methodological correctness, efficiency, elegance, and ethicality, while external correctness includes the issues (or limitations) of efficacy and effectiveness, and truth covers the issues (or limitations) of pragmatism and consensus, and the coherence of the methodological process.

Researchers can use the guidelines for addressing limitations alongside existing cornerstone references throughout the IS DSR lifecycle. For example, specific recommendations on reporting limitations can complement Gregor and Hevner (2013)'s influential proposals. Researchers can also use our proposed typology and guidelines to identify limitations in the early stages of IS DSR to select the most suitable evaluation strategy as a preliminary step to adopting the FEDS framework. IS DSR authors can also use the guidelines to report remaining uncertainties after applying FEDS. As suggested by Iivari et al. (2021), the involvement of practitioners in the evaluation of design principles is also an important source for identifying limitations. Practitioners' insights are especially relevant for *Design Knowledge* limitations and to understanding the potential causes for limitations in *Input Knowledge and Technology* and *Resulting Artifact*. Finally, our work can also assist IS DSR researchers in identifying and reporting potential limitations to address in the evaluation of the artifacts defended by Prat et al. (2015).

The guidelines suggested in this paper were also applied to our paper, clearly identifying the limitations that matter (Brutus et al. 2013) in Sect. 6.2 (Guideline 1) and separating the suggestions for future work (Guideline 2). The remaining four guidelines are crucial to the distinctive nature of "theory for design and action" (Gregor 2006). Stating "*how to do something*" (Gregor 2006) is not compatible with infallibility, requiring risk analysis and the awareness of possible failures (Guideline 3). Guideline 4 was perhaps one of the most helpful while writing this paper: limitations should be a lighthouse for the research team. The second evaluation phase explains how we assessed each limitation during the process and the impact on researchers' decisions (e.g., selection of papers). The theoretical foundations for more specific design guidelines 5–7 emerge from the need to identify IS DSR dimensions (Vom Brocke and Maedche 2019) and the centrality of the artifact (Wieringa 2014), revealing a differentiation from related work (Brutus et al. 2013; Aguinis et al. 2020) and the unique nature of IS DSR.

Space restrictions are relevant, particularly in conference papers. Therefore, to maximize applicability, the six guidelines focus on the research process and paper structure rather than on the number of self-reported limitations or the extension of their descriptions. However, given the importance of reflecting on limitations, including in research-in-progress papers, with more uncertainties that need earlier evaluation, a minimum baseline should be considered. Our suggestion is to state (1) delimitations when presenting the method/research approach, (2) artifact-related uncertainties in the discussion or evaluation section (categories *Input Knowledge and Technology* and *Resulting Artifact*), and (3) DSR process and theory-specific limitations in the conclusions (suggested categories *Research process* and *Design Knowledge*). A dedicated section may be more suitable for journal articles, theses, and book chapters.

6 Conclusion

We have proposed a typology of IS DSR limitations classified into four categories: (1) *Input Knowledge and Technology*, (2) *Research Process*, (3) *Resulting Artifact*, and (4) *Design Knowledge*. For each type of limitation, we have suggested actions to mitigate them throughout the

entire IS DSR project lifecycle. Furthermore, we have also proposed guidelines for reporting them.

6.1 Study Implications

For design theory, our research presents essential examples of study limitations found in recent literature, proposes a typology to facilitate their analysis and mitigation in IS DSR, and guidelines to report limitations in IS DSR. Similar studies in the fields of medicine, biology, management, and experimental studies inspired this work in the IS. Moreover, our contribution extends other proposals available for key sources of limitations that authors should report, such as validity (Wieringa and Daneva 2015; Larsen et al. 2020).

For practice, the examples of self-reported limitations provided in this paper can increase IS DSR researchers' awareness of uncertainties that may emerge in different phases of their projects. The typology and guidelines can be helpful in the early stages of IS DSR training for teachers, thesis supervisors, and students that employ IS DSR in their projects. IS DSR authors can use the typology and guidelines (1) to anticipate and eventually mitigate some limitations, (2) as a checklist to identify limitations that must be disclosed, and (3) as a reference to address self-reported limitations in different sections of the paper. Our contribution is also helpful for the reviewers and editors to frame the limitations, assess rigor and relevance and provide feedback.

6.2 Limitations of our DSR

There are important limitations in our work. First [*Input Knowledge and Technology*], our study's delimitation to recent IS DSR publications influences the proposed guidelines. Therefore, they might not apply to DSR works in different research fields. Additionally, the classification and the suggestions emerge from past research, and essential insights can emerge from non-IS-related publications or differences between early DSR and most recent studies. Second [*Research Process*], we used a particular sequence of steps (e.g., search for keywords, if not present, then examine the conclusions, then the discussion, and so on) to evaluate the papers indexed in AISeL and Scopus; however, we did not read all the papers in full. Therefore, some limitations (e.g., in the method section or the introduction) may have escaped our research team's analysis. Third [*Resulting Artifact*], our evaluation does not prove that there are no other types of limitations; it just confirms that the identified limitations exist in recent DSR publications, are common in the papers published in the selected outlets, and the summary table is inclusive to consider different examples. Nevertheless, the typology and guidelines are grounded in the researchers' evaluation, which embodies the risk of subjectivity. The typology and guidelines will undoubtedly evolve. Fourth [*Design Knowledge*], other researchers have not used the guidelines we propose, so we do not yet know if the IS community will find them valuable and relevant to assist with artifact and theory since the early stages of IS DSR.

6.3 Opportunities for Future Work

Departing from our limitations, we believe that it would be informative to analyze DSR publications in specific time frames. There are indications in other fields that the number of reported limitations may change over time, but we do not have the same evidence about the types of limitations. It would also be interesting to go beyond the limitations and understand how the typology and guidelines may change over the years. For example, are we creating DSR artifacts for short-term needs? How are our artifacts capable of anticipating and even promoting specific futures in organizations? It would be interesting to identify how the limitations in IS DSR influence subsequent studies by the same or other authors. Additional research is necessary to understand limitations across a mix of research approaches. For example, case study or action research limitations may share similarities with those seen in DSR.

Some opportunities emerge from a reflection on future scenarios. For example, artificial intelligence techniques to identify limitations could be developed to assist researchers and editors. A database of limitations and future research opportunities in the IS field could improve how we are building cumulative knowledge. Titles and abstracts are already indexed, but a new indexation based on future work opportunities and existing limitations would be exciting. Finally, as with other contributions that have been emerging to assist design researchers, our contribution "*needs to be evaluated according to how well it helps its users accomplish their goals*" (Gregor et al. 2020). However, it is "*not feasible to test any combination of design principles with a suitable group of participants in sufficient numbers*" (Janiesch et al. 2020). Therefore, evaluating how the community will use, adapt, and extend the typology and guidelines of self-reported limitations will be necessary.

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