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A DELPHI STUDY OF OBSOLETE ASSUMPTIONS IN FREE/LIBRE AND OPEN SOURCE SOFTWARE

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Research Paper

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Abstract

Free/libre and open source software (FLOSS) has evolved significantly over the past 20 years and estimates suggest that it accounts for 80-90% of any given piece of modern software. A consequence of this evolution is that many of the assumptions made by FLOSS researchers may be obsolete. This would have major negative implications for research validity and hampers theory generation on FLOSS. This study sought to identify significant obsolete assumptions that persist in FLOSS research. Using Delphi research design with a panel of 20 expert researchers, 21 obsolete assumptions about FLOSS were identified and ranked. We performed a thematic analysis and grouped these obsolete assumptions into six themes: Sampling, Project/Community, Product, Contributor, Evaluation, and Development Process. The Sampling theme was ranked as having the most significant obsolete assumptions although only two assumptions were associated with this theme. The Project/Community theme contained six obsolete assumptions – the most of any theme.

Keywords: Free/libre software, open source software, FLOSS, ranking-type Delphi, obsolete assumptions.

1 Introduction

In the two decades or so since the first research studies on Free/Libre and Open Source Software (FLOSS), our modern digital society has become strongly 'FLOSS-dependent.' The term FLOSS is used as a broad term to refer to two concepts together: "free/libre software" and "open source software" (OSS) (Crowston & Howison, 2006) that both represent software applications deployed under a license allowing inspection, reuse, and editing of source code (Crowston & Wade, 2010), in contrast to proprietary closed source software of which source code is under the control of the software licensor (Alspaugh et al., 2010). The FLOSS phenomenon has changed how organizations and individuals create, distribute, acquire and use information systems and services (Crowston and Wade, 2010). Experts estimate that FLOSS represents a staggering 80-90% of any given piece of modern software (Nagle et al., 2020). It has become vital in almost all industries, as both the public and the private sectors strongly depend on it, including a large number of non-IT companies. However, the FLOSS phenomenon has considerably metamorphosed from its original form over that period of time. Fitzgerald (2006) identified a significant transformation of the concept, a metamorphosis into a more mainstream and commercially viable form, in his characterization of the emergent "OSS 2.0" phenomenon. This evolution has been documented in various other studies. For example, early FLOSS projects were all initiated by hobbyist developers, but organizations later perceived strategic opportunities in initiating new FLOSS projects by opening up their own platforms and software development activities to external developers (Bonaccorsi et al., 2006). Aksulu and Wade (2010) emphasize the constant growth of the FLOSS phenomenon by studying the evolution of FLOSS research through a comprehensive literature review. They discovered that studies moved from a general and descriptive overview or very isolated topics (such as the potential benefits of FLOSS compared to proprietary software, the quality and lessons learned, and strategies for traditional companies) to other more mature topics where specific areas of knowledge emerged (such as licensing, developer motivations, open innovation, and open source governance). More recently, Franco-Bedoya et al. (2017) discuss a major evolution in FLOSS: the emergence of open source ecosystems defined as software ecosystems placed in heterogeneous environments each involving a set of niche players and a FLOSS community as a key player around a set of interdependent FLOSS projects. Steinmacher et al. (2017) also discuss the major changes faced by the FLOSS phenomenon and identify emerging FLOSS research themes such as communication and coordination within FLOSS communities and the adoption of Kanban in FLOSS settings, while concluding that FLOSS has reached the "end of the teenage years."

This FLOSS metamorphosis surfaces significant challenges for research. Initial preconceptions about FLOSS such as being primarily a voluntary endeavor undertaken by solitary developers who are pan-globally distributed, are clearly no longer fit for purpose (Carillo and Bernard, 2015). A number of other assumptions have been recurrently made about FLOSS which are now open to question and deserve reconsideration. This is a major concern for the building of a cumulative body of FLOSS knowledge in IS. Indeed, the perpetuating of obsolete knowledge about an evolving phenomenon while reusing this knowledge as the basis for new studies represents a major threat for the validity of new results. Besides, FLOSS is certainly at the point where theory development should be occurring. Theory development typically involves a statement of relations among concepts within a boundary set of assumptions and constraints (Rivard, 2014). It is obvious that if the underlying assumptions are no longer valid, this triggers significant issues and biases in FLOSS research. A bias is defined as any influence, condition, or set of conditions that singularly or together distort data (Leedy and Ormrod, 2001). Biases undermine the integrity of facts and are particularly pernicious when they are undetected as they form the basic assumptions that remain unchallenged (Leedy and Ormrod, 2001). Consequently, biases may distort the truth of the situations under scrutiny, thus leading to inaccurate generalizations. Studies on FLOSS are not immune to such situations and we argue that the major transformation faced by FLOSS over the last decades has engendered a high risk for disseminating obsolete assumptions in FLOSS research, jeopardizing its validity, applicability, and overall legitimacy towards FLOSS practice.

For instance, Carillo and Bernard (2015) point out the existence of inaccurate or erroneous beliefs on FLOSS found in IS research. The authors emphasize the fact that we need to consider the impact this can have on the methodological aspects of FLOSS research studies, the problems this raises for the validity of results and overall theory building, and the threat this represents to the overall credibility and legitimacy of the IS field when it comes to studying FLOSS.

Consequently, we believe it is time to step back before conducting further FLOSS research studies and to rigorously investigate the potential existence of obsolete assumptions on FLOSS in IS research. The timing is more important than ever considering the enthusiasm and increased use of evidence-based management by the information systems (IS) practitioners to improve their practice, as highlighted in Templier and Paré (2015). It would be fundamental for the durability of our relationship with the FLOSS practitioners and the credibility of our research results that they consume, to be consistent with the current state of evolution of the FLOSS phenomenon by taking care that we don't carry obsolete assumptions in the next FLOSS studies. This paper strives to answer the following research question: *What are the obsolete assumptions in recent academic research literature about the FLOSS phenomenon?* To answer this question, we conducted a ranked-type Delphi study with 20 expert researchers in the field in order to identify and rank according to their importance level, existing obsolete assumptions. We then discuss our results and provide implications for research and practice while recommending to carefully discard such assumptions in future FLOSS research.

2 Literature review

2.1 Obsolete assumptions

Multiple definitions of the term 'assumption' exist in the literature, although they have some degree of commonality. Ennis (1982, p. 78) defines an assumption as what is "taken for granted as a basis of argument or action." In a similar vein, Delin et al. (1994) suggest that assumptions may act as 'implicit premises' for thought and action, may be unconscious, or at least go unnoticed. Thus, we see that assumptions are frequently invisible to researchers, not so much because they are difficult to see, but rather because they appear to be consensually accepted as existing facts (Russo and Stolterman, 2000). For the purpose of this research, we adopt a definition in line with Leedy and Ormrod (2001), namely that an assumption is a premise taken for granted by researchers.

This research seeks to identify assumptions which are obsolete and so we devote some attention to the meaning of obsolescence. It has been defined by Line and Sandison (1974) as the "decline over time in validity or utility of information." Bearing this point in mind, we define an obsolete assumption as *a premise, taken for granted by a researcher, for which the validity or utility has either declined over time or never been established*. This is in line with the point made by Kock et al. (2008) who suggest that obsolescence can be demonstrated by falsifying validity with new facts or evidence. However, our use of the term "obsolete" is not to be confused with the term "outdated" or "faddish" which were the focus in Baskerville and Myers (2009) for instance.

2.2 Update FLOSS knowledge by challenging existing assumptions

Alvesson and Sandberg (2011) propose to adopt problematization as a methodology to identify and question assumptions in research and the consensus of prevailing theoretical perspectives. This can then allow researchers to formulate relevant research questions leading to possibly even more influential theories. Davis (1971) pointed out that a subject evolves over time, and frequently those who wish to assert current and interesting proposals can do so by refuting the more traditional assumptions. A useful example is the work of Russo and Stolterman (2000) which questioned several assumptions concerning the IS development methods and discussed the implications for research and practice in this field. Similarly, in their study of digitally-enabled coordination, Gkeredakis and Constantinides (2019) identified and revised outdated assumptions in order to help develop new theories on this emerging phenomenon.

2.3 Assumptions in FLOSS research

Given the increasing importance of FLOSS in the modern software industry and beyond (e.g., open hardware, open data, open innovation, peer production…), it is appropriate to study the long-held assumptions that may still underpin FLOSS research despite being obsolete. As already mentioned, several researchers have identified the transformative evolution of FLOSS over time. For example, Fitzgerald (2006) discussed the transformation of the FLOSS phenomenon into OSS 2.0 to respond and adjust to changing market needs. He identified the importance of updating several aspects of the phenomenon including the FLOSS development lifecycle, product domains, primary business strategies, product support and licensing. Paulson et al. (2004) investigated the existence of supporting evidence for five common beliefs about FLOSS products versus proprietary closed source software products:

- FLOSS development fosters faster system growth (in functionality, lines of code, and complexity over time)
- FLOSS projects foster more creativity (functionality added over time)
- FLOSS projects succeed because of their simplicity (overall complexity and average complexity of all functionalities)
- FLOSS products generally have fewer defects as they are found and fixed rapidly

- FLOSS projects are more modular than closed source projects.

The results show that only two of these five common beliefs were actually supported by the literature, demonstrating once again the importance of questioning assumptions that may underpin FLOSS research. More recently, a study by Carillo & Bernard (2015) highlighted some of the inaccurate or mistaken beliefs in IS research on FLOSS. Their work also raises awareness on the consequences of those beliefs on how we propose, test and falsify theories on the FLOSS phenomenon. The discussed beliefs were:

- FLOSS project inception: ‘Scratching the itch’ of a lone developer
- The linear and ineluctable career trajectory of contributors in FLOSS projects
- Contributors are unpaid and work for free
- FLOSS projects are open communities

In conclusion, previous studies, while being informative, have challenged some assumptions made on FLOSS that were preidentified by the authors. Nonetheless, such beliefs and assumptions were limited to certain facets of FLOSS, thus potentially omitting important ones. To date, there is no exhaustive and encompassing understanding of those assumptions while little is known about their respective degree of importance. We believe that it is now time to adopt a scientific approach to rigorously question the existence of obsolete assumptions that have pervaded FLOSS research of the years. Our main contribution is to shed light on the most significant obsolete assumptions so that future FLOSS research can operate on updated and current knowledge.

3 Research Method

3.1 Delphi method

Characterized as a method for soliciting information from experts about a subject (Okoli and Pawlowski, 2004), the Delphi method is a well-established technique in IS research that aim at reaching a reliable consensus within a group of experts, while allowing participants to provide individually inputs. It is well suited to addressing complex problems, especially in cases where judgmental information is indispensable (Okoli and Pawlowski, 2004). The method is flexible, allowing individual consultation of participants in several stages, in a rhythm appropriate to the context of the study, while also allowing for group consultation. Another advantage is that while ensuring anonymity between participants, the method allows the research team to do more in-depth follow-up, including requests for additional details or validations with participants after each consultation. This has advantages when compared to a once-off anonymous survey. Also, the Delphi method is feasible with a panel of participants, e.g., between 10 and 18 experts, and also avoids any confrontation and direct influence among the participants of the study during the process (Okoli and Pawlowski, 2004).

Furthermore, the method does not require the physical co-location of participants, thus allowing for consultation among geographically-distributed experts, which is particularly appropriate for a study on FLOSS development. Finally, the results of a Delphi study can contribute directly and immediately to both theory and practice. The design and rigor of the study can help build theory, while practitioners can immediately avail of the prioritized critical factors that are generated by the experts, which they can apply to their individual situations (Okoli and Pawlowski, 2004).

While sharing a common core of fundamental characteristics, there exist several Delphi method variants (classical, policy, decision, ranking-type, etc.) depending on the specific objectives and approaches needed (Paré et al., 2013; Skinner et al., 2015). In this study, we adopt a “ranking-type” Delphi design as we wished to reach a group consensus about the relative importance of a set of issues (Paré et al., 2013), in our case, obsolete assumptions. This goal is achieved by obtaining experts' judgment using an iterative controlled feedback process that includes three main steps all with the same panel of experts (see Table 1), namely, brainstorming, narrowing-down, and ranking (Paré et al., 2013; Schmidt et al., 2001).

#	Step	Objective
1	Brainstorming	Elicit as many issues as possible about the desired subject
2	Narrowing down	Reduce the list of issues to a manageable number to keep only the most important
3	Ranking	Rank the issues to reach the highest possible consensus rate

Table 1. Steps in a ranking-type Delphi

We used the "ranking-type" Delphi framework proposed by Schmidt et al. (2001) and followed the recommendations from Paré et al. (2013) about rigor in conducting ranking-type Delphi studies. Some researchers have opted to replace the first step (the brainstorming with the panel of experts) of the Delphi method with a literature review to generate the initial list of items, to reduce the number of questionnaire rounds and save time, and started at the second step (the narrowing down) with their participants (Paré et al., 2013). To help our participants understand what an obsolete FLOSS assumption is, and rather than skipping the step of brainstorming in favor of a literature review only, we used both approaches in a complementary way. In fact, we provided four obsolete FLOSS assumptions discussed in the recent literature to our participants to help them generate a full list of such assumptions. One of the important characteristics in the context of a ranking-type Delphi is the stopping rules in the last step (the ranking) which determines when to end the process. The latter is recommended when one of the following three situations occurs: (1) Kendall's coefficient *W* of concordance is > 0.7, (2) three rounds have been performed, or (3) the mean rankings for two successive rounds are not significantly different. As recommended for this type of Delphi study, the Kendall's coefficient of concordance (*W*) is used to measure the level of agreement among the participants in the panel. The interpretation of the coefficient is as follows (with the confidence level) according to Schmidt (1997): 0.1 indicates very weak agreement (none), 0.3 is a weak agreement (low), 0.5 is a moderate agreement (fair), 0.7 is a strong agreement (high), and 0.9 is an unusually strong agreement (very high).

3.2 Recruitment of participants

The Delphi method requires knowledge and experience from people that are well-versed in the domain and who can provide meaningful and valuable results. In this study, we identified the experts by relying on the approach suggested by Okoli and Powlowski (2004). In our context, we considered the FLOSS experts comprised of researchers who write, read, and review scientific papers on FLOSS. Indeed, researchers are the main reviewers and consumers of scientific articles and therefore are expected to be particularly knowledgeable about assumptions held by FLOSS researchers. That is why we focused specifically on this group of experts.

We first defined the selection criteria based on contribution and experience in FLOSS: (1) be an active contributor in FLOSS as a researcher (published papers, communications at conferences) and (2) be a consumer of FLOSS research results for at least 10 years (thereby having witnessed changes in the FLOSS context). All authors in this study proposed names and contact details of other potential candidates for the study. Next, an internal protocol was defined to ensure that all members of the research team would recruit potential experts in the same way and would provide the same information and instructions. Invitations were sent to potential candidates while also asking them for suggestions of other potential candidates to increase our list. Through this procedure, we reached an adequate number of participants for the study - in this case 52 potential participants. There is no consensus in the literature about the adequate number of experts, but most studies report a panel size between 7 and 30 (Paré et al., 2013). The recruitment process took place from mid-June to September 2020 and the response rate to the initial call for participation was 63.5% (33/52). Eventually, 20 participants officially agreed to partake the study and signed the ethical consent form. This number of participants is considered largely adequate compared to several other recognized studies using this method and is aligned with the best practices proposed by Paré et al. (2013) to assure rigor in ranking-type Delphi studies. The most mentioned reasons that was expressed for not participating to the study were lack of time, health issues, or dealing with the impacts of the covid-19 pandemic.

3.3 Participants' profile

The panel of participants (Table 2) was composed of experienced researchers formally associated with a university and active in FLOSS research. They were retained in our final selection as we wanted to obtain a consensual view from those who have regularly produced and consumed scientific FLOSS literature over the years. Therefore, the selected researchers were in a strong position to inform us about the most recurring obsolete assumptions that are still present in recent research and also to decide which of these assumptions are the most important to be addressed. Moreover, all participants had a doctoral degree and were distributed internationally across 12 countries and 4 continents. In total, the panel was made up of 20 participants - 17 men and 3 women with an average age of 48 years and an average of 16 years of FLOSS research experience. These researchers comprised 60% full professors, 25% assistant professors, 10% associate professors, and 5% senior lecturers.

P#	Gender	Age	Years in FLOSS	Country of the University	Role/Title
1	Man	46	12	Netherlands	Full professor
2	Man	43	20	Spain	Full professor
3	Man	56	23	United States of America	Full professor
4	Man	44	8	United States of America	Associate professor
5	Woman	46	8	Canada	Assistant professor
6	Man	58	20	United States of America	Full professor
7	Man	*NA*	18	United States of America	Associate professor
8	Man	49	10	United States of America	Full professor
9	Man	46	16	Canada	Assistant professor
10	Man	34	10	Brazil	Assistant professor
11	Man	41	15	Brazil	Assistant professor
12	Man	50	13	Belgium	Full professor
13	Man	54	34	Greece	Full professor
14	Man	54	20	Spain	Full professor
15	Woman	53	18	Italy	Full professor
16	Man	42	14	Netherlands	Full professor
17	Man	63	20	Oman	Full professor
18	Man	46	22	France	Full professor
19	Man	40	12	Japan	Assistant professor
20	Woman	48	15	Ireland	Senior lecturer
	Average :	48	16.4		

Table 2. Profile of the Experts

3.4 Data collection and Analysis

Data collection took place over a period of eight months from October 2020 to June 2021. Before starting the Delphi study with the participants, the entire process, instructions, and questionnaires were pre-tested with the research team members as well as with two independent researchers who met the inclusion criteria for participation in this research but were not actual participants. Some minor modifications to the instructions and the questionnaires were made following their comments.

Data collection was carried out following the three main steps of the Delphi method as shown in Figure 1 and for a total of six consultations (consultation #1 to consultation #6) with participants during the entire process. To help our participants start the brainstorming we provided them with four obsolete assumptions discussed in the recent literature as valid examples of obsolete FLOSS assumptions for the initial list.

1 - Brainstorming

1.1. **Preliminary action:** Four valid examples of obsolete assumptions with justifications of obsolescence taken from Carillo and Bernard (2015) were provided to participants to start the process.

1.2. **Consultation #1:** A list of obsolete assumptions with justifications of obsolescence was collected from participants, for a total of **79 assumptions** including the four examples provided at the outset.

1.3. Duplicate assumptions were removed, similar assumptions merged together, and assumptions containing more than one subject were split by the first author. Some assumptions were reformulated by the first author to ensure uniformity and consistency within the list, but all justifications of obsolescence were kept intact.

1.4. The removals, merges, splits and reformulations were examined by the second author and discrepancies were discussed with the first author, for a new total of **63 assumptions**.

1.5. **Consultation #2:** Any changes (removed, merged, split or reformulated assumptions) were validated with the participants whose generated assumptions were altered, to ensure that their views were still adequately represented in the assumptions.

2 - Narrowing down

2.1. **Preliminary action:** The list of **63 assumptions** were randomized and given to participants along with the justifications of obsolescence for each assumption.

2.2. **Consultation #3:** Each participant was asked to select the 10 most important assumptions to discard or update in future FLOSS research (in no particular order).

2.3. Assumptions that were selected by more than 20% of the participants were retained for the next phase for a new total of **21 assumptions**.

3 - Ranking

3.1. **Preliminary action:** The list of **21 assumptions** was randomized and given to participants along with the justifications of obsolescence for each assumption.

3.2. **Consultation #4 (round 1) :** Each participant was asked to rank the 21 assumptions on the list and justify this ranking according to those they consider the most important to discard or update in future FLOSS research.

3.3. **Consultation #5 (round 2)** and **Consultation #6 (round 3):** The participants received the following information: the overall ranking of the panel, the group's coefficient of correlation, additional information for each assumption of the ranking such as the average rank and the difference between the rank of the group and his/her own and the justifications of obsolescence provided by the other participants. Each participant revised the list of 21 assumptions after taking into consideration the information provided from the previous round. The information provided to each expert for each assumption was: the rank given by the expert, the overall group rank, the difference between the rank given and that of the overall group, the mean rank, the percentage of experts placing the assumption in the upper half of the ranking, the comments and justifications from the other experts.

3.4. Ranking was stopped after three rounds when two stopping rules for a ranking-type Delphi have been reached. First, three rounds have been performed. Second, the mean rankings for two successive rounds were not significantly different (only five of the twenty-one assumptions moved in the ranking including four of them by only 1 rank and one assumption by 2 ranks).

Figure 1. Delphi study process of the study executed

The Delphi method led to the identification of 21 obsolete assumptions (see Figure 2) and obtained a moderate group agreement on the relative priority of each of them with a Kendall's coefficient of concordance W=0.538, which means a level of confidence judged to be "fair" according to Schmidt (1997). The panel obtained this final level of agreement after starting with a less than very weak agreement W=0.065 after the first round but quickly reached a weak level of agreement after the second round W=0.331 to finish with a fair one W=0.538.

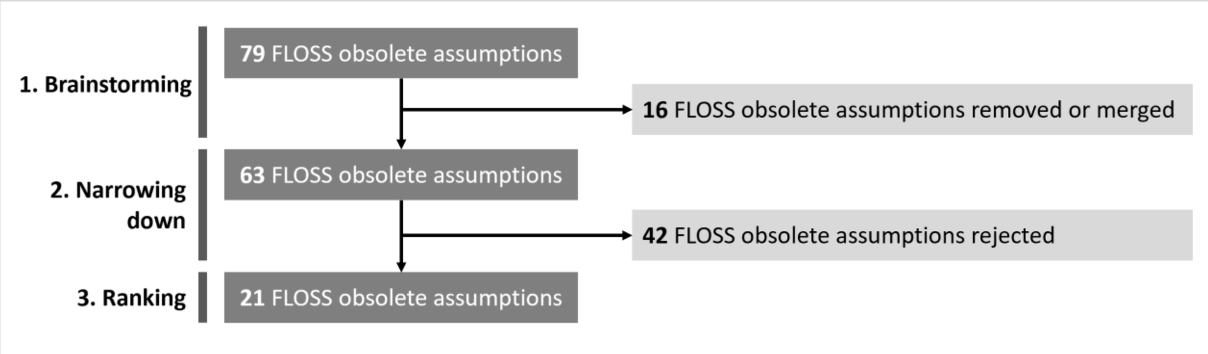

Figure 2. Approach for obtaining the final list of obsolete assumptions

Given the vast scope of a phenomenon such as FLOSS, we used a thematic analysis method as proposed by Braun and Clarke (2006) for identifying, analysing and reporting themes within data. The method involves 6 phases as follows: (1) Familiarizing yourself with your data, (2) Generating initial codes, (3) Searching for themes, (4) Reviewing themes, (5) Defining and naming themes, and (6) Producing the report.

In this study, all steps proposed by Braun and Clarke (2006) were performed by involving all the five researchers in our team : researcher #1, who was not directly involved in data collection, looked at the data and generated a first set of codes. Researcher #2 took these initial codes and formalized them with a revised proposition. The revised set of codes was confirmed by Researcher #3, who performed the data collection. Then, Researcher #3 identified, reviewed, defined and named themes. Finally, Researchers #4 and #5, as well as Researchers #1 and #2 who proposed the initial codes, validated the themes that would be used to facilitate the interpretation and the discussion of the results.

4 Results

As mentioned, the brainstorming and narrowing-down rounds resulted in the 21 most important assumptions according to the expert panelists. This was followed by the ranking step where three rounds were performed and from which the main results are presented in more details below. It should be noted that all the results generated during the three steps of the Delphi method (brainstorming, narrowing down, and ranking) come entirely from the participants without influence and opinion from the researchers conducting the Delphi study.

Once the ranking step has been completed and in order to facilitate the interpretation and discussion of the results, we grouped the 21 FLOSS obsolete assumptions into six distinct themes: **(1) FLOSS Sampling** (how to sample FLOSS projects), **(2) FLOSS Project/Community** (how to describe FLOSS projects/communities), **(3) FLOSS Evaluation** (how to measure/evaluate FLOSS products), **(4) FLOSS Product** (how to describe FLOSS products), **(5) FLOSS Contributor** (how to describe FLOSS contributors), and **(6) FLOSS Development process** (how to describe FLOSS development process). The ranked assumptions, themes, and the mean ranks round by round are shown in Table 3.

		Mean Ranks		
Final ranking	**FLOSS obsolete assumption**	**R #1**	**R #2**	**R #3**
FLOSS Sampling				
1	Getting a random sample of GitHub repositories is a good sample of FLOSS repositories	8.32	3.74	2.74
7	Most starred projects on GitHub comprised the most popular FLOSS projects	10.26	8.42	7.58
FLOSS Project/Community				
2	FLOSS is all the same; It is just one big thing, and we can make broad generalizations about FLOSS without context setting	9.58	6.58	4.74
3	Looking at code contributions alone is sufficient to describe a FLOSS project	8.42	6.74	5.68
8	FLOSS coordination is fully observable from online trace data	10.37	9.26	8.47
16	FLOSS projects are open communities: anyone can join a FLOSS project	12.63	13.47	14.37
20	FLOSS is a space without hierarchy	12.79	16.05	17.00
21	Truck factor will kill FLOSS projects	14.37	17.58	19.58
FLOSS Evaluation				
4	FLOSS popularity can be detected with number of downloads	10.16	7.37	6.63
11	Popularity is a good proxy for FLOSS product quality	10.74	10.58	10.68
FLOSS Product				
5	Adopting FLOSS does not cost anything	9.16	7.63	6.74
9a	FLOSS cannot be commercially exploited	10.58	10.47	10.42
17	FLOSS products are less reliable than proprietary ones; for this reason, FLOSS cannot be used in business	11.68	13.79	14.74
18	FLOSS means low security	13.00	14.47	15.95
FLOSS Contributor				
6	FLOSS contributors are mainly unpaid volunteers/hobbyists	9.63	8.16	7.00
9b	FLOSS projects are open and composed of a diversity of contributors (gender, culture, race, and ethnic group)	11.26	11.58	10.42
12b	FLOSS community members are not employed by companies	10.79	12.11	12.53
15	When the individual is the unit of analysis, we can understand his/her behavior by looking at a single FLOSS project he/she is involved in	12.74	14.05	13.95
FLOSS Development process				
12a	Drive-by contributions are not important to the FLOSS projects, since 80% of the code is usually developed by less than 20% of the developers	10.63	11.74	12.53
14	There is one way of developing FLOSS: the Open Source way™	11.68	12.58	12.74
19	Bugs are shallow in FLOSS because multiple eyeballs can scan the source code	12.21	14.63	16.53
	Kendall's W :	***0.065***	***0.331***	***0.538***

Table 3. Final ranking of obsolete assumptions

5 Discussion and Conclusion

This study reveals an array of potential challenges to the validity and legitimacy of IS research on FLOSS by identifying and prioritizing obsolete assumptions still in use. By directly questioning experienced researchers in the field about these biases that can have an impact on FLOSS research results, we identify several obsolete assumptions that cluster into six higher-level themes which we discuss below.

5.1 Interpretation of results

The obsolete assumption "***Getting a random sample of GitHub repositories is a good sample of FLOSS repositories***" is at the top of the final ranking list. The participant who initially identified and challenged this assumption argued that "*I still find this underlying assumption in many large-scale studies. Even a quick exploration of any random sample of GitHub repositories with a certain size (say, 100 repositories) includes personal projects not intended for distribution, documentation projects, tests, and even almost-empty repositories.*" Then, the importance of this assumption was recognized and supported by the other participants of the panel, moving this assumption from an average rank of 8.32 in the first round, followed by 3.74 in the second round to end at 2.74. In their ranking justifications, the experts wrote the following :

- "*Many repositories in GitHub are really a backup, just thought and used for and by their authors.*"
- "*There are projects outside of GitHub. There is no such thing as "a random sample" of GitHub projects and the entire notion of representativeness is problematic anyhow.*"
- "*Research proved there is a lot of noise in FLOSS projects (GitHub students' projects). Thus, random samples might be biased.*"
- "*There are projects outside of GitHub.*"
- "*This is a very clear and very important wrong assumption that I have seen being made several times, hence researchers need to be communicated about this urgently.*"

This result corresponds to the obsolete assumption that experts have evaluated as the most important and urgent to signal to researchers not to perpetuate anymore in future research on the FLOSS phenomenon. We are not surprised that an assumption pertaining to FLOSS sampling is at the top of the final list, considering that the panel of experts is composed of researchers. In fact, representative sampling not only enhance the rigor of research, but also the relevance of the research results for practice, both rigor and relevance being increasingly important for IS researchers as demonstrated by Straub and Ang (2011).

The first theme concerns **FLOSS Sampling** theme. Even if it only represents 2 of the 21 identified obsolete assumptions, both assumptions are in the first third of the ranking and occupy first position of the ranking: **#1** *Getting a random sample of GitHub repositories is a good sample of FLOSS repositories* and **#7** *Most starred projects on GitHub comprised the most popular FLOSS projects*. These results highlight the critical issue of sampling biases in FLOSS research. Bias diminishes research integrity, and sampling issues have been identified as a significant precursor to bias (Leedy and Ormrod, 2001).

FLOSS Project/Community is the second theme. It is the most represented in the list with 6 obsolete assumptions and with positions distributed throughout the ranking: **#2** *FLOSS is all the same; It is just one big thing, and we can make broad generalizations about FLOSS without context setting*, **#3** *Looking at code contributions alone is sufficient to describe a FLOSS project*, **#8** *FLOSS coordination is fully observable from online trace data*, **#16** *FLOSS projects are open communities: anyone can join a FLOSS project*, **#20** *FLOSS is a space without hierarchy*, and **#21** *Truck factor will kill FLOSS projects*. These obsolete assumptions represent diverse aspects of FLOSS projects and the surrounding community that supports them.

The first three (**#2**, **#3**, and **#8**) are in the top segment of the ranking and concern the generalization bias in research induced by limited information or by not considering important contextual variables. An important problem when generalizing a phenomenon is to understand its variation, and the diversity in a phenomenon is often underestimated in qualitative research especially given inadequate sampling, emphasis on common characteristics, minimizing differences, or using theories that do not fit all the data (Maxwell, 2012). To elaborate an example of proof of obsolescence, the notion of

FLOSS community citizenship behaviors is studied by Carillo et al. (2014) and indicates that we should not only consider the code contributions to describe a FLOSS project (**#3**) because non-code contributions form a significant part of the tasks being undertaken in larger projects.

There are three other obsolete assumptions under this group (**#16**, **#20**, and **#21)** and these are positioned at the end of the ranking. They emphasize the managerial aspects of a FLOSS project and its community of contributors. These indicate the need to be cautious with assumptions concerning: the openness of FLOSS projects to welcome any type of new contributors, the absence of hierarchical structures in FLOSS projects, and the incapacitation of a FLOSS project due to a number of developers quitting the project. An example of the falsification of one of those obsolete assumptions is the work of Di Tullio and Staples (2013) who identified 19 distinct control mechanisms used to govern FLOSS projects, putting into perspective that FLOSS projects are open communities where anyone can join (**#16**). Since they identified control mechanisms for the inclusion of new participants, it demonstrates that not everyone can join a FLOSS project.

The third theme is about **FLOSS Evaluation**. Two obsolete assumptions fall into this category, and both express a bias towards indicators for evaluating FLOSS products: **#4** *FLOSS popularity can be detected with number of downloads* and **#11** *Popularity is a good proxy for FLOSS product quality*. The number of downloads to measure the popularity (**#4**) of a FLOSS product and that this popularity reflects the quality (**#11**) of a FLOSS product are commonly used measures of success, but there are several others as mentioned by Medapa and Srivastava (2019). One explanation for their presence in the list and their high position in the ranking may be that these indicators should not be taken alone to assess popularity or quality. Another example of falsification of the obsolete assumption about popularity reflecting quality (**#11**) is a paper by Sajnani et al. (2014) demonstrating that there is no correlation between software popularity and software quality.

The fourth cluster of assumptions relate to **FLOSS Product**s. Four obsolete assumptions emerged in relation to this theme: **#5** *Adopting FLOSS does not cost anything*, **#9a** *FLOSS cannot be commercially exploited*, **#17** *FLOSS products are less reliable than proprietary ones; for this reason, FLOSS cannot be used in business*, and **#18** *FLOSS means low security*. The first two (**#5** and **#9a**) obsolete assumptions identified here concern the financial aspects of a FLOSS product. Concerning the no cost obsolete assumption (**#5**), it has been shown by Russo et al. (2009) that the cost for initial purchasing is not the only cost to consider; there are other costs that form the Total Cost of Ownership (TCO) of a FLOSS product. Regarding commercial profitability for FLOSS product (**#9a**), there are many ways for turning commercial for Open Source (Fosfuri et al., 2008), therefore making this assumption erroneous.

The two other assumptions (**#17** and **#18**) under this theme, relatively far down the list, are related to the attributes of reliability and security in FLOSS products. Here again, the results indicate that researchers must be careful when making assumptions about the reliability and security of FLOSS products since many examples show the contrary. For example, several studies (e.g., Fitzgerald, 2011) demonstrate the higher reliability of FLOSS products in comparison with proprietary source code software products (**#17**). Regarding the link between FLOSS product and low security (**#18**), Payne (2002), Cowan (2003) and Schryen and Kadura (2009) demonstrate that security was already highly important for FLOSS developers at the very beginning of the FLOSS movement. Moreover, empirical results have shown that FLOSS and closed source software do not differ significantly in terms of vulnerability severity (Schryen, 2011).

FLOSS Contributors is the next category. Four obsolete assumptions emerged: **#6** *FLOSS contributors are mainly unpaid volunteers & hobbyists*, **#9b** *FLOSS projects are open and composed of a diversity of contributors: gender, culture, race, and ethnic group*, **#12b** *FLOSS community members are not employed by companies*, and #**15** *When the individual is the unit of analysis, we can understand his/her behavior by looking at a single FLOSS project he/she is involved in.* Two obsolete assumptions that emerge from the results relate to the fact that FLOSS contributors involve unpaid volunteers (**#6**) and contributors are not employed by companies (**#12b**), subjects that have long been covered in research on FLOSS. In relation to the unpaid volunteers assumption (**#6**), nowadays, there is a global consensus on the fact that a large number of contributors are paid to contribute to FLOSS projects (e.g., Robles et al., 2019). Regarding the idea that contributors are not being employed by companies (**#12b**), many articles demonstrate the involvement of companies and their employees as FLOSS contributors (Zhang et al., 2020; Germonprez et al., 2017). Regarding the openness and composition of a diversity of contributors (**#9b**), several studies indicate that it is not so clear-cut as it has been shown that the country of origin of pull request submitters plays a role in their acceptance rate (Rastogi et al., 2018) and although not generalizable, FLOSS projects pose barriers of entry that might disproportionately disadvantage women and people with a cognitive style that differs from the dominant style in software development (Mendez et al., 2018). The last assumption in this theme concerns understanding the behavior of a contributor with a single FLOSS project (**#15**). This statement is contradicted by the results of Barcomb et al. (2019) showing that a person who participates episodically in a FLOSS project participates in a median of 1 FLOSS project usually, and 3 FLOSS projects episodically.

Last but not least, the **FLOSS Development process** theme is represented by 3 obsolete assumptions positioned between the middle and the end of the ranking: **#12a** *Drive-by contributions are not important to the FLOSS projects, since 80% of the code is usually developed by less than 20% of the developers*, **#14** *There is one way of developing FLOSS: the Open Source way™*, and **#19** *Bugs are shallow in FLOSS because multiple eyeballs can scan the source code*. The development process is a large theme and the variety of the three obsolete assumptions demonstrate that. Concerning the low importance of drive-by contributions (**#12a**), it is interesting to consider research such as Barcomb et al. (2019) which offers suggestions for projects to incorporate and manage episodic volunteers, so as to better leverage this type of contributor and potentially improve project sustainability. As for the 'one way to develop FLOSS' view (**#14**), there are many projects that do not use the full spectrum of available tools like the ones that have been termed "engineered" projects by Munaiah et al. (2017). As for the obsolete assumption that bugs are shallow (**#19**), the study by Kug (2010) suggests the contrary.

5.2 Contribution to Research and Practice

Several studies have considered the continuous evolution of the FLOSS phenomenon e.g., Fitzgerald (2006), Aksulu and Wade (2010), Franco-Bedoya et al. (2017), Steinmacher et al. (2017). Others (e.g., Carillo and Bernard, 2015) have raised the flag about the existence of certain b erroneous beliefs that are still used in recent FLOSS research and which are now obsolete. However, that research focused on only a few elements of the broad and current context of FLOSS. Recognizing the vast scope of the FLOSS phenomenon, its complexity, and its continuous transformation for over two decades now, the first contribution of this study is to highlight potential threats to the validity and legitimacy of FLOSS research through the dissemination of obsolete assumptions in FLOSS studies. As some of the researchers involved in the panel told us during the study, this discussion is urgent in order to benefit future FLOSS research. The second contribution for research is the identification and the prioritization of a list of 21 obsolete assumptions which identify specific elements to challenge and be aware of in future FLOSS research considering the detrimental impacts they can have on the validity of the results and the legitimacy of FLOSS research in IS. This study also contributes to practice in the sense that it directly tackles the gap that may exist between the knowledge used in research and the current state of the FLOSS phenomenon in practice. This gap between research and practice is a serious threat to the legitimacy of our past, current, and future body of FLOSS knowledge, which can ultimately affect the relationship between FLOSS practitioners and IS researchers. Thus, like any other area of knowledge based on the study of evolutive phenomena, practitioners can only benefit from research when the generated body of knowledge is free from biases such as obsolete assumptions. In turn, practitioners will then be more inclined to partaking and collaborating into FLOSS research projects, leading to the strengthening of the continuous development of FLOSS knowledge in our field.

5.3 Limitation and Future research

The main limitation of this study is that it is based on the views of researchers alone, albeit expert candidates. This can represent a limitation with regard to their own work and view towards obsolete assumptions, but the chosen method (the Delphi method) eliminates, by step #2 - the narrowing down, the unique items raised by a very limited number of participants. Also, the researchers are the most directly involved in the regular consumption of scientific articles (more than the practitioners) where these obsolete assumptions can be identified for this study. We believe that the wide range and diversity of experts, their geographical context, their research context (information system or software engineering), and for some of them their proximity and implications in FLOSS practice, are forces of the panel built and help to mitigate this concern.

To pursue along the path of identifying obsolete assumptions and their impacts on the validity and the legitimacy in FLOSS research, future studies could also consult expert FLOSS practitioners to get their point of view and compare the results in order to have a broader overview. Also, a logical next step would be to rigorously explore the IS literature on FLOSS in search for specific instances of the use of obsolete assumptions. This would allow to quantify the extent to which obsolete assumptions have tainted current FLOSS research. Finally, the questioning and updating of our obsolete assumptions is another logical direction to continue along this line of inquiry. The gradual transformation of FLOSS development and practices has not and will not cease: it will keep evolving. It is thus essential to regularly assess the existence of other assumptions that may infuse future FLOSS research results. We thus call for future replications of this work. In conclusion, the existence and detrimental impact of obsolete assumptions on research do not solely pertain to the FLOSS phenomenon.

To conclude, this paper also provides a methodological contribution by encouraging researchers to adopt a similar approach and research design to investigate the erroneous assumptions that are triggered when studying IS-related phenomena that are highly evolutive in nature and in constant change. We sincerely hope this paper will trigger such research efforts.

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