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# Mapping and Analysis of Open Source Software (OSS) Usability for Sustainable OSS Product

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**ABSTRACT** The increase in the number of open source software (OSS) users have drawn attention to improving usability. Usability is a clear concept that encompassing both task and user characteristics as well as functionality. Usability is an essential factor that affects user acceptance and OSS sustainability, which is considered as the key to the success of the OSS. To some extent, usability is one concern of the larger issue of system acceptability and sustainability. Therefore, usability is an important factor that needs to be considered since the software that is not usable is not going to be sustainable. The objective of this paper is to review researchers' efforts to improve, investigate, and evaluate the usability factor that may affect the OSS acceptability and sustainability and map the research scenery from the articles into a comprehensible structured taxonomy, which would help the researchers to identify different research gaps of this field. A survey of the usability in OSS conducted and 6033 studies identified by a search in four scholarly databases using a query that includes the keywords (usability or learnability or efficiency or satisfaction) and (open source software or OSS). A total of 46 studies are selected. By manually searching in ACM, Springer, and Google Scholar five other studies identified, and thus a total of 51 studies were the final set that includes in this paper. Based on research topics, a taxonomy created and divided into four principal categories which improve OSS usability, analyze OSS usability, evaluate OSS usability, and select and adopt OSS. A comprehensive overview and synthesis of these categories are presented as well. This paper contributes to identifying the possible opportunities and gaps for enabling the participation of interested researchers in this research area. And give possibilities for extending the use of usability research and practices to create more sustainable software. Also, helps in selecting suitable OSS among the alternatives.

**INDEX TERMS** Usability, learnability, efficiency, satisfaction, open source software, and sustainability.

## I. INTRODUCTION

The growing use of OSS applications and the increase in the number of non-developer OSS users have been formed a need for developing usable OSS [1]–[3]. Usability is an essential quality factor that needs to consider [4]–[6]. Usability is a feature associated with software sustainability [6]. One recognized risk of using OSS applications is OSS sustainability; It would be expensive for the community if the OSS application fails halfway [7]. In the development process of OSS, developers generally build the software for themselves; therefore, the usability of OSS is poor [1], [8]. Such poor usability limits the adoption of OSS [9] and therefore affects its sustainability. Sustainability is an essential driver for the industry to adopt OSS [7]. Different OSS development projects use dissimilar methods to produce products [1]. Consequently, usability in the OSS environment needs to be investigated [10]. Therefore, a survey to investigate the usability in OSS conducted.

This survey presents relevant insights into usability in the OSS environment and helps researchers by explaining the possible options and gaps in this research area would support and improve the research in this field. The survey intends to address and show researchers' efforts on the new methodology, outline the research aspects into a comprehensivetaxonomy and determine the characteristics that define a research line in OSS usability. This would permit the researchers to be equipped to review or assess

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existing literature based on the known lack to look for or expect.

The purpose of this study is to improve the quality of evidence in the usability of OSS by investigating and evaluating the usability factor that may affect the OSS acceptability and sustainability and Map the research scenery from the articles into a comprehensible structured taxonomy which would help the researchers to identify different research gaps in this field.

## II. METHOD

This section described the search strategy and the sources of the information, the criteria for inclusion and exclusion articles, study selection, and data extraction.

### A. SEARCH STRATEGY AND INFORMATION SOURCES

A four database indexes which are ScienceDirect, IEEE Xplore, Web of Science (WoS) and Scopus searched for articles dating from 2007 to 2019 using the following keywords 'usability', 'learnability', 'efficiency' and 'satisfaction' connected with 'OR' and 'AND' operators and then followed by 'open source software' or 'OSS' to formulate the search query. And ACM, Springer, and Google Scholar used by a manual search.

### B. CRITERIA FOR INCLUSION AND EXCLUSION ARTICLES

Studies were included if they focus on usability in open source software in either one or more of the following aspects: i) define or discuss usability issues in the context of open source software; ii) employs at least one knowledge-based approach to address usability problem in open source software; iii) reviewing or surveying the new trend of utilizing usability in the open source software; iv) designing or developing a usability or reporting the related experience and lessons learnt; v) analyzing the use or evaluating the usability through a scientific study. The exclusion criteria are as follows: i) non-English articles, (ii) the articles present a duplicate in different search engines (iii) studies that do not cover usability in OSS.

### C. STUDY SELECTION

The selection involves a search for papers in the aforementioned database indexes and the application of three rounds of filtration. All irrelevant articles are removed in the first round of screening and filtering. In the second round, the titles and abstracts are scanned to remove duplicates and irrelevant articles. In the last round, the careful full-text reading review is applied to all articles from the second-round. See Fig. 1. The eligibility criteria followed by the authors are applied to all iteration steps.

### D. DATA EXTRACTION

All the data extracted from papers that meet the inclusion criteria are summarized and tabulated into an excel file. The authors perform extensive full-text reading to obtain an extensive collection of data. For each paper, the data are organized and categorized based on the style preferred by the authors. The following were extracted for each paper: author/s name, title, study type, method or model or technique used, motivation, challenges, recommendation, strength, and weakness.

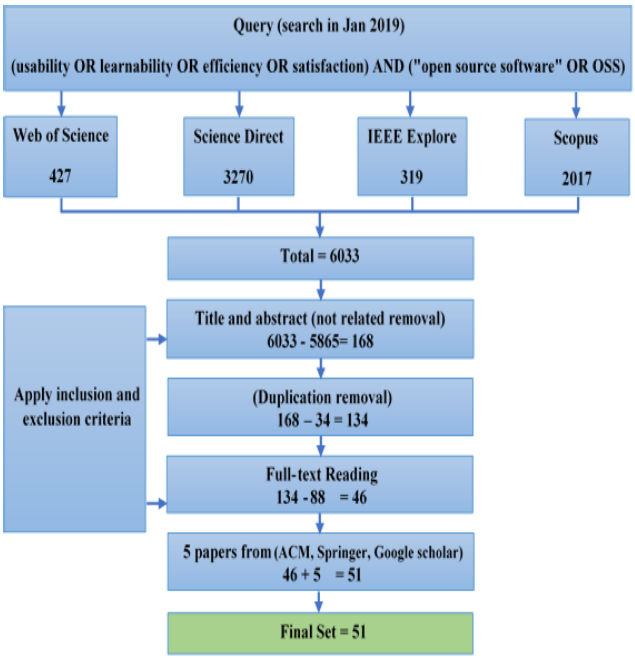


**FIGURE 1.** Study selection flow diagram.

## III. RESULT AND STATISTICAL ANALYSIS

In this section, the numbers of studies screened, assessed for eligibility, and included in the review will be given. The initial query from the four database indexes results in 6033 papers, of which 427, 3270, 319 and 2017 are from WoS, ScienceDirect, IEEE Xplore and Scopus, respectively. As an outcome of implementing the inclusion criteria on title and abstract, 134 candidate articles selected. During the full reading of candidate papers, the inclusion criteria employed again and resulting in 46 main papers related to OSS usability, the rest 88 articles are excluded because not defined or discussed usability issues in the context of open source software. Five papers from ACM, Springer, and Google Scholar are included. Therefore, the final set of papers is 51 See Fig. 1.

Fig. 2 shows the taxonomy used to review the main research streams that focus on OSS usability. The taxonomy divided into four principal categories which are: improve OSS usability, introduce OSS usability, analyse OSS usability, and evaluate OSS usability. A comprehensive overview and synthesis of these categories are presented as well.

The articles are distributed among these categories as: (56.86%; 29/51) in improve OSS usability category, which is comprises 15 articles on involving usability experts, two articles on introducing concept of usability and user awareness, four articles on usability defect report, one articles on Identify the OSS major challenges from the perspective of HCI, one article on a participative design approach, one article on

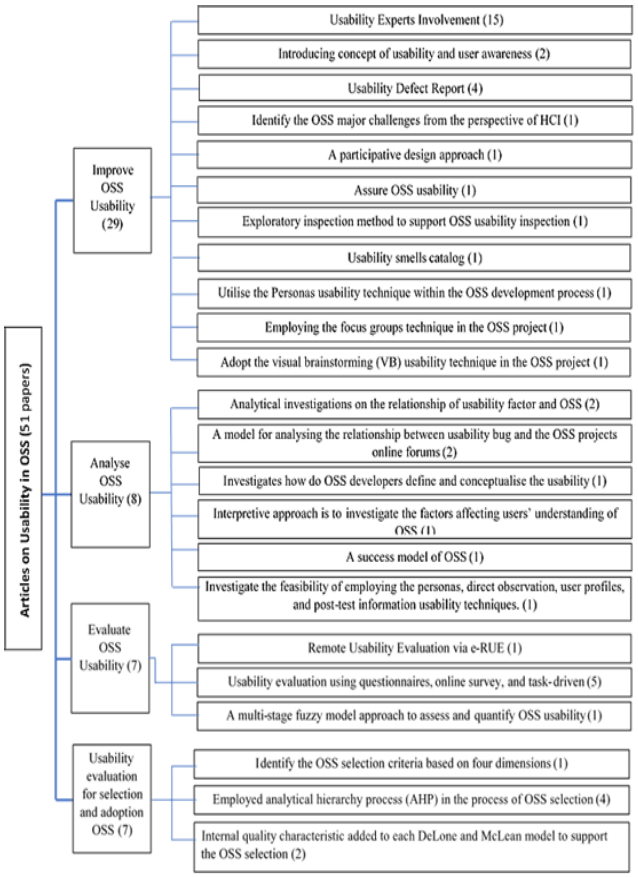


**FIGURE 2.** Taxonomy of research literature on OSS usability.

assure OSS usability, one article on exploratory inspection method to support OSS usability inspection, one article on usability smells catalog, In OSS development process one article utilizes the personas usability technique, In the OSS project one article employing the focus groups technique, and one apply the visual brainstorming (VB) usability technique.

(15.68%; 8/51) in analyse OSS usability category which is comprises two articles on analytical investigations on usability factor and OSS relationship, two articles on analyzing the relation between usability bug and the online forums of OSS projects, one article on investigates how do OSS developers define and conceptualize the usability, one article on investigating the factors affecting users' understanding of OSS, one article on a successful model of OSS, and one article on Investigate the feasibility of employing the direct observation, user profiles, personas, and post-test information usability techniques.

(13.72%; 7/51) in evaluating OSS usability category which comprises one article on Remote Usability Evaluation via e-RUE, five articles Usability evaluation using questionnaires, online survey, and task-driven, one article on open source usability maturity model, and one article on a multi-stage fuzzy model approach to assess and quantify OSS usability.

(13.72%; 7/51) in evaluating OSS usability for selection and adoption OSS category, which comprises one article on identifying the OSS selection criteria based on four dimensions which are information quality, system quality, service quality, and the potential internal constraints. Four articles on the employed analytical hierarchy process (AHP) in the process of OSS selection, and two articles on internal quality characteristic added to each DeLone and McLean model to support the OSS selection.

Many organizations have been adopted OSS applications due to significant advantages that the application offer. Sustaining development activities is a challenge in many OSS applications. Although many researchers performed the sustainability of OSS projects, ultimately there is a necessity for further research to examine the longitudinal impact of project sustainability [11]. Hence, the following sections discussed and described details of each taxonomy category that would support the achievement of OSS sustainability goals.

### A. STUDIES CONDUCTED ON IMPROVE OSS USABILITY

In this section, some of the existing OSS usability studies concentrate on how bugs are reporting, and other studies focused on the involvement of users in the design processes.

[12] the study introduces usability and user awareness into the community of an OSS developer. To facilitate an understanding of actual users and use in an OSS development community, a year-long intervention is presented. This study focuses on the reaction of the development community towards users' bug reports. The discussion analysis shows that the understanding of the usability concept is poor, and that technical solution is the focus of the community.

In [13]–[15] studies shows the ignorance of the user-centric design and usability experts has been a project managers global problem, the OSS developer willing to features-centric design rather than user-centric design. Furthermore, there's a lack of usability bug reporting tool that will help in showing the usability issues. Therefore, the authors focus on usability experts' involvement in OSS projects, the OSS developers and human-computer interaction (HCI) experts' interaction, and the eligibility of reporting systems to issue usability bugs as well. The authors analyzed the problems to finds the best way to overcome them in an uncomplicated manner. Their analysis shows that the high involvement of usability experts leads to the high acceptance of the product. While the late involvement will lead to narrows the point of involvement usability expert to crucial usability bug fixing. Moreover, the unsuitable usability reporting tool will cause decreasing of the reporters' number and the reports as well. The absence of the database to hold the bug reports make the follow, fixing, and giving the feedback to the reporter to laborious. Furthermore, misunderstood the purpose of the bug reporting tool. Moreover, the authors mention that to achieve usable and competitive OSS applications, then the developers' usability activity in projects should be measured, and proper user center design (UCD) methodology should be used. To improve the usability of applications and communication and collaboration of HCI experts and developers, the authors proposed a measurement method of OSS project. Two surveys were used

to investigate the work of usability experts and developers. The authors use the finding from the two surveys to analyse and measure OSS usability. High usability indicates enhanced productivity, selling and revenues, user satisfaction, reduced training, and support cost. Therefore, the research aims to study usability improvement aspects and propose a metric model. However, Poor OSS product evaluation is due to lack of clearly identified requirements of usability, UCD awareness and a helpful social tool to discuss the issues of usability. On the one hand, users have to understand how the OSS project deals with usability. On the other hand, the usability measurement method of the OSS project and its metric sets are needed to help stakeholders self-evaluate their project. The proposed measurements metrics has been not validated; therefore, this is considered the main lack of this study, at the same time, can be considered as future work.

There is a correlation between the speed of defect-removal and sustainability; the higher rate of defect-removal increases the OSS usability and therefore its sustainability. References [16]–[18] studies show that the usability defect report is a way for developers to improve OSS usability because concentrating on usability defects can help recognize the defect pattern. Producing a robust usability defects report can be a tiresome job, producing a robust usability defects report can be a tiresome job, mainly in distinguishing what significant information could be involved and bring the attention of software developers in fixing them. Although existing studies explore a variety of defects, a few concentrates on usability defects. To accurately grasp the problems related to usability defect report, the authors of a study conducted an online survey to survey 56 software projects of Mozilla and Google Chromium software contributors for usability defect reporters and developers and in their extended study, they survey 377. The authors identify numerous issues and limitations in the current usability defect reporting tools. Possibilities to improve defect reporting tools based on the needs of the OSS community are also highlighted. The most relevant and helpful information should be obtained to address usability defect report issues. The defect report must contain descriptive details that state the software problem clearly to ensure it is timely fixed by the developers. The failure in correctly fixing usability defects is due to that the reported problems are unclear or invalid for the software developers. The authors compare the expected reports of the developers and those sent by the reporters. The results show that the most anticipated information by the developer is the least produced by the reporter. Much defect information is required to address usability defects. Among the comments that grasped the attention of the authors, was the weaknesses of using a general defect report form. The author's advice to use the result of this study to customize the form of defect report to include a different kind of usability defects.

In [19] study, the authors focus on end-users supporting, they attempt to improve the usability of OSS via critical analysis of the system user interface. The authors present a case study of a small OSS project called Carrot2. usability practices are introduced to a mentioned OSS project, and a user interface (UI) is redesigned to support end-users. The authors mentioned that the developers claim that usability is a high superiority for them, but they seldom implement it in their projects. A study finds that the essential factors of successful usability practices are 1) usability enthusiasts working with project developers, 2) presence of usability practice for changing a primary system architecture 3) and presence of a straightforward UI.

In [20], the aim of this study is to recognize the OSS major challenges from the perspective of HCI. The authors comprise descriptive investigations. Works under this category support the OSS adoption and development processes for end-users, developers, and organizations. Considerable challenges of OSS from the perspective of HCI are also identified and discussed. A study argues that software usability, accessibility, and support for user and development communities are major HCI concerns. Through their investigation, the authors explored that the absence of usability experts and the improvement of functionality instead of usability in OSS development were the major issues. And the developers' communication and misunderstanding of the user audience considered as the biggest challenges. One possible solution is that the involvement of the end-users throughout software lifecycle to provide software products that meet user requirements.

In [21] study, the special interest group intends to inspire the participation of the UX community and to determine a good combination of UX in the development of OSS solutions. The results show that the increase in participation and contribution of UX professionals in OSS is instrumental in its usability.

[22] A study summarizes the current practices and recommends their use to ensure quality and usability in OSS development. This study concentrates particularly on OSS targeted at a community with different users, including OSS developers. The authors aim to review and compare the quality and usability assurance of OSS and software engineering and HCI field. the authors mentioned that the OSS projects testing is very limited; normally, there is no plan for testing. Iterate the design of OSS application based on the early feedback from the users will improve the OSS usability. They believe that OSS quality and usability can be guaranteed by utilizing proven methods and processes. A good practice is to employ UCD methods that provide a distributed environment in OSS development.

Reference [23] reviews eight case studies on usability in OSS projects. The results show that the lack of user research limits usability initiative in the projects. User research is a crucial phase in processing UCD and creating usable products. Lack of research in OSS projects is due to weak or ambiguous leadership of the project, cultural misunderstandings between developers and designers, and the absence of usability experts. the authors agreed that to well define the vision of the project and the target audience, clear and powerful leadership is required. Furthermore, usability experts'

involvement as contributors it also required. With these important issues, usability activities can be effective and work problems can be addressed when the OSS usability community creates a large number of usable OSS products. The authors aim to explore the reported challenges or failure commonalities. Further research on usability methods used in OSS projects and feedback from projects can help solve the complexity of user research.

In [10] study shows that in the OSS context, usability and its improvement are vital issues that need further investigation. the flaws of software usability that often result from a misunderstanding of user requirements would cause poor usability. Furthermore, usability specialists are usually not involved in OSS development. Moreover, the capability to design for usability is a skill that is not commonly found between contributing users of OSS. Therefore, the authors encouraged to propose an exploratory inspection method to assist the contribution of OSS users to OSS usability inspection. Exploratory learning can be identified as inspiring learning by exploration and experimentation to attain experiences. The proposed method is intended to support the problem-solving process of discovering usability bugs in the OSS development context. The authors provide an adequate alteration of the 'learning-by-doing' approach to the usability inspection domain. Using a supervised experiment in a real-world OSS setting the effectiveness of this method has been validated.

Reference [24] presents a smells catalog which is called usability smells, this catalog defines the usability exceptions in an interactive application context, the catalog acquired from the catalog of source code smells defined by Fowler. Usability smells reflect the poor design of UI, which may impede the usability, maintenance and evolution of OSS. In this study, a set of programs (i.e. usability refactoring) is proposed to eliminate such usability smells. To validate the proposed usability smells catalog, the authors perform an empirical study on a real OSS hospital management application context.

Reference [9] show efforts to produce and motivate the consistent application of usability and the UI design concepts in the OSS project. the authors proposed a Kitchen Sink tool. The Kitchen Sink tool included five components which are specification, documentation, illustration, design, and testing. A participative design approach used, in which the developers considered as clients, and works with them to develop the aspects of the Kitchen Sink.

References [8] and [25]–[27] focused on the involvement of usability experts in making design decision when taking part in the development process. Reference [25] analyse the development of UI and its usability in the context of OSS company as a software development interpretive case study. This study focuses on commercial software development that uses OSS as a product part for further development, and the source code is released to the OSS community. How an OSS company develops usability and UI is investigated. Developers commonly produce software for themselves; thus, OSS usability is poor for the end-users. Furthermore, OSS developers also do not know the end user's tasks and the context of use. From the results on user participation, the authors observe that OSS project users have informative, consultative and participative roles. The authors suggest including usability and HCI specialists in the early stage of the OSS design context. In [8] this study focus on investigating usability practices in the OSS community by the analyzing the usability discussion forum. The results of investigating show that the developers lack knowledge on the end-users, their tasks nature, and context of use. The authors show that user involvement could be combined with OSS projects.

In [26] study, the author explores the emergence of end-user usability innovations in OSS development to increase usability. These initiatives are recognized via communication amongst OSS users and between OSS users and developers in the discussion forum of OSS usability. Existing research on OSS has already drawn several issues that may create problems in usability innovation in the development of OSS. Developers usually do not know the end user's tasks and the context of use. End-users also have difficulty reporting usability problem to the developers. Fixing and textually explaining confusing usability bugs are also complex. Whilst including usability experts highly improve OSS usability, they are lacking in OSS projects. While in [27] study, the author examines the involvement of usability experts as users in the development phase. The author state that the impact of including usability experts in the design decision is crucial for software usability. Nevertheless, the usability experts have difficulty in making design decision when taking part in the development process. Excluding them results in poor OSS usability. The author focuses on the contribution of OSS emergence to the dynamics with 'user configuration' and 'designer configuration' involvement.

References [5] and [28]–[33] focuses on the involvement of usability experts in OSS development. In [33] study, the authors focus on the context of OSS development implications on usability cost-benefit. In OSS development there is a lack of studies on usability costs and benefits. In the past years, traditional software development has not involved usability specialists and integrated usability activities in the development process. Accordingly, the authors of a study assume that the standards adopted for selling usability to traditional out software development can also employ in the development of OSS with a few adjustments [33].

In [5] study, the authors examine usability practice in OSS development in the community context. The usability activity in the OSS project is poor because the work of usability experts may be isolated, and their works do not impact the actual solution. The authors investigate a way to introduce usability activity into the development of OSS, specifically, how can usability experts cooperate within the community of OSS to affect usability activities. While in [28] the authors investigate the introducing of usability activities into an OSS project to conduct 'fitting' between OSS development and usability work. It also focuses on integrating the OSS

philosophies and HCI in OSS development. In this study, the philosophy is recognized as a 'theory or attitude that acts as a guiding principle for behavior'. The authors mention that an HCI literature recommends that the context in which the practices are to be presented should be comprehensively understood to select the proper approach when usability practices are introduced into the software. the authors recommended that the usability experts and OSS developers should work closely, so the usability activities will have an impact on the OSS project.

Furthermore, [29] utilize a culture-oriented approach to improve usability work impact in OSS projects which has not been used before in OSS research. Seven OSS development cases are investigated using cross-case analysis. The analysis shows that the enculturation of usability specialists is important to enhance usability work. When usability experts participate in the project from the early stage, enculturation occurs naturally. However, this method is not popular in OSS development, and enculturation costs extra effort from usability specialists. The aforementioned study intends to raise the participation of usability specialists in the projects of OSS. In [30] study, the challenges in involving usability experts into OSS projects are explained using boundary management as the theoretical framework. Usability plays a role in OSS, but the involvement of usability experts in such a project presents limitations. The study identifies the importance of managing boundaries in online communities. Based on numerous years of performing research on the projects of OSS, this study recognizes and describes three gatekeeping tactics that impede usability work, namely, false acceptance, non-response and social exclusion. The principal contribution of this study on the boundary management literature is the comprehensive review of gatekeeping tactics in action. The usability work is also an interesting contribution to HCI literature on FLOSS projects. Ways to integrate usability specialists into OSS development should be proposed. In [31] study, The authors mention that this research is part of a broader research program that intends to involve usability experts into OSS development. Therefore, a complete theoretical framework on power and empowerment introduced. However, the authors of this study argue that power and politics also describe the development of OSS and exhibit critical implications on OSS usability. The importance of power and politics has already been pointed out by previous research on OSS usability. However, the aforementioned study tackles the matter through theoretical treatment. The authors use the existing body of knowledge and empirical data on OSS usability to explore the topic. based on their findings, the authors conclude that the challenge of usability teams is how to gain access and influence OSS projects decision making. In [32] study, the authors mention that the usability in the OSS project has been neglected, and the usability has not been a primary interest of OSS developers. Therefore, the authors have been examined the usability practice and organizational culture in OSS development. The successes and failures of organizational work can be affected by organizational cultures, which are essential factors. Research on organizational culture in the development of OSS is limited. This study shows various cultures in the development of OSS projects and suggests the relationship between culture and usability work in such developments. The usability work aims to make systems and products usable. it comprises the activities of usability that related to analysis, design, and evaluation. The organizational culture is required to prove the success of usability work. The finding of this study implies that in the context of OSS development the adhocratic culture type is the best one for usability work.

In [34] study, to determine the feasibility of the personas usability technique for an application, the authors utilize it in the OSS development process. By using this technique can gather, analyse and synthesize the information related to software users. The authors conclude that it is essential to instruct users and OSS society members to increase awareness of the significance of software usability.

In [35] study, the authors aim to ascertain the feasibility of employing the focus groups technique in the project of OSS. The focus groups technique is a helpful tool for evaluating user requirements. The authors mention that according to Mayhew, the accepted number of focus group members is a range between six to eight. After implementing the focus groups technique to the OSS case study, the authors confirm that it the significant obstacle with implementing the focus groups technique was users' availability. They mentioned that the results of employing the focus groups usability technique not what they suspected. The authors conclude that it is essential to instruct users and OSS society members to increase awareness of the significance of software usability.

In [36] study, the authors aim to utilize a usability technique which is called visual brainstorming (VB) in the OSS project. The VB technique is a tool used to generate ideas about a selected topic or problem. A group of three to four participants is the perfect number for implementing this technique. The authors state that they selected the VB among other techniques because it can support the process of user interface (UI) design. A blog was used to collect the sketches correlated to the UI of the application under their study. he authors conclude that to enhancing the OSS usability techniques integration, should awareness the OSS community about the effects of the HCI field on software development.

### B. STUDIES CONDUCTED ON THE ANALYSIS OF OSS USABILITY

This [37], [38] comprises analytical investigations. The authors empirically investigate and analyse the relationship between the usability factor and OSS usability. The impacts of usability criteria like understandability, operability, learnability, and attractiveness on the usability of OSS analyzed from industry users' perception. Moreover, the authors investigate the impact of the usability factor on OSS usability from the end-users' perspective. The study contribution is empirically explaining the impacts of usability criteria on the usability of OSS.

In [39], [40] study, the authors offer a model for the relationship analyses between usability bug and the online forums of OSS projects. In other words, the authors attempt to investigate if the online forums support in maintaining usability bugs in OSS projects. The relationship of usability defect and support in OSS via online public forums is empirically analyzed. The outcome of the empirical investigation gives evidence about the effective management of usability-related issues in OSS.

In [41] study, 27 individuals connected with 11 OSS projects are questioned to know how the OSS community conceptualizes the usability concepts, how usability is tackled in projects and the stimulus for the undertaking. The author investigates how the OSS developers describe and conceptualize the idea of usability, the motivations that stimulate OSS developers in building usable software used by users other than developers, the current usability works in the OSS community, and how do OSS usability works differ from traditional usability practices. A participative approach is employed to introduce usability practice into the development of OSS. In this approach, the usability experts are involved in the OSS development community by integrating their work behavior into the OSS project culture and submitting code patches.

In [42] study, The aims of the authors are to investigate the factors affecting users' understanding of the quality principle in terms of functionality, usability, efficiency, and reliability of an e-learning OSS application which is named Moodle. The authors utilized an interpretive approach to explain how the end-users grasp the OSS. The results show that the users have high satisfaction, but the fields that impact on understanding quality diversify with the variation in experience and practice concentration.

In [43] a success model of OSS that considers OSS characteristics is developed in this study. Five success determinants of OSS and their relationships identified. The findings show that software quality and community service considerably affect user satisfaction. Moreover, the usability of OSS is influenced mainly by software quality and user satisfaction. This research contributes to the theoretical knowledge of OSS success and proposes the importance of OSS practitioners in enhancing OSS success. The developed model of OSS success and the significance of OSS success determinants are tested and examined. The findings also show that user satisfaction and software quality determine OSS usability. Understanding and analyzing users' requirements and considering them in OSS projects improve user satisfaction.

[3] The feasibility of using four usability techniques which are personas, direct observation, user profiles, and post-test information from the development team perspective investigated in this study. The authors utilize four OSS projects as the research method of multiple case studies to validate the feasibility of selected usability techniques. The authors formalized the application procedure of each of the adapted usability techniques. They found that either there were no procedures for adopting usability techniques in OSS or they were not fully established.

### C. STUDIES CONDUCTED ON THE EVALUATION OF OSS USABILITY

Usability is the essential quality factor that effects OSS sustainability which is becoming a requirement for OSS competing. Usability evaluation is a critical phase in a system development cycle. To run a usability test, numerous methods can be used.

In [44] study, the authors discussed the Remote Usability Evaluation via e-RUE. The e-RUE technique developed based on the integration of mRUE and aRUE approaches, which are synchronous and asynchronous approaches; in the first one, evaluator and participant required to run the test in real time, while in the later one, to run the test the evaluator and participant not required to be in real time. Video recording and questionnaires techniques via online automating in the e-RUE system. Using e-RUE, experts, researchers and participants can run the usability test from various geographical places.

References [45] and [46] the authors evaluate the usability of the Moodle system. In [45] study, the authors evaluate the Moodle learning management system usability by using several testing of usability techniques such as questionnaires and task-driven. The authors used the questionnaires and task-driven techniques to give the users more flexibility to state their view regarding the usability of the system. Eighty-four students, four university professors, and two system administrators participated in the evaluation. Each participant held a task to perform three questionnaires with various questions type (scaled answer, and open-ended questions, and multiple-choice). One week after using Moodle, questionnaire A released. The intent of this questionnaire to assemble an introductory response of the user interface of the system. After two weeks of using the system, questionnaire B released. The user must complete tasks such as open chat, upload/download files to answer the questionnaire B. Following the second questionnaire, participants requested to complete tasks and to answer the results in questionnaire C. The intent of questionnaire C is to assess the criteria associated with usability factor which are efficiency, memorability, effectiveness, ease of use, and satisfaction. The results provide significant information for users on how to promote efficient use of this system. The other work inspects system usability from users' perception [46]. This study evaluates usability attribute testing and course system management and intends to enhance OSS quality in the academic institutions in the Middle East area. The open source course management system named 'Moodle' is designed to support the lecturer in providing course materials for students. The online survey is offered to the population of the American University of Beirut, which includes 189 professors and 1867 students, to evaluate Moodle usability on the basis of their perceptions. This survey reflects the system performance in the academic environment by ranking 30 items correlated to 5 usability

attributes, namely, efficiency, learnability, error prevention, memorability and satisfaction.

User satisfaction is a vital usability criterion that indicates the success of OSS or proprietary software. Usability features in OSS projects cannot be improved without assessing them. Therefore, a usability evaluation methodology is required to increase OSS projects between end-users. As a result, a questionnaire based maturity model of usability in OSS projects is proposed in a study [2]. In software engineering, the maturity models used to collect extensive information about various processes and their activities alongside their current maturity levels. Consequently, this information can be used by the organizations for their strategic plans and future activities improvement. In this study, the model measures the coordination of OSS projects and their usability aspects. The model instrument includes selected factors from four empirical studies conducted by the authors, namely, studies on the viewpoints of OSS developers, users, contributors and industries. This study contributes to the OSS area by developing a usability evaluation methodology.

In [47] study, the authors practice aesthetic dimensions for evaluating the UX of OSS besides the usual practical usability study. They examined and present a qualitative analysis of four separate graphical Linux desktop usability and aesthetics based on proper Ubuntu versions. Earlier prepared virtual machines were used to test the participants. Additionally, analyzing screen recordings produced through tests. Furthermore, a questionnaire was developed to gather participants feedback based on System Usability Score (SUS) and usability (hedonic) questions. Throughout testing, almost 24 h video records were obtained from several computers. There was quite an extensive difficulty to assemble all data from various computers and analyse it. The evaluation goal is to acknowledge OSS competitiveness. User experience (UX) can be evaluated to confirm whether the OSS is practically useful and satisfying.

References [48] proposed an approach to quantify the usability level for an Arabized OSS library system compared with its original version of the application. The suggested approach involves three steps. The first step is to choose the usability evaluation method. The second step is to use the usability quantification technique for finding the usability quantified values of the original OSS library system and its Arabized version. The third and last step is to determine the difference between usability quantified values for the original OSS library system and its Arabized version for indicating the usability quality of the evaluated software. The authors used a questionnaire as a technique for usability evaluation. The participants were requested to rate quality measure of usability; usability factor defined in six criteria which are user interface aesthetics, learnability, user error protection, operability, appropriateness recognisability and accessibility. The authors utilize the fuzzy multi-criteria technique for usability quantifying. The outcomes prove that the quality of the Arabized software does not match the respected original version and it needs improvement. Hence, this study proposes an approach to quantify the Arability degree of Arabized OSS usability.

In [4] study, the authors propose a multi-stage fuzzy model approach which Involves nine usability criteria to assess and quantify OSS usability. In this model, the usability criteria divided into three groups using the stage-wise fuzzy reasoning approach. The proposed model evaluates and quantifies the usability of OSS based on the generated fuzzy rules from the knowledge of experts and by using the MATLAB software. The proposed model has been verified, and its features ranked by utilizing the analytical hierarchy process technique (AHP). The features of the proposed model are listed by their importance as: ''learnability, understandability, efficiency, error prevention, memorability, operability, familiarity, attractiveness and usability compliance''.

In [49] study, the authors empirically examined the usability of the Koha OPAC from a user perspective. Experienced and novice users engaged in the testing. Seven assignments are provided to users to measure their achievement in terms of time spent, the number of errors they did, and achievement scores. Two data collection tools employed for the usability test which is a computer screen recording application and a questionnaire on QUIS. In terms of success scores a significant difference between experienced and novices' retention.

### D. STUDIES CONDUCTED ON OSS SELECTION FOR ADOPTION

The select of the software packages that meet the users' requirements considered challenging [50]. One significant issue for the government and the private sector is the selection of proper OSS. Lack of commonly accepted evaluation criteria and the growth in OSS availability to solve a particular problem caused the difficulty of the evaluation and selection of OSS. The next section presents different studies that attempt to solve the selection problem.

In [51], [52] study, the authors aim to identify the OSS selection criteria based on four dimensions that the authors find it as important for users to identify their priority on selecting an appropriate selection solution. the dimensions were: system quality, information quality, service quality, and the potential internal constraints. Selecting proper OSS with assigned problems or requirements is vital so that the users can thoroughly employ its practice and solving the selective problem. Despite, the selection difficulty because 1) there is no agreement on evaluation criteria for selection. 2) the growth in the OSS availability. 3) the lack of OSS documentation and user manuals. After the identifying of the selection criteria as mentioned above, the authors designed a set of questionnaires and identified then notified the respondents to answer the questionnaires using online survey tools. The questionnaire includes selection features which are: system quality dimension, information quality dimension, service quality dimension. based on mentioned features, the respondents require to indicate the level of importance on selecting the OSS products. Five Likert scales were used in this survey. For the usability factor, the Learnability, Operability,

Accessibility, and User interface aesthetics criteria were used. the authors recommended using Group decision making due to the group of decision-makers were involved. In [52] extended their study to employed an analytical hierarchy process (AHP) in the process of OSS selection in order to support the users in their selection process.

In [53], [54] study, the authors aim to recognize all potential OSS features and to introduce new quality characteristics for OSS selection in the process of the adoption. This study based on the Information System Success Model for DeLone and McLean. The authors proposed the internal quality feature that can be appended to the DeLone and McLean model to support the selection of OSS application. The DeLone and McLean model encompasses six main success dimensions: information quality, service quality, system quality, user satisfaction, net benefits, and intention to use (adoption). The system quality indicates the acceptable features of the OSS, which comprises Availability, Reliability, Performance, Usability and Functionality. Usability in OSS signifies the learnability, accessibility, operability, and user interface. To show the usefulness of the presented OSS selection approach the authors to employ eight OSS from the learning management system and network tools for evaluation.

In [55], [56] study, the authors attempt to evaluate and select an open source electronic medical record (OSS-EMR) software packages. The authors utilize multi-criteria decision-making (MCDM) by using integrated AHP–TOPSIS. A hands-on study conducted and a collection of OSS- EMR applications implemented using a virtual machine. As a part of the OSS evaluation, the authors employed usability in addition to the other factors as one factor that affects OSS quality. Efficiency, learnability, satisfaction criteria used to evaluate the usability. The authors selected criteria from different standards and models, particularly, efficiency and satisfaction criteria from ISO 9241-11 (1998) standard, and learnability from other books and studies. Three users were selected to perform the evaluation. Two users from the medical field and one user is a professional programmer. The alternatives were ranked, and the best software was selected based on TOPSIS technique.

In [57] study, extensive intuition into evaluation and selection of OSS-LMS packages offered. The authors merged and organized a set of criteria proper for OSS-LMS evaluation. The criteria classified into different groups such as usability, reliability, functionality, maintainability, efficiency, and portability. The usability criteria used for evaluation are Error reporting, User interface, Learnability, Efficiency, Satisfaction. The ability of selected suited methods for solving the OSS-LMS packages problem on multi-criteria evaluation and selection discussed. Hence, the selection process of the OSS-LMS packages considered as an MCDM problem.

## IV. DISTRIBUTION RESULTS

The current study targets four database engines, namely, WoS, IEEE Xplore, Science Direct and Scopus. These database engines are the most reliable sources of research.

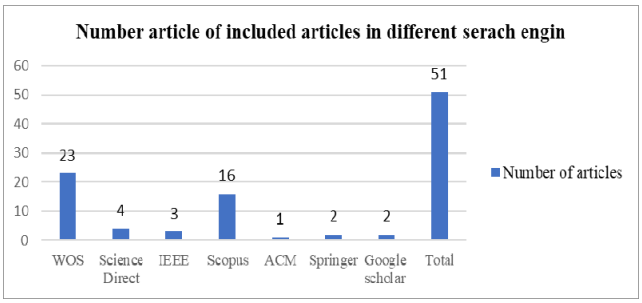


**FIGURE 3.** Number of included articles in different search engine.

Fig. 3 shows the selected 51 articles from different sources. Amongst the articles, 23, 4, 3 and 16 are from WoS, Science Direct, IEEE Xplore and Scopus, respectively.in addition to 1,2,2 from ACM, Springer, Google scholar, respectively, which are selected manually. These sources produce various studies that involve surveys on OSS usability from several international journals.

### A. DISTRIBUTION BY PUBLICATION JOURNAL

Fig. 4 shows the various works obtained from digital databases. The review results are classified and distributed into four categories, namely, Improve OSS usability, analyse OSS usability, evaluate OSS usability, and usability evaluation for selection and adoption OSS.

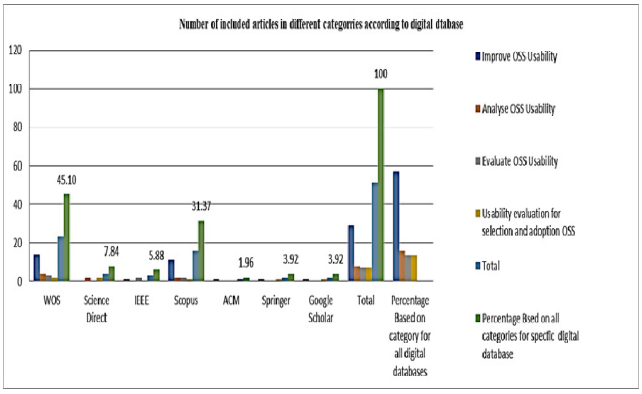


**FIGURE 4.** Distribution by digital database.

Amongst the articles obtained from databases, 23 is from Web of Science which are distributed amongst the four categories as 14 belongs to improve OSS usability studies, 4 belongs to analyse OSS usability, 3 for evaluating OSS usability studies, and 2 belonging to usability evaluation for selection and adoption OSS. 4 articles are from Science Direct; 2 belong to analyse OSS usability and 2 belong to usability evaluation for selection and adoption OSS. 3 articles are from IEEE Xplore; 1 belongs to improve OSS usability, and 2 belongs to evaluate OSS usability. 16 articles are from Scopus; 11 belong to improve OSS usability, 2 belong to analyse OSS usability, and 2 belongs to evaluate OSS usability, and 1 article belong usability evaluation for selection and adoption OSS. 1 article from ACM which

belongs to improve OSS usability. 2 articles from Springer; one belongs to improve usability and the other belong to usability evaluation for selection and adoption OSS. 2 articles from Google Scholar; 1 belongs to improve OSS usability and the other 1 are belongs to usability evaluation for selection and adoption OSS.

### B. DISTRIBUTION BY PUBLICATION YEAR

Fig. 5 shows the articles obtained from seven databases by year of publication from 2007 to 2019.

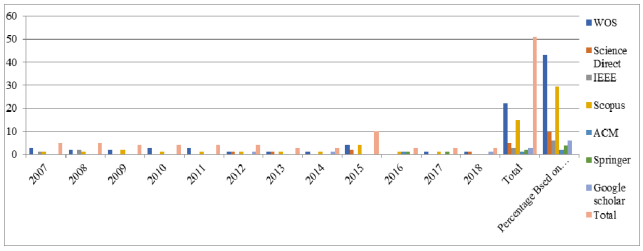


**FIGURE 5.** Distribution by publication year.

This review covers five articles published in 2007 and five articles published in 2008; four articles published in 2009,2010,2011, and 2012 respectively; three articles published in 2013, 2014, 2016,2017, and 2018 respectively; ten articles published in 2015.

## V. DISCUSSION

In the circumstances of organized attempts to improve software sustainability, there are opportunities for usability to help and support this approach. The authors of the current review aim to offer the most relevant studies on OSS usability. This study aims to highlight and call attention to the research direction in this area. This survey is distinguished from others because of its recentness and focus on the literature on the usability of the OSS application rather than the function of the application. Based on the covered literature, the related taxonomy is proposed. Several benefits can be provided from developing an emerging taxonomy of literature in a research line. On the one hand, the published articles are classified and organized into a meaningful, manageable and consistent layout that shows the direction of each group in the taxonomy. A new researcher who studies in the same research area may inundate by a massive number of articles on the subject and the inadequacy of any structure may cause failure in obtaining an overview in this area. Thus, the existence of this taxonomy helps solve this issue. On the other hand, the taxonomy structure provides researchers with helpful and valuable insights into the related research scope in different ways. Firstly, possible research directions in the related area can be drawn. As an instance, the taxonomy of OSS usability in this study reveals that previous researchers introduce frameworks, models and methods to develop an application to evaluate and test OSS usability, thereby presenting a potential direction in this area. Secondly, the research gaps can be revealed and identified from the taxonomy. Classifying the articles on OSS usability into different categories shows delicate and important features that concern the coverage of the research. For example, the current taxonomy highlights the essential features of OSS usability, such as factors affecting usability, and the relation between those factors that lead to successful OSS application. The aspects revealed from the literature content of the conducted survey are the motivations to improve and evaluate OSS usability and the challenges connected with usability and its effectiveness in OSS and to propose recommendations for tackling these challenges.

### A. MOTIVATIONS

OSS usability is a promising area of research. The software that is not usable is not going to be sustainable. This section presents the researchers' motivation to follow this pathway of research.

#### 1) MOTIVATION RELATED TO INTRODUCING UCD AND USABILITY EXPERTS' INVOLVEMENT

Traditionally, The OSS developers design the applications from their viewpoints and neglect the participants of usability experts and UCD requirements. Therefore, the developers provide good functionality but ignore usability [3], [13].

The OSS using is not restricted to developers but spreads to use by the novice users [37], [38], the development in the number of OSS users [22], [25], [34]–[36] highlights the necessity to identify and determine their requirements and expectations [40]. Many researchers motivated to enhanced usability and increase the interaction and collaboration of developers and usability experts.

Common OSS projects lack usability experts involvement, encouraging the developers to trust the usability experts will give value to the work, usability experts and designers could effectively participate in the project [9], [10], [30].

Daniel Schwartz state that Increases the involvement of usability specialists in OSS improves the usability of the application [21]. Based on the motivation to enhance the OSS usability and encouraging joint work between developers and usability experts, Çetin and Göktürk proposed a measurement method that measures the developer's usability activity to conduct proper user-centered design methodologies [14], [15]. In the same scene, an interpretive case study carried out by Iivari et al. to explore how usability is perceived and carried out within the project of OSS. The authors' initial findings recommended the involvement of usability experts in the OSS context. [8], [25]. Furthermore, comprehend OSS project members behavior and deal with their usability concerns is useful to OSS and HCI communities [41].

Moreover, various methods for incorporating usability in OSS development have not evaluated yet, that motivated Mikko Rajanen et al. to explore the benefits of usability experts involved in the project of OSS through a participative approach [5]. Additionally, the restrictions that exist for usability experts' involvements in OSS projects were motivated Rajanen et al. to attempts to explain the involvements challenges with focusing on boundary management as the theoretical framework [30].

#### 2) MOTIVATION RELATED TO ENHANCING OSS SUCCESS

Different motivations encouraged the researchers to conduct studies to improve the success of OSS. As in, A. Raza, L. F. Capretz, and F. Ahmed study they conduct experimental and analytical investigations on the correlation between the usability attributes and OSS usability based on an industrial and end user's perspectives. The motivation of this study is to understand the impacts of the usability attributes in OSS usability [37], [38]. Moreover, the growing popularity of OSS amongst the non-technical and novice users and the limited awareness for OSS usability evaluation has been motivated and encouraged the authors to presents a model that investigates the extent of coordination between the projects of OSS and the usability aspects. In another study for the same authors, and based on the abovementioned motivations, the authors present research model that builds a relationship between online public forums and OSS usability errors [2], [39]. In the same scene, as a result of the increase in novice users of OSS, usability started to attract the attention of the OSS community which has some specific characteristics that impediment the utilisation of several usability techniques designated in HCI field [3].

Addressing usability issues in the OSS community has been motivated Michael et al.; therefore, their research emphasizes on addressing usability issues in the OSS community by investigating the significance of the relations between developers and users. While Michael Terry has been used a participative approach to examines how the OSS developers deal with the usability [41]. Furthermore, with the spread of OSS, there is no guarantee for the converge of users and developers. Alessio et al. utilized an interpretive approach to attempt to understand how end users experience the OSS [42]. The factors that lead to OSS success was the motivation that encourages S.-Y. T. Lee et al. to measure the success of OSS by conducting an empirical study. The authors identified five OSS success determinants as well as several vital relationships between these determinants [43].

Developing usability activities in the OSS project needs to be investigated to improve the usability and competitiveness of OSS. Two studies offer a measurement method of success OSS project to improve the application's usability and the interaction amongst developers and experts [14], [15]. Additionally, many OSS-based solutions studies in different contexts focus on the internal perspective usage of OSS but neglect novice users [42]. OSS usability and its improvement remain vital issues that require further research [10]. Furthermore, the principles and practices of usability can be integrated into OSS projects [9].

To date investigation in software bug report not examined the acquisition of various information based on the types of defect, such as the usability defects. However, the motivation that encourages the authors in this study to investigate the practices of software development practitioners when dealing with usability defects was the importance of usability defects report and what relevant information should be included in the reports to captivate the attention of software developers in order to fix the defects [16]–[18].

#### 3) MOTIVATION RELATED TO DEVELOPING QUALITATIVE AND ACCEPTABLE PRODUCTS

OSS usability is poor [3], [4], [8], [9], [21], [58] and rarely investigated in the OSS context. Nevertheless, usability needs further investigation to develop qualitative and acceptable applications [8]. An effective, efficient and usable system can help achieve users' goals, decrease users' time to accomplish tasks efficiently, fast and easy and satisfy users' need. Therefore, usability evaluation is crucial [2], [3], [44]. Usability acts as a significant part of a system, and its evaluation is a critical phase in a system development cycle. More usability consideration in the system design leads to more opportunity to be successful [44].

The improvement in usability aspects of OSS projects must be tested and measured [2], [30]. The increase in the number of novices users of OSS projects [37], [39], [40] highlights the need for a usability evaluation methodology [2]. OSS usability evaluation, which is a critical and essential quality factor [3], can support the development and implementation of qualitative and acceptable products [4]. Moreover, assessing the quality of the provided software can improve the software on the basis of the results of the assessment [48]. The increasing use of OSS applications has raised the need for developing usable OSS. in addition to unclear which techniques should be used in the development process among the OSS communities [58].

#### 4) MOTIVATION RELATED TO OSS SELECTION FOR ADOPTION

OSS systems are available with as a free. However, with different options, the adoption of OSS is still low amongst possible users because there is no agreement on an acceptable set of criteria to evaluate and select different OSS. Thus, the significant issue for the government and the private sector is the selection of the relevant OSS system. Inappropriate adoption of software may result in incorrect decisions and consequent economic loss of organizations. Therefore, users need to consider how to enhance their decision making when selecting the OSS system [51]–[55], [57], [59].

### *B. CHALLENGES*

Usability is an essential quality factor [3], [4], [17], [25], [35], [39] that needs to be considered. However, OSS usability work is a challenging task [5], [9], [10], [32], [40], [41]. Different participants, from developers to end-users, contribute to OSS product development. The surveyed articles show that researchers focus on various challenges related to OSS usability and its effectiveness. Challenges reported for OSS usability are discussed along with citations of relevant references to which readers can refer to for initial suggestions and other discussions on the challenges. Few authors classify these challenges depending on their characteristics for ease of discussion (Fig 6).

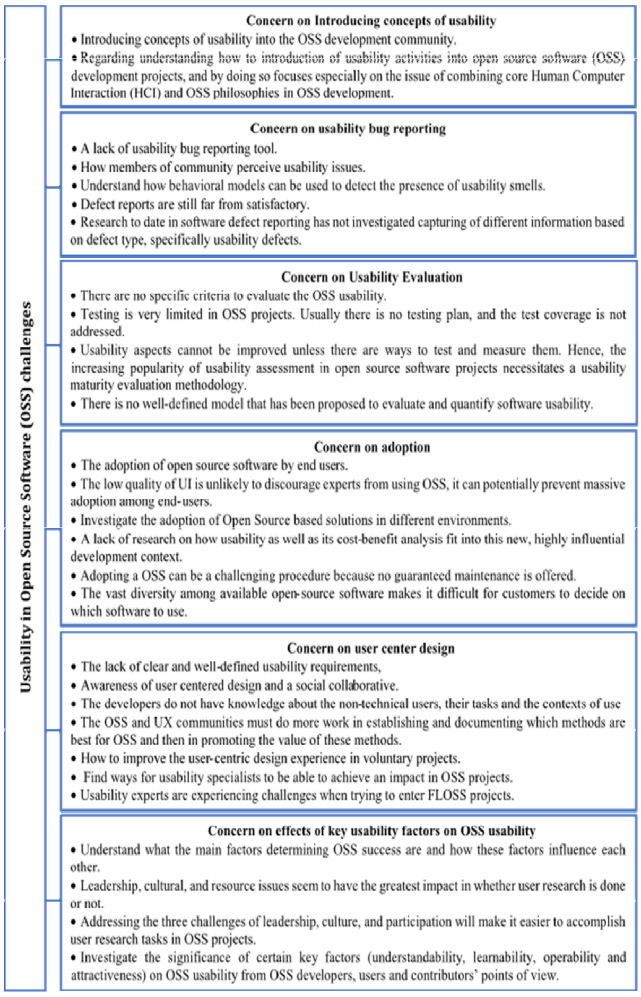


**FIGURE 6.** Categories of challenges for OSS usability.

### 1) CONCERN ON INTRODUCING USABILITY CONCEPTS

Introducing usability concepts to OSS development community users is challenging [12]. Improving usability in OSS development needs much effort and introducing usability activities in this context is complex. Research on their impact on the actual solution is lacking as well. Although methods for ensuring usability are available, introducing them and usability activities in the development is difficult [5]. Furthermore, combining HCI and OSS philosophy in OSS developments is complicated [28]. The challenges of introducing usability into software developments, particularly OSS developments are examined in a study [32]. The principles and practices of usability in OSS projects are also consistently and concretely explored in another study [9].

The usability of the OSS community has been got attention because of the increase in non-developer of OSS application users. Generally, OSS communities lacked sufficient experience on how to select the proper usability techniques and how to apply it in in each activity of the OSS development process [3], [34]–[36].

### 2) CONCERN ON REPORTING USABILITY BUGS

Different types of information are included in software reporting of usability defects, but they have not been examined by defect type [60]. Usability defects are insufficiently addressed because the reported problems are unclear or invalid for the developers [16], [17]. The quality of software defect reports is usually unsatisfactory [18]. Usability defect reports, laboratories and experts should be considered during the development process. Furthermore, usability bug report tools can be used to determine the usability issues on particular software through submitting, storing, modifying and maintaining videos, audio files and pictures provided by users [13].

Previous research provides an indispensable basis for understanding the difficulties and associated works in handling usability issues in OSS development. However, most of these activities conducted at a distance, particularly by testing bugs report and mailing-list archives. Thus, information on how the community members understand usability issues or what motivates them to handle the issues in software development is limited (Michael Terry, 2010). Exploratory inspection methods are used to improve usability in the OSS context. These methods are designed to support problem-solving in discovering usability bugs in OSS development [10].

Specific bugs can be examined by inspecting the role of online user forums and the users' interaction [39]. Behavioral models can also be applied to discover the usability smells presence [24].

### 3) CONCERN ON EVALUATING USABILITY

Usability evaluation is an essential part of system development. Powerful and effective usability evaluation methodologies are needed to develop software applications that meet users' needs and expectations [44]. OSS project testing is limited by a lack of test plan and coverage. Although OSS development is tool centered, only a small number of projects use testing tools [22].

In OSS projects, usability features cannot be improved without assessing and measuring them. Therefore, methodologies for increasing the publicity of usability assessment in OSS projects are necessary [2].

OSS project developers focus more on software functionality than its usability; thus, software usability is poor [3], [29], [35]. Imperfect methods and procedures of usability evaluation cause the failure of software systems [61], thereby decreasing productivity and user satisfaction. Researchers in the software quality and usability measurement field agreed that there is no well-defined model offered for software usability evaluation and quantification [4].

### 4) CONCERN ON ADOPTING OSS

While the license of OSS applications is free still there is a lack of OSS adoption amongst possible users. The main reason for this lack that there is no consensus on a set of

criteria for different OSS evaluation and selection. Thus, OSS system selection is a significant issue [51]–[55], [57], [59].

When an end-users attempt to migrate from their previous application to an equivalent OSS, they may face challenges in importing and exporting their data [20]. In the meantime, OSS experts are discouraged by low-quality UIs, which can probably impede large adoption by end-users. Therefore, OSS usability problems are crucial [19]. Several studies have begun examining the adoption of OSS-based solutions in various contexts; the majority of available studies focuses on internal perspective usage of OSS but neglect the end-users [42]. Research on fitting usability into the development context is lacking because of the difficulty of this task [33]. Specifying and selecting suitable applications for adoption are difficult for academic institutions and stakeholders because of the vast number and variation of applications. Lack of guaranteed support also limits the adoption of OSS [46], [59].

#### 5) CONCERN ON USER CENTRE DESIGN (UCD)

The lack of communication among OSS developers and usability experts, in addition to the absence of standard design guidelines, leads to poor usability. Poor evaluation of OSS products is due to lack of clearly determined requirements of usability, UCD awareness and collaborative social tools to discuss usability issues [14]. Furthermore, the developers do not know the end-users, the tasks entrusted to them and their work environment. To avoid contradiction with the philosophy of OSS, no conventional methodologies or approved process models of usability are employed [8].

Usability and enhanced UI quality are essential issues in the OSS context. In OSS development, several challenges associated with the development of usability and UI are reported. OSS developers design software applications for themselves and ignore the users. Thus, OSS usability is poor for end-users, and the developments process anything but 'user-centred'. OSS usability and UI developments lack research in this context [25]. Therefore, the sophisticated design of interfaces decreases OSS application by casual end-users. To make OSS applications competitive with equivalent closed source software (CSS), UX must become an essential part of OSS development. UX practitioners in OSS developers' community must support to identify, encourage and employ UX methodologies for CSS in OSS [21].

OSS developers usually focus on improving software functionality but ignore its usability. However, usability improvement is important when end-users are involved because it increases user satisfaction. However, this improvement may be challenging for end-users [20]. Additionally, the lack of standard design guidelines of usability and communication methods for usability specialists and OSS developers results in low usability. The factors causing a lack of OSS application usability must be investigated and UCD should be adopted in the OSS project to enhance OSS usability. The measurement methods of OSS project usability and the corresponding metrics must be assessed to help project stakeholders self-evaluate their projects [15].

HCI studies have shown the challenges of usability experts when trying to join OSS projects [30]. Thus, usability or UX in OSS development is rarely explored [31].

#### 6) CONCERN ON THE EFFECTS OF USABILITY FACTORS ON OSS USABILITY

Various factors that affect the OSS usability shown by different studies. Lee shows that the relationships amongst the principal factors of OSS success enhance the OSS success rate [43]. Paul shows that lack of user research hinders usability action in the projects; this lack is due to cultural differences among developers and designers, weak or ambiguous project leadership, and resource issues, therefore user research in OSS projects can be easily performed when the three challenges are addressed [23].

The specific vital factors (learnability, attractiveness, understandability, and operability) of OSS usability can be obtained from the viewpoints of developers, users and contributors [37], [38].

### C. RECOMMENDATIONS

Critical recommendations in the work of literature are summarized to alleviate the challenges and promote reliable and efficient OSS usability by specialists and end-users.

#### 1) RECOMMENDATIONS TO DEVELOPERS

Many recommendations presented by the authors to improve OSS usability; such as Rajanen et al. recommend more focus on the approach of user-centred design, furthermore, the developers have to be open to usability practice and grasp the user needs [30].

An assessment needs to be carried out to distinguish areas where enhancement is required [2]. G. Çetin and Göktürk recommended to using the given metrics in their study and apply it to different OSS projects; then the usability of a project and its particular extension must be measured and the relationship between them must be determined [14]. Moreover, developers and designers of OSS must fully grasp the effectiveness of the relationships among the required factors and their usability in projects [37].

In term of defects reports Yusop et al. recommended to investigate the various types of usability defects belong to OSS projects and customize the defects report. Furthermore, they recommend employing text mining tools to automatically classify and categories the words and phrases related to defects report [16]–[18]. Furthermore, In the context of interactive applications, Almeida et al. attempt to produce a catalog of smells. Catalog of smells also called usability smells which is consider as signs of poor design on user interface application. The authors have been used as a program/usability refactoring concept to eliminate such usability smells. Therefore, the authors recommend a possible enhancement by integrating the smell detection with

model-based testing to enhance the testing process quality by using smells as a guide to relevant features to test [24].

Furthermore, In the context of interactive applications, Almeida et al. attempt to produce a catalog of smells. Catalog of smells also called usability smells which is consider as signs of poor design on user interface application. The authors have been used as a program/usability refactoring concept to eliminate such usability smells. Therefore, the authors recommend a possible enhancement by integrating the smell detection with model-based testing to enhance the testing process quality by using smells as a guide to relevant features to test [24].

E-Rue development is cheaper than other solutions for usability evaluation. The mRUE and aRUE approach used to develop the e-RUE system. The e-RUE system is an online automated video recording and questionnaires techniques. The participants and evaluators have to Login twice or more to the system. By utilizing the aRUE approach, the authors recommended future improvement of e-RUE by supporting the JRK and PAT techniques in the RKPM Methodology [44].

#### 2) RECOMMENDATIONS TO DESIGNERS

Designers provide various necessary solutions that help improve usability. A sound designer needs to determine which procedures of design features and analysis can result in satisfactory usability.

The UI in OSS should be designed in a certain way to improve its usability similar to components of common proprietary software [4]. Moreover, usability standard requirements should be considered and adopted in the early stage of development [13].

The assessment of the contributions and contributor values completely depends on the OSS project decision makers; therefore, usability experts cannot stay as impartial experts outside of the power struggles and OSS project politics. Usability experts need to succeed and influence in decision arenas [31].

#### 3) RECOMMENDATIONS TO THE PROJECT MANAGER

The project manager is a specialist responsible for planning, executing and assigning responsibilities to project pursuits and goals. In this section, the recommendations that can support and help the project manager are summarized.

To increase usability impact, usability experts and OSS developers should work as a team, should not be too involved with the development and should not ignore usability [28]. The enculturation concept recommends involving usability experts in OSS projects. Comprehensive enculturation analysis can be done to determine the variation in attitudes, practices, and meanings related to enculturation [29]. The contributors of OSS, including developers, testers, architects, designers and users, should be involved in recognizing and addressing usability flaws in OSS projects [21], [22], [25], [39].

#### 4) RECOMMENDATIONS TO RESEARCHERS

Usability research should offer new usability methods for the development of the OSS community and company [33]. Moreover, Mikko Rajanen et al. recommend more works needed to include usability into the development of OSS. Furthermore, the authors recommended maintaining the usability activity and methods obtained from industry or academia, which has clear culturally different from the development of OSS. Therefore, analysis of the relevant and culturally harmonious of coupling usability and OSS development philosophies still required [5], [28]. To address the usability problems, must investigate what is missing. Therefore, Paul recommends employing more user research into OSS projects. Furthermore, to provide a better understanding of the difficulty of user research and how it can be achieved the author recommend more investigation in usability methods used in OSS [23].

In the same scene, studies recommend further investigation in cooperation support like communication and coordination between OSS members, typecially in community support [3], [20], [34]–[36].

Netta Iivari et al. investigated how the usability and user-interface developments dealt within the context of company OSS development. The 'Company OSS development context' relates to 'OSS 2.0', which is a new commercially OSS development. The authors recommend a direction for future work which is a deep mind of the company OSS context usability and devising methods that facilitate the participation of usability specialists in communities of OSS. Generally, the usability impacts on OSS products, communities and companies, and the means to achieve those effects are interesting research topics [8], [25], [26].

Moreover, qualitative empirical research on OSS developments is necessary to understand the challenges associated with OSS usability and quality assurance. One possible direction is integrating the existing methods and procedures of software engineering and HCI into OSS philosophy and development [22].

Research projects with various maturities in usability readiness can also be assessed [15]. Further research on OSS is also needed [43]. The essential role of developers and their manifestations in OSS projects with various structures and cultures should be examined in detail as well [31].

### D. METHODOLOGICAL ASPECTS ILLUSTRATED FROM PREVIOUS STUDIES

Previous studies included in our survey show that the articles rely on four categories, namely, improving usability, analyzing usability, evaluating usability, and usability evaluation for selection and adoption as shown in Fig. 2.

In proprietary software, the software product can be checked against the user requirements. However, checking the OSS system against the user requirements is difficult because the OSS system is not designed for a specific user.

Based on previous studies included in this survey, different methods are used to evaluate the usability of OSS. Usability can be assessed by interviews, questionnaires, surveys, observations and empirical methods (e.g. T-test and coefficient factor). Many authors propose other means of evaluating usability, such as heuristic evaluation, usability testing, cognitive walkthrough, focus group and thinking aloud. Each of the aforementioned techniques exhibits their advantages and disadvantages. The methods can be used individually or in groups depending on which test has to be made. The taxonomy in Fig. 2 shows different usability assessment techniques.

### 1) OSS USABILITY ASSESSMENT CATEGORY

From the previous studies shown in Fig. 2, the assessment methods of OSS usability can be divided into four usability categories: improving usability, analyse usability, evaluate usability, and select and adopt OSS based on usability evaluation as shown in Fig. 7. Each category uses its own items to assess and evaluate OSS usability.

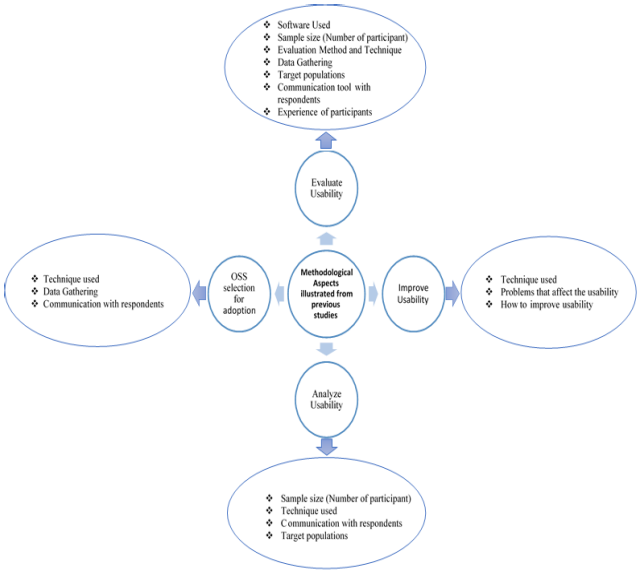


**FIGURE 7.** Categories and items used in usability assessment.

### 2) ASSESSMENT ITEMS OF OSS USABILITY

As mentioned in Section (1) form part D, each category uses its own items to assess and evaluate OSS usability. These items are discussed in the following sections.

#### *a: ASSESSMENT ITEMS FOR EVALUATING USABILITY*

ISO defines usability as 'the extent to which the product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use' [30].

Effective and efficient usability evaluation methodologies are needed to develop and maintain software applications that meet users' expectations and needs. Evaluating OSS usability, which is a critical quality factor, can ease the implementation and development of qualitative and acceptable products. The common items in each usability evaluation method are software type, sample size (number of participants), evaluation technique, evaluation method, data gathering, communication with respondents, target populations and UX in using OSS.

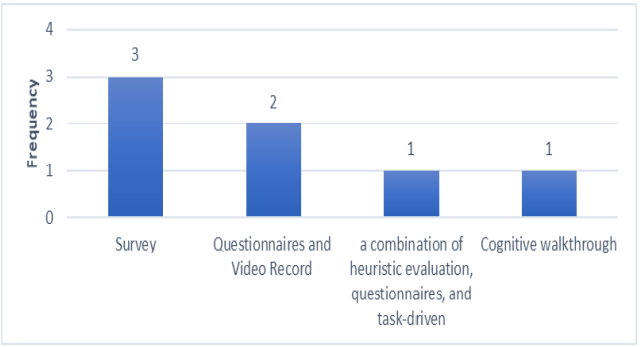


**FIGURE 8.** Shows data gathering methods for usability evaluation based on previous studies.

Reference **[44]** uses e-RUE technology to evaluate the 'Smart School Courseware usability' application as a case study. However, the author does not mention the sample size (number of participants) in the study. Questionnaires and record videos of users' interaction and facial expression are used to obtain participants' opinions on software performance. The e-RUE test is run in the evaluator and users' environment, that is, separate room and time through the network.

Reference **[45]** Analyses learning management system (LMS) modules. A combination of heuristic evaluation, questionnaires, and task-driven techniques used for evaluation. Eighty-four students, four academic professors, four research assistants and two system administrators participated in this study. For data collection, three questionnaires with different types of questions as a task to be completed by each participant.

**[46]** uses an online survey to evaluate the usability of the open source course management system called 'Moodle'. Usability is evaluated based on a population from the American University of Beirut, including 189 professors and 1867 students. The survey members are invited via email addresses to complete a 20-question survey.

Reference **[4]** quantifies usability criteria in order to rank the OOS usability by utilizing a multi-stage fuzzy model approach and analytic hierarchy process (AHP). Twenty computer science graduate students are surveyed to collect data. 2 to 3 years were the participant's experience in using various OSS applications. To decide which usability criteria is more important and gets more priority for OSS a survey of 36 pairwise comparison questions used to compare 9 usability criteria with each other. The proposed model stages simulated and linked using MATLAB Simulink Software.

Reference **[47]** use a cognitive walkthrough to test the usability of four Linux desktop environments based

on compatible Ubuntu versions. The data are collected by observing the work of 46 participants. The participants' pragmatic satisfaction is measured using a questionnaire.

Reference **[48]** use the fuzzy technique to quantify the quality of an Arabized OSS (PhpMyBibli integrated library system) compared with its original version. Usability data from the participants are collected using a questionnaire. The target population includes two sample groups of Arab librarian specialist. The first group consists of 10 librarian specialist who used the original version of the software application in their work, whereas the other group comprised 10 Arab librarian specialist who used the Arabized version of the same software application. The participants are requested to fill out the questionnaire.

Reference **[49]** empirically examine the usability of the Koha OPAC OSS integrated library system. Two groups of experienced and novice students engaged in this study. Each group included 12 participants. A questionnaire and screen recording application utilized as data collection tools.

**In summary,** amongst the seven studies shown in Fig. 8, three have been used survey to collect data to be used for usability evaluation [4], [46], [48]; two used a combination of questionnaire and video recording [44], [49]; one used a combination of heuristic evaluation, questionnaires, and task-driven techniques [45]; and one used cognitive walkthrough [47].

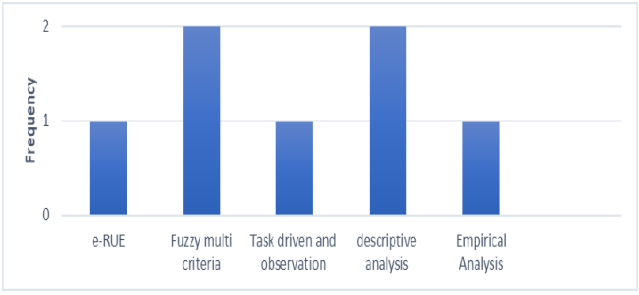


**FIGURE 9.** Shows the evaluation Technique based on previous studies.

Fig. 9 shows that, out of seven studies, one uses RUE as an evaluation technique to evaluate the usability [44]; two used fuzzy multi-criteria [4], [48]; one uses Task driven and observation [47]; two used descriptive analysis [45], [46]; and one empirically examine the usability [49].

Fig. 10 shows that, amongst seven studies, two target professors and students [4], [46]; Two targets only students; one targets expert librarians [45], [48]; and two do not mention the target populations [44], [47].

Sample size can be divided into four groups: the first group in the range of 1–40, the second in the range of 41–80, the third in the range of more than 80 and the last group categorized as unspecified sample size. Fig.11 shows that, out of seven studies, three involve the sample size of 1–40 participants [4], [48], [49]; one involves the sample size of 41–80 participants [47]; two involves the sample size

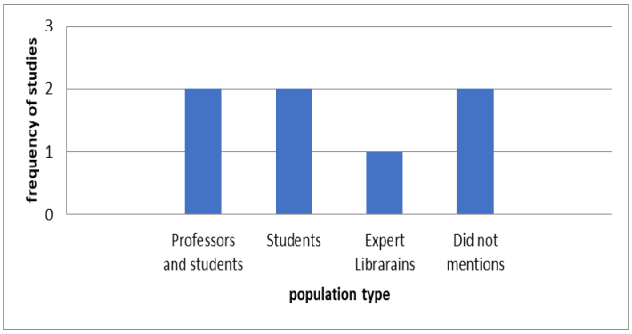


**FIGURE 10.** Shows target populations based on previous studies.

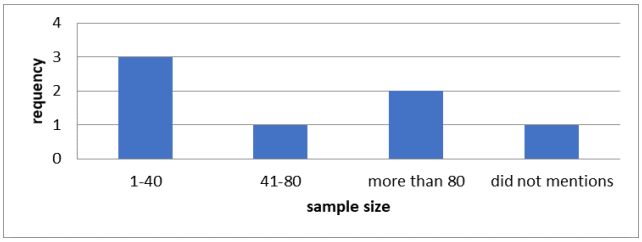


**FIGURE 11.** Shows sample size based on previous studies.

of more than 80 participants [45], [46]; and one study does not mention the sample size [44].

### *b: ASSESSMENT ITEMS FOR IMPROVING USABILITY*

Evaluating OSS applications is important in software design and performance. Usability is a fundamental characteristic of users' acceptance of software that may hinder OSS success [3]. Powerful and effective usability methodologies are required to develop software applications that meet users' expectations and needs.

In recent surveys and reviews on the improvement in OSS usability, the authors conclude that the important factors affecting OSS usability are the absence of usability expert and a bug report [5], [8], [13]–[15], [21], [25]–[33]. These authors propose to involve and adopt usability experts and improve usability defect management tools for improving OSS usability.

In empirical studies concerning the improvement in OSS usability, the authors conclude that poor UI design affects OSS usability [24], [28], [30], [32]. Lack of research on the compatibility of the OSS philosophies and HCI restricts the participation of usability specialists in OSS projects, thereby resulting in a lack of research on OSS development culture. These authors suggest performing empirical tests and usability expert investigations, providing re-designed solutions for eliminating any of the recognized usability problems, conducting usability refactoring and involving usability experts in OSS projects. Moreover, the usability team needs to produce a usability report on issues of usability and suggestions for refactoring and fixing.

Some studies focused on introduce usability and increased user awareness amongst the OSS community [12], [19].

Other studies utilized different approaches an techniques and methods to improve the OSS usability, such as participative design approach [9] which is focus on integrated the usability experts with OSS projects, another study adopts exploratory inspection method to support OSS usability inspection [10], in the same direction of usability improvement L. Llerena et al. adopts the Personas usability technique within the OSS development process, the focus groups technique in the OSS project, and the visual brainstorming (VB) usability technique in the OSS project [34]–[36].

Usability defect report is a step for developers to improve OSS usability which is conducted by four authors in this study [16]–[18], [23]. Usability smells are signs of poor user interface design, with the potential to hinder software usability and evolution. one study proposed usability smells catalog to reduce such usability smells [24].

Two studies identify that the factors affecting OSS usability are lack of knowledge in usability from developers and lack of communication between project stakeholders and HCI studies [14], [15]. They utilize a measurement method of usability activity. They propose to improve usability by increasing the usability and competitiveness of OSS, measuring usability activities of developers and conducting suitable methodologies of UCD.

Another works conducts an interpretive case study to analyse usability [25]–[27]; They identify that the developers are more interested in improving software functionality than its usability. Consequently, OSS usability is poor. Three studies also argue that the usability in OSS software development is not a primary concern amongst the developers [5], [9], [21]. Studies of [13], [29] suggest to create reporting methodology for every OSS usability issue and to adopt enculturation of usability specialists for improving OSS usability.

### *c: ASSESSMENT ITEMS FOR ANALYSING USABILITY*

Introducing usability concepts and understanding OSS development community users are challenging tasks. Effective and efficient usability analysis methodologies are required to offer usability experience to the community. Various analysis techniques are used to introduce usability awareness.

Four studies used the survey to analyse the usability of different OSS projects for understanding and identifying the impact of the key usability factors on OSS success [37], [38], [42], [43]. These studies analyse usability using perceptions of 59, 145, 105, and 102 respondents, respectively. The target populations are OSS students, users and developers. The participants are invited by direct communication and via email. The participants have 1 year to more than 9 years of experience in using OSS.

One study uses interviews at a conference of OSS, at a company that provides OSS software and in an OSS community [41]. This study analyses usability using 27 responses from 12 developers, 5 project members, 5 end-users contributing to project members and 5 core users. The participants are interviewed by direct communication and via Skype.

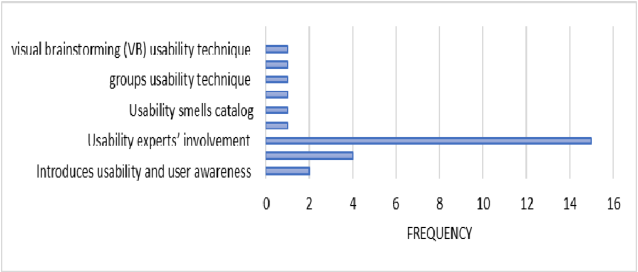


**FIGURE 12.** Shows methods utilized to study usability improvement.

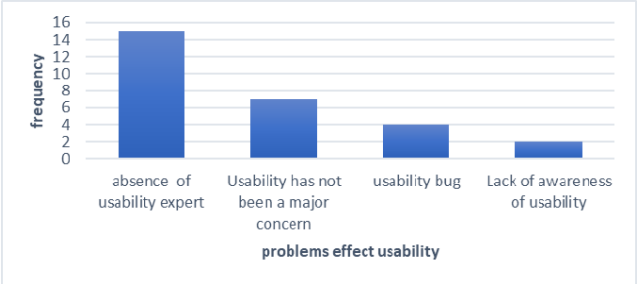


**FIGURE 13.** Shows problems that effect the usability.

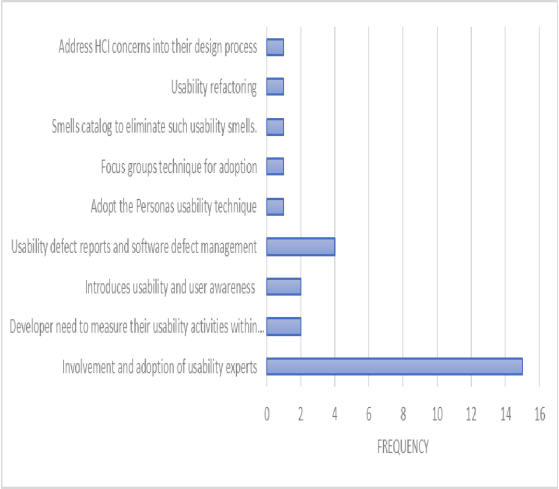


**FIGURE 14.** Shows a proposed solution to improve the usability.

The authors of a study empirically explore the role of online user forums [2], [39]. The authors focus on user interaction, bug reporting and usability fix. They proposed a model. The model is verified using a dataset of 192 projects of OSS selected to cover various classes.

One study adapts and assesses the usefulness of employing four usability techniques to four OSS projects from the developers' viewpoint. The personas, user profiles, direct observation and post-test information were the techniques employed. The user profile and personas were selected as usability analysis techniques. 22 users participated in usability evaluation using direct observation and post-test information techniques [3].


**FIGURE 15.** Shows techniques used to analyze usability.

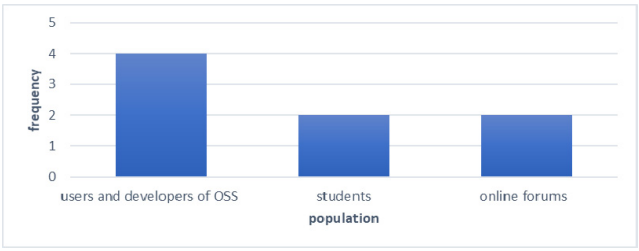


**FIGURE 16.** Shows target populations.

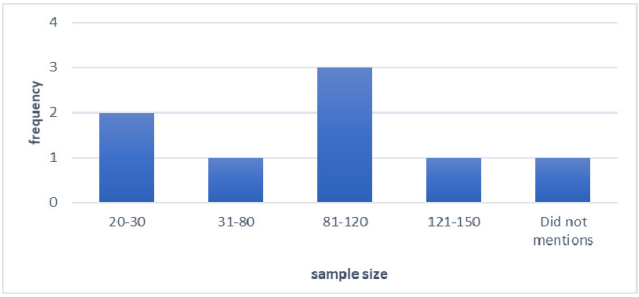


**FIGURE 17.** Shows sample size.

### *d: ASSESSMENT ITEMS FOR OSS SELECTION FOR ADOPTION*

The growing numbers of OSS systems have become more challenging for users who are looking for systems that deliver highly accurate results in a short time and no errors. Notwithstanding the free accessibility of the OSS source code, its selection is still challenging [50]. Therefore, the organizations have been facing a challenge in how to evaluate and compare OSS systems in order to determine which is better.

The evaluation processes of usability in the OSS system to determine which the automated system is the best among many available alternatives is crucial in the quest for getting the best result. Such a process is critical because the wrong of system selection can cost the organizations legal accountability and even financial costs if the system fails to live up to the expectations. Consequently, organizations will have a negative impact on reputation and performance. Due to that, it is necessary to seek the most efficient technique to help the organizations in making the right decision for system selection.

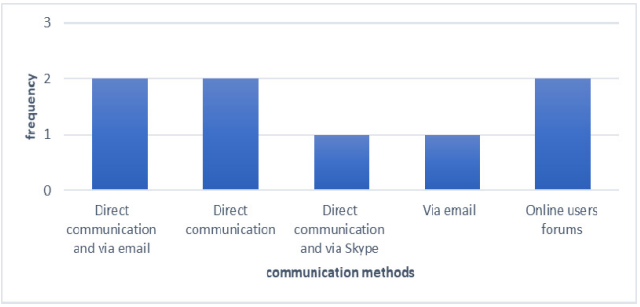


**FIGURE 18.** Shows communication methods with population.

There are many potential and good open source software (OSS) products available on the market with a free license. However, with various choices, the adoption rate is still low among potential users because there is not an agreed acceptable set of criteria to evaluate and select various OSS [52].

A. A. Zaidan et al. have been used as an online OSS medical repository to select 13 OS-EMR software packages, which are evaluated using MCDM techniques, particularly using Integrated AHP and TOPSIS. The evaluation test is run with three participants, of whom two are medical specialists and one is a professional programmer. Usability is tested using the cognitive walkthrough because using direct observation is time-consuming. Users' subjective feeling is assessed using users' satisfaction [55], [59].

Abdullateef et al. presented a study in the evaluation and selection of OSS-LMS packages. Multi-attribute or multi-criteria decision-making (MADM/MCDM) techniques recommended as a solution [57].

OSS selection is a significant concern for the government and the private sector. The authors utilize new internal quality characteristics for selecting OSS. Eight OSS evaluated the two broad kinds of recognized software from the learning management system and network tools [53], [54].

This study discussed and explored the proposed OSS adoption and selection criteria. A questionnaire based on online survey tools is used for gathering data; 30 respondents answered the online survey which are one IT Director, three Senior IT Officer, 26 IT Officer [51]. Based on the criteria that obtain from their previous study, the authors employed the analytical hierarchy process (AHP) technique for selecting the OSS products [52].

## VI. CONCLUSION

Classifying the articles on OSS usability into different categories shows delicate and important features that concern the coverage of the research. Numerous innovative OSS applications have been developed, but their poor usability hinders their adoption and sustainability. Many users of popular OSS applications rate the functionality of these applications as high but the usability as low. The reason is that the developers of OSS applications do not concern usability. Thus, usability is an issue in OSS. However, popular OSS projects concentrate more on functionality than on usability.

Therefore, awareness of an OSS developer community to usability concept will lead to developing sustainable OSS application that significantly influence the future user interest in OSS projects.

There are various methods used for usability evaluation. Therefore, there is an opportunity to share those methods within the community to support highly usable software and improve the usability for not very useful one to achieve the adoption and sustainable applications since the software that is not usable is not going to be sustainable.

Unattractive or difficult-to-use OSS applications are usually ignored by users. Thus, usability experts must be involved in OSS projects to improve the products by enabling users to achieve their goal easily and quickly. Usability is an essential part of OSS development and should, therefore, be applied at the early stage of the development cycle to achieve sustainable OSS applications. OSS developers must involve usability experts in the development to attract and retain users and ensure the competitiveness and relevance of the applications.

In OSS projects, the user community is a vital part of testing new releases. Therefore, the developer–user relationship is a vital strength of OSS development. Many usability methods can be adopted by OSS developers. These methods range from a regular usability test to a central observation. By observing the interaction of users with the design, the developer can gather much information.

Intensity analysis of the articles helps identify and explain the challenges, benefits and recommendations related to OSS usability. The results show and identify the existing gaps in OSS usability evaluation. Previous researchers have specified the issues and presented detailed recommendations for solving the challenges in OSS usability. They also provide a chance for research in this field. The problems are related to usability expert involvement, UCD, developer–user relation improvement and OSS usability evaluation and selection. In the current review, the insights are specified, and previously published studies on OSS usability are summarized. Researchers must be updated on emerging trends and technologies because of their continuous development. Thus, this review can be used as a reference by future researchers.

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