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The Factors Affecting User Experience Maturity in Free and Open Source Software Community: An Empirical Study

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ABSTRACT

Assessing User eXperience (UX) maturity is mandatory in the free and open-source software (FOSS) community to avoid wasting resources on projects that may fall short of expectations. Best practices suggest employing UX Capability Maturity Models (UXCMMs), which often specify an evolutionary plateau toward developing a UX-matured system and quantify organizational UX maturity into maturity levels ranging from no or ad hoc improvement to integrated continuous improvement. Numerous generically developed UXCMMs exist. However, none is created for the FOSS community, and less information is available to support their perfect match. Thus, raise suspicions if they have proper UX maturity influencing factors (UXMIFs) for the FOSS community or measure the right thing. The FOSS community differs from traditional software-developing communities and may have different dynamics and UXMIFs, necessitating unique and new methodologies for their discovery. This study, therefore, aims to identify the FOSS community's UXMIFs and evaluate the community's knowledge of UX maturity-related concepts. Its findings may help future researchers, practitioners, and other FOSS developers to develop UXCMMs exclusive to the FOSS community. The study's design is both qualitative and quantitative. It adopted a systematic literature review, interviews, fuzzy Delphi Method, and thematic analysis to collect and analyze data and present the findings. The study's sample included sixty-two active FOSS projects, fifteen FOSS stakeholders, and twelve UX experts. The outcome shows that 84% of UX experts agreed on the thirty-six FOSS's UXMIFs with threshold $d = 0.143$ and crisp values greater than α-cut $= 0.5$. User feedback and adopted technologies were ranked first, while learnability and use speed were ranked last. Similarly, FOSS stakeholders have shown a shared understanding of UX maturity, connected concepts, and impacting factors.

KEYWORDS

User experience; maturity; free and open-source software; UX maturity influencing factors; Fuzzy Delphi Method

1. Introduction

Assessing User eXperience (UX) maturity is now a de facto requirement for any organization as it helps identify strengths and weaknesses in implementing UX-related tasks (Chapman & Plewes, 2014; Pernice et al., 2021). However, it is still challenging to describe, evaluate, and track UX and its maturity (Hellweger & Wang, 2015; Novák et al., 2023). Zarour and Alharbi (2017) attest that UX is relatively new, and much has not been explored in the concept. UX lacks a globally accepted definition (Coelho et al., 2022; Pettersson et al., 2018; Roto et al., 2010; Zarour & Alharbi, 2017) and assumes different explanations based on how it is approached (Roto et al., 2010). Alben (1996), Nielsen and Norman (2017), Hassenzahl and Tractinsky (2006), Sutcliffe (2009), Anthony et al. (2016), Mirnig et al. (2015), and Hassenzahl (2007) have contributed to developing the classified and robust definitions of UX. However, Mirnig et al.'s (2015) and Hassenzahl and Tractinsky's (2006) definitions are commonly used.

Despite disagreements in definitions, UX is agreed to be a broader concept that goes beyond usability and functionality by including all aspects of the end user's interaction with the company's services and products (Nielsen & Norman, 2017). It significantly affects the success and quality of any software, including free and open-source software (FOSS) (Luther et al., 2020; Weichert et al., 2018). UX is often a result of a robust UX design. Designing a robust UX design that improves organizational efficiency (Castillo-Vergara et al., 2018) demands adopting UX/HCI best practices and assessing the organizational capacity to implement them. However, the FOSS community has limited tools and methods to analyze the ability to implement UX-related activities (Namayala et al., 2023). Nevertheless, UX assessment tools and methods from other software-developing communities cannot be directly adopted in the FOSS community (Terry et al., 2010).

Due to the attached benefits, developing products with desirable UX is now a choice of many businesses (Da Silva et al., 2018; Hokkanen & Väänänen-Vainio-Mattila, 2015; Nguyen-Duc et al., 2021), including the FOSS community. For example, UX may help businesses increase return on investment (ROI), win competitors, engage more users,

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enhance customer loyalty, and acquire positive brand reputations (Al-Azzawi, 2014).

The design for UX is an organizational endeavor rather than a function or ability of individuals. (Chapman & Plewes, 2014; Cheng & Guo, 2018; Stone et al., 2016). As a result, its success requires the knowledge and dedication of an entire organization (Stone et al., 2016). For example, implementing the design for UX may require organizations to focus on quality, consistent research, well-planned design procedures, resources, and tools (Rukonić et al., 2019). Best practices in UX assessment suggest determining organizational strengths and weaknesses, referred to as UX maturity, to implement UX-related activities for better UX design outcomes. Organizations with higher UX maturity better implement UX-related tasks and are likely to develop products with desirable UX, and the opposite is true (Von-Wangenheim et al., 2010). Nevertheless, UX-matured organizations provide complete user-centric products, well-defined and repeatable UX processes, effective metrics for determining user satisfaction, and well-experienced UX designers capable of delivering UX-focused plans.

Generally, UX maturity holistically communicates the organization's status quo on serving user-centered design (UCD) best practices at any time. However, it assumes different definitions in the knowledge body (Vallerand et al., 2017). For example, Pernice et al. (2021) define UX maturity as the "measure of an organization's desire and ability to deliver UCD successfully," while Molich (2021) describes UX maturity as "the ability of an organization or a product team to define and meet UX goals that help to achieve business goals."

UX Capability maturity models (UXCMMs) or frameworks are often adopted to quantify organizational UX maturity attained at a given period (Pernice et al., 2021) and propose a roadmap to improve UX-related activities and advance to higher levels. They show evolutionary plateaus toward developing a mature UX-related process by specifying maturity levels, ranging from no or ad hoc process improvement to integrated continuous improvement (Paulk et al., 1993). Many versions of UXCMMs have lately emerged. For example, a corporate UX maturity by Nielsen (Nielsen, 2006), the 6 levels of UX maturity by Pernice et al. (2021), the UX maturity model by Feijo (2010), the Keikendo UX Maturity Model by Carraro (2014), and the UX Maturity Model for e-commerce websites by Anchahua et al. (2018), the Corporate User-Experience Maturity Model by Van Tyne (2009) and a UX Maturity Model: Effective Introduction of UX into an organization by Chapman and Plewes (2014). Each UXCMM aspires to assess organizational UX maturity with novelty. However, Sauro et al. (2017) claimed they are just sales gimmicks because they are architecturally indistinguishable and tentatively made from the same concepts and ingredients.

Although many editions of generically developed UXCMMs exist and are assumed to apply in any software community and context, it is still unknown if we can use them in the FOSS community because they have not been rigorously tested in actual FOSS projects (Lacerda & von Wangenheim, 2018; Namayala et al., 2023; Raza et al., 2012a). Namayala et al. (2023) showed that no UXCMM was created for the community, implying they may not have the FOSS community's specific UXMIFs. Nevertheless, many UXCMMs have failed to define or are not clear on what makes a UX-matured system (Buis et al., 2023; Kocaballi et al., 2019; Namayala et al., 2023), imposing challenges of not containing the right contents or factors influencing UXCMMs. It is also uncertain if they measure UX maturity correctly (Sauro et al., 2017). Finally, the development process of many UXCMMs did not adhere to formalized development methods or models (Monteiro & Maciel, 2020; Otto et al., 2020). Thus, they are not empirically developed and often accommodate relatively few UMIFs originating from the authors' years of working experience (Lacerda & von Wangenheim, 2018; Namayala et al., 2023; Rukonić et al., 2019; Sauro et al., 2017).

This study, therefore, aims to offer novel contributions to knowledge by empirically identifying and ranking UXMIFs exclusive to the FOSS community. It has responded to the research questions: -

RQ1 How do the FOSS community's stakeholders understand UX maturity and linked terms?
RQ2 What UX maturity influencing factors affect the UX maturity of the FOSS community?

The specified UXMIFs may help researchers, academicians, practitioners, and other FOSS stakeholders develop the correct UXCMMs for the FOSS community. Nevertheless, areas suggested for future studies may inspire future researchers to engage in the topic and help the FOSS community assess its UX maturity precisely and practically.

The rest of this paper is organized as follows. The second section explains the study's background information. The third section presents the adopted research methodology, the fourth section presents the findings, and the fifth section discusses the results. Finally, section six is devoted to the conclusion and way forward.

2. Background

2.1. Free and open-source software (FOSS)

FOSS is software distributed with licenses that permit programmers to examine and modify the source code in desired ways for bug repair, enhancing functionality, and customizing to meet their demands (Amega-Selorm & Awotwi, 2010; Nagy et al., 2012; Pickett, 2019). According to the Free Software Foundation (FSF, 2011) and Open Source Initiative (2010), FOSS has a Low Total Cost of Ownership (TCO) compared to proprietary software and is therefore considered an alternative solution (Abramova et al., 2016; Bahamdain, 2015; Kundu et al., 2010; Bouras et al., 2013; Petrinja & Succi, 2012; Shekgola et al., 2021). The word "free" in FOSS refers to the liberty to use the software, but it may not necessarily be at a free cost. However, FOSS must certify four mandatory user privileges that allow the

use of the software for any purpose, modify source codes to fit needs, redistribute the software without authors' consent, and improve the source codes (Engard, 2010; Free Software Foundation, 2012; Srinivasa, 2017; Stallman, 2002).

The FOSS projects supply chain differs from other software-developing communities (Kuwata et al., 2014). For example, they are often built and maintained by the entire FOSS community (Haaland et al., 2010) in dynamic environments (Méhat et al., 2015). FOSS community is self-governed, with no executives overseeing the whole community (Engard, 2010). Its structure is highly complex (Scacchi et al., 2006) and does not formally describe activities and their order of implementation (Senyard & Michlmayr, 2004). As a result, it may have unique UX challenges, such as different UXMIFs, and demand special treatment. However, the community still uses generically developed UXMIFs, which may not be a replica of the actual image, resulting in incorrect outcomes. This notion is reinforced by recommendations by Terry et al. (2010), which state that generically designed UXCMMs and contained ingredients in their current state should not be directly adopted because they will likely overlook FOSS context-specific variables. After all, they have various drawbacks that require particular adaptations.

Generally, the FOSS community lacks empirically established studies investigating what UXMIFs are appropriate for FOSS projects. As a result, evaluating UX and its maturity has remained rather complex, subjective, and slow (Novák et al., 2023). However, having UXMIFs pertinent to FOSS projects is necessary (Petrinja & Succi, 2012). Among other benefits, understanding UXMIFs exclusive to the FOSS community may bring several advantages to the FOSS community, such as improved user-centricity, enhanced usability, increased adoption, and community engagement. In addition to this, they may contribute to FOSS projects' overall success and sustainability by creating FOSS projects that meet user needs and expectations and attracting and retaining a loyal user base.

Based on the above annotations, The FOSS community requires either wholly novel ways to uncover UXMIFs and new UXCMMs, or contextualization of existing UX/HCI methods, tools, and theories to meet its dynamics (Bornoe & Stage, 2014; Dawood et al., 2019; Raza et al., 2013; Terry et al., 2010). Petrinja and Succi's (2012) observations confirm that generically developed UXCMMs are irrelevant to the FOSS community, sealing evidence for a requirement to examine the relevancy of UXMIFs included in current UXCMMs. These findings are confirmed by systematic literature reviews and mapping studies of Namayala et al. (2023) and Choma et al. (2022).

2.2. UX capability maturity models in the FOSS community

In the FOSS community, evaluating UX, including capability and maturity, is still thought-provoking (Stol & Ali Babar, 2010). Nevertheless, traditional quality models are extremely hard to adopt (Adewumi et al., 2013). However, the FOSS community does little to develop tools like UXCMMs and other quality models specific to its projects (Namayala et al., 2023). Present UXCMMs and other quality models do not address the FOSS community's unique characteristics (Adewumi et al., 2016; Namayala et al., 2023), leaving gaps that demand the development of new UXCMMs and other quality models (Haaland et al., 2010).

Precise evaluation of FOSS UX maturity is imperative, just as it has been in other software-developing communities. Thus, the FOSS community must adapt or develop UXCMMs to meet the needs of its user base intensified beyond technically equipped (Dawood et al., 2019; Llerena et al., 2018, 2019; Raza et al., 2012a). The community must adopt and employ accepted development procedures, such as planned releases, peer review of modifications, submission and review of changes, and supply of a test suite (Adewumi et al., 2016). However, as confirmed by an exhausted literature review, the FOSS community often adopts ad hoc interventions, and its structure does not smoothly accept valuable contributions from UX professionals (Bach et al., 2009; Nichols & Twidale, 2003). As a result, practiced interventions may be incorrect, inconsistent, and difficult to replicate across projects.

Like several other capability maturity models (CMMs), many current UXCMMs have adopted structures from the ancestors of CMMs, including the Capability Maturity Model (CMM) by the Software Engineering Institute (SEI, 2006), Crosby's Quality Management Maturity Grid (QMMG) by Humphrey and Sweet (1987) and Total Quality Management (TQM) by Lakhe and Mohanty (1994). However, UXCMMs exclusive to the FOSS community are still limited (Namayala et al., 2023). Many available efforts establish usability capability maturity models (UCMMs) and other quality models for selecting high-quality FOSS projects or components to include in other applications (Adewumi et al., 2016). For example, the Open-source Usability Maturity Model (OS-UMM) by Raza et al. (2012a), the Open Source Maturity Model (OSMM) by Golden (2008), the CapGemini Open Source Maturity Model (C-OSMM) by Dujinhouwer and Widdows (2003), the Qualification and Selection of Open Source software (QSOS) by Semeteys (2008), the Open Business Readiness Rating (OpenBRR) by Taibi et al. (2007), and Software Quality Observatory for Open Source Software (SQO-OSS) by Samoladas et al. (2008). However, they are not highly adopted (Li et al., 2009; Petrinja & Succi, 2012).

2.3. Factors affecting UX maturity

Formalizing UXMIFs is critical to uniformly assess UX maturity across FOSS projects (Petrinja & Succi, 2012). They must be based on organizational context (Traynor, 2022). However, experimentally established UXMIFs are missing (Cheng & Guo, 2018; Choma et al., 2022; Raza et al., 2012b). Those currently used pay little attention to UX standards (Traynor, 2022) and do not adequately explain the crucial UXMIFs, particularly in the FOSS community (Petrinja & Succi, 2012).

Little has been done to establish UXMIFs (Osinusi, 2020), particularly in the FOSS community. However, multiple initiatives to develop usability maturity influencing factors exist. For example, Raza et al. (2012a) systematically and experimentally conducted four different empirical studies, Raza et al. (2013), Raza and Capretz (2010), Raza et al.(2012b), and Raza et al. (2010) that sought perceptions from users, developers, industry and contributors to develop the Open Source Usability Maturity Model (OS-UMM). However, Raza et al. (2012a) did not test the model to determine if it fits in assessing the UX of actual FOSS projects, insinuating that used factors do not guarantee their relevancy in creating FOSS UXCMMs (Namayala et al., 2023).

Several available UXMIFs that currently form the generically developed UXCMMs are the derivatives of professional working experience (Sauro et al., 2017) lacking formalized techniques, and others are derived from organizational behaviors and standards such as ISO 33020 (Traynor, 2022). To a large extent, the FOSS community may continue delivering projects with poor UX if it does not formalize its methods for establishing UXMIFs since unsystematically formulated UXMIFs may often fail to account for organizational-specific dynamics and contexts.

2.4. Related studies

This study found limited to no studies reporting the empirical development of UXMIFs, notably in the FOSS community. Encountered UXMIFs lack development methodological rigor and do not demonstrate the context in which they can be more effective; for example, the UXMIFs used in models developed by Rukonić et al. (2019), Pernice et al.(2021), and Chapman and Plewes (2014). Nevertheless, of all the studies we examined, Pernice et al. (2021) from the Nielsen and Norman Group have thoroughly discussed and classified UXMIFs today regarded as de facto. They grouped them into four main clusters: a strategy that incorporates user experience leadership, planning, and resource prioritization; a culture that fosters the development of user experience careers and practitioners; a process that demonstrates the systematic application of user experience research and design methods; and, finally, the outcome that consciously defines the effects of UX works.

2.5. Limitations of the current studies

Using generic UXMIFs derived from the owners' years of working experience for every company may not be the best option. It is an unrealistic endeavor since every organization has unique dynamics affected by its goals, strategy, environment, technology, and size and requires personalized solutions (Ahmady et al., 2016). Therefore, we cannot use the same UXMIFs in every community, including FOSS, because they may skip specific issues. Generally, there is nothing like a general solution, particularly in the UX assessment, due to the subjectivity, holistic, dynamic, and situational nature of UX (Bosley, 2013; Hassenzahl, 2010; Namayala et al., 2023).

Nevertheless, to the authors' knowledge accumulated from the completed literature review, the FOSS community still lacks comprehensive studies on determining UXMIFs, which may be regarded as baselines. As a result, this is the first analysis, and the data gained supplements previous studies of UXMIFs in the FOSS community.

3. Research method

The study adopted a mixed research design approach involving quantitative and qualitative techniques and was conducted online with the help of Internet technologies. It examined sixty-two (62) active FOSS projects hosted in FOSS source code hosting facilities. The projects' inclusion/exclusion criteria included projects regularly updated with an activity level of 90% and above, weekly downloads count of 100 and above, active mailing lists, and other discussion forums. The activity levels were calculated from projects' user ratings. For example, a user rating of 4.9 out of 5 provides an activity level of 98%. Examined projects were grouped into seven application areas: accounting (11), office (6), project management (9), games and entertainment (9), knowledge management (6), development (5), and scientific and engineering (16).

The authors completed different phases to collect and analyze data and report the findings. In the first step, the study reviewed current literature and ISO 9241-11:2018 by the International Organization for Standardization (ISO) (ISO/IEC 9241-11, 2018) to generate a tentative list of UXMIFs for stakeholder interviews and expert discussions. In the second phase, the authors interviewed fifteen (15) FOSS stakeholders from the selected projects who actively discussed UX issues in projects' mailing lists or other discussion forums (see adopted questionnaire in Appendix A). Personalized e-mails were sent to selected stakeholders' e-mails extracted from discussion forums explaining the study's purpose and seeking participation consent. The recruitment process of stakeholders took place between mid-July 2021 and November 2022, with an initial response rate of 32.29% (31/96). Finally, fifteen (15) FOSS stakeholders agreed to participate and signed consent forms.

Nevertheless, the authors explored stakeholders' understanding of UX maturity-related concepts in the same phase. They adopted the thematic analysis method that Braun and Clarke (2006) proposed to identify themes from the collected data to streamline the interpretation and discussion of the results. The method contained six steps: (1) Familiarizing with data, (2) Generating initial codes, (3) Searching for themes, (4) Reviewing themes, (5) Defining and naming themes, and (6) Producing the report.

In the third phase, the study adopted the Fuzzy Delphi Method (FDM) for screening to obtain experts' consensus on UXMIFs established from a completed literature review, stakeholder interviews, and brainstorming with UX experts. The FDM finally assisted in the defuzzification and ranking of UXMIFs. The execution of the FDM usually begins with formulating triangular fuzzy numbers (TFNs) that use

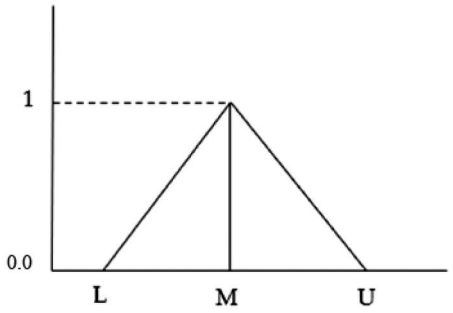

Figure 1. Triangular fuzzy number. *Source*: Adapted from Lee et al. (2021).

Table 1. Triangular fuzzy scoring and 7-points Likert scale.

Likert Scale scoring	Linguistic variable	Fuzzy Scale scoring
1	Extremely unimportant	(0.00, 0.00, 0.10)
2	Very unimportant	(0.00, 0.10, 0.30)
3	Unimportant	(0.10, 0.30, 0.50)
4	Moderately important	(0.30, 0.50, 0.75)
5	Important	(0.50, 0.75, 0.90)
6	Very important	(0.75, 0.90, 1.00)
7	Extremely important	(0.90, 1.00, 1.00)

Source: Habibi et al. (2015).

binary ratings ranging between 0 and 1 inclusively (see Figure 1 for TFNs' graphical representation).

TFNs often create fuzzy scales similar to Likert scales that translate linguistic variables into fuzzy numbers (see Table 1 for the fuzzy scale and corresponding 7-point Likert scale representation we adopted). Fuzzy numbers are a special type of fuzzy sets that are normalized, convex, and have bounded sets. Unlike classical logic, each number in fuzzy logic has an approximate value. As a result, using fuzzy sets aligns more with human linguistic and occasionally ambiguous descriptions (Habibi et al., 2015).

TFNs are often displayed with three real numbers constructed using the formula $\mu_A(\mathrm{x}) = (\mathrm{L},\ \mathrm{M},\ \mathrm{U})$. L is the left threshold denoting minimum values of $\mu_A(\mathrm{x})$, U is the right threshold denoting the maximum value of $\mu_A(\mathrm{x})$, and M is the median value denoting the most likely value of a fuzzy number. The total values (T) of the TFN's defuzzification are often established according to the fuzzy set, deffuzify, proposed by S.-J. Chen and Hwang (1992). The equation below explains the TFNs' membership function (MF).

$$\mathrm{MF(x)} = \begin{cases} \dfrac{\mathrm{x-L}}{\mathrm{M-L}} & L < x < M \\ \dfrac{\mathrm{U-x}}{\mathrm{U-M}} & M < x < U \\ 0 & \textit{Otherwise} \end{cases}$$

The FDM is a more advanced technique than the traditional Delphi Method (DM) developed by Dalkey and Helmer (1963) since it combines the classical Delphi Method (DM), and Fuzzy Theories (Kadir et al., 2019; Saffie et al., 2016). It easily determines the distance between the consensus levels among experts (Ishikawa et al., 1993) and saves time, effort, and cost in running questionnaires due to the extreme reduction in survey rounds (Jarana-Díaz et al., 2021; Lee et al., 2021). This argument is supported by the single-round study performed by Habibi et al. (2015). The distance between Fuzzy numbers or threshold value (d) is calculated using the formula

$$d = \sqrt{\frac{1}{3}\left[(\mathbf{m}_1 - \mathbf{M}_1)^2 + (\mathbf{m}_2 - \mathbf{M}_2)^2 + (\mathbf{m}_3 - \mathbf{M}_3)^2\right]}$$

where, $\mathbf{(M_1,\ M_2,\ M_3)}$ are the fuzzy values of each item and $\mathbf{(m_1,\ m_2,\ m_3)}$ are the corresponding fuzzy average values. According to C.-T. Chen (2000) and Cheng and Lin (2002), if each screened variable's threshold value (d) does not exceed 0.2, the variables fulfill one condition among the three conditions for reaching experts' agreement. The second requirement is that the total percentages of items with $\mathrm{d} \leq 2$ be 75% or above (Chu & Hwang, 2008; Murry & Hammons, 1995).

Several investigations, such as Alharbi and Khalifa (2021), have offered efforts to create FDM variants. However, stakeholders have not agreed on the variations (2015). According to Alghawli et al.(2022) and Habibi et al. (2015), the FDM in its classic form provides sophisticated ways of handling ambiguity resulting from experts' aptitude and subjectivity in getting the UXMIFs that could later be used to construct UXCMM tailored to the FOSS community.

The FDM algorithm for screening consists of four main stages (see Table 2), and each step is tied to a specific goal(s) that must be accomplished (Habibi et al., 2015).

In the first step, an appropriate fuzzy spectrum is selected or developed, for example, a triangular fuzzy spectrum of three, five, or seven fuzzy scales. Once the fuzzy spectrum is selected, execution goes to the second step, where different methods may be applied. However, if experts' opinions in the first step are displayed as triangular, calculating the fuzzy average numbers is the most viable option to complete this step. The formula shown below and explained by Manakandan et al. (2017) has been used in this study.

$$\mu_{\mathbf{A}}(\mathbf{x})\mathbf{AVE} = \frac{\sum_{i=1}^{n} \boldsymbol{L}}{\mathbf{n}}, \frac{\sum_{i=1}^{n} \boldsymbol{M}}{\mathbf{n}}, \frac{\sum_{i=1}^{n} \mathbf{U}}{\mathbf{n}}$$

However, other experimental formulas for aggregating experts' opinions may also be adopted. For example,

$$\mu_{\mathbf{A}}(\mathbf{x})\mathbf{AGGR} = \left(\boldsymbol{min}\{\boldsymbol{L}\},\ \left\{\frac{\sum \boldsymbol{M}}{\boldsymbol{n}}\right\}, \boldsymbol{max}\{\boldsymbol{U}\}\right) \text{ and}$$

$$\mu_{\mathrm{A}}(\mathrm{x})\mathrm{AGGR} = \left(\min\{L\},\ \prod\{M\},\ \max\{U\}\right).$$

Studies may also adopt different methods to accomplish the third stage. This step turns the final fuzzy values into crisp values to check if the experts' agreement's third and final condition is fulfilled. However, the study has used a method of defuzzification that uses formulas.

$$\mathbf{x}_{\mathbf{M}}^{1} = \frac{\mathbf{l} + \mathbf{m} + \mathbf{u}}{3},\ \mathbf{x}_{\mathbf{M}}^{2} = \frac{\mathbf{l} + 2\mathbf{m} + \mathbf{u}}{4},\ \text{and}$$

$$\mathbf{x}_{\mathbf{M}}^{3} = \frac{\mathbf{l} + 4\mathbf{m} + \mathbf{u}}{6} \text{ where } \mathrm{l} = \frac{\sum \mathbf{L}}{\mathbf{n}},\ \mathrm{m} = \frac{\sum \mathbf{M}}{\mathbf{n}},$$

$$\text{and } \mathrm{u} = \frac{\sum \mathbf{U}}{\mathbf{n}}. \text{ and } \mathbf{Crisp\ number} = \mathbf{Z}^{*} = \mathbf{max}\left(\mathbf{x}_{\mathbf{M}}^{1},\ \mathbf{x}_{\mathbf{M}}^{2}, \mathbf{x}_{\mathbf{M}}^{3}\right)$$

The calculated crisp values are then compared to the α-cut value, which is the median value for TFNs "0" and

Table 2. Stages of the Fuzzy Delphi Method algorithm for screening.

Sn.	Step	Goal(s)
1	Use or develop common fuzzy spectra.	Identify/develop an appropriate fuzzy spectrum for the fuzzification of linguistic expressions.
2	Collect and fuzzify experts' opinions	Fuzzy aggregation of experts' opinions
3	Defuzzification	Defuzzification
4	Testing the acceptability of each item	The authors decided which items to accept or reject based on the comparison between the threshold of 0.6 the study opted for and the items' crisp numbers.

Table 3. UX evaluation experts' demographic information.

Gender	Experience (years)	Age	Country	Title	Research area
Male	18	61	Tanzania	Professor	eLearning, HCI, and information systems success
Male	10	67	Finland	Professor	UX and UX design
Male	11	58	Germany	Professor	Human-centered artificial intelligence, UX, HCI, ubiquitous computing, and mobile interaction
Male	22	55	USA	Professor	UX, HCI, Interaction Design, and Persuasive Technology
Female	25	55	Finland	Professor	UX design, UX, and human-automation interaction
Male	19	49	China	Associate Professor	HCI, Usability, UX, conversational Agents (Chatbots), and affective Computing
Male	16	48	France	Associate Professor	Cognitive science, emotion, HCI, and computational modeling
Male	23	65	Brazil	Professor	HCI and accessibility
Male	15	54	Italy	Professor	E-learning, Accessibility, HCI, UX, and Digital Health
Male	20	44	Spain	Professor	UX and social connectedness
Male	11	42	Tanzania	Lecturer	FOSS, HCI, and ICT4D
Female	10	47	Canada	Professor	eHealth, UCD, UX, and Requirements Engineering

"1," calculated as α-cut $= (0+1)/2 = 0.5$. If the value of Z^* is less than the α-cut value, the item is rejected because experts dispute it; nevertheless, if the value of Z^* exceeds the α-cut value, the item is accepted because experts have agreed (Mohamed Yusoff et al., 2021). Nevertheless, the Center Of Gravity (COG), the Center Of Area (COA), and the mean of maxima are other methods that might be adopted for the defuzzification step. However, the simplest and preferred method is the COA calculated using the formula.

$$\mathbf{DF_{ij}} = \frac{[(\mathbf{U_{ij}} - \mathbf{L_{ij}}) + (\mathbf{M_{ij}} - \mathbf{L_{ij}})]}{3 + \mathbf{L_{ij}}}$$

In the fourth and final step, the acceptability of all factors is tested. A threshold is first decided based on the researcher's opinion; in this study, "0.6" was preferred to denote low-ranked items. The threshold (0.6) is critical, particularly when executing an additional FDM round is not an option. It helps eliminate or retain items based on the crisp values of defuzzification of aggregated expert opinions. When the item's crisp value exceeds the threshold, the item is accepted, and if it falls below the threshold, the item is rejected (Alghawli et al., 2022).

Likewise, Okoli and Powlowski's (2004) principles were used to establish the final set of UX assessment experts who were purposively selected. Their inclusion/exclusion criteria demanded those who have published, read, or reviewed scholarly publications on UX/usability maturity assessment. They must, however, actively participate in evaluating FOSS UX/usability maturity or have seen the progress of FOSS projects' UX maturity evaluation over the last ten years. Authors sent personalized e-mails to UX experts whose initial list of names and contacts was proposed by both authors. The list was continually updated using snowballing, and the recruitment process took place between mid-July 2021 and November 2022, with an initial response rate of 40.20% (41/102). Finally, twelve (12) UX experts agreed to participate and signed consent forms (see Table 3 for profiles' information).

4. Results

4.1. Initial FOSS UX maturity influencing factors

After completing the first research phase, the study discovered twenty-one (21) UXMIFs that may fit in the FOSS community (see Table 4).

4.2. Reliability and validity of the study

All instructions and questionnaires adopted by the study were pre-tested with all authors and two independent postgraduate students who aided in various research-related activities. As a result of the offered recommendations, minor tool adjustments were made. Involved stakeholders were selected from FOSS projects with activity levels of at least 90% calculated from user ratings. Nevertheless, predetermined standards for quality and inclusion/exclusion criteria decided which document and scholars to include or exclude in the survey. Finally, several initiatives were made to secure communications with respondents to ensure the integrity of the collected data.

4.3. Knowledge of UX maturity and linked concepts in the FOSS community

In response to research question one," How do the FOSS community's stakeholders understand UX maturity and linked terms?" The findings show that among fifteen (15) FOSS stakeholders, 26.67% were UX designers, 13.33% were product designers, 6.67% were visual designers, 26.67% were UX researchers, 6.67% were content strategists, and 6.67%

Table 4. Initial list of UX maturity affecting factors appealed to apply in FOSS.

Sn.	Proposed FOSS UXMIFs	Source(s)
1	Allocating adequate financial resources for UX-related works	Van Tyne (2009), MacDonald et al. (2022), Chapman and Plewes (2014), Rukonić et al. (2019), Peres et al. (2014), Sauro et al. (2017), and Young et al. (2020)
2	Dedicate UX staff with specialized UX skills.	Van Tyne (2009), MacDonald et al. (2022), Chapman and Plewes (2014), Rukonić et al. (2019), Peres et al. (2014), Sauro et al. (2017), and Young et al. (2020)
3	UX leadership	MacDonald et al. (2022), Chapman and Plewes (2014), Peres et al. (2014), Sauro et al. (2017), and Young et al. (2020).
4	Include UX professionals as decision-makers	Raza et al. (2012a) and Terry et al. (2010)
5	Adopt UCD techniques	Young et al. (2020) and Rukonić et al. (2019).
6	Consider UX as a professional	Rukonić et al. (2019), Raza et al. (2012a), and Terry et al. (2010)
7	Buy-in of UX ideas	Rukonić et al. (2019), Peres et al. (2014), Sauro et al. (2017), and Young et al. (2020).
8	Clear UX maturity roles for each stakeholder	Chapman and Plewes(2014), and Rukonić et al. (2019).
9	Timing to UX techniques in the development process	Chapman and Plewes(2014) and Peres et al. (2014)
10	Regular and systematic use of UX research methods	Van Tyne (2009), Pernice et al. (2021), Anchahua et al. (2018)and Rukonić et al. (2019),
11	Formalise UX design standards.	MacDonald et al. (2022), Chapman and Plewes (2014), Peres et al. (2014), Sauro et al. (2017), and Young et al. (2020).
12	Participation of stakeholders beyond the UX team during UX design	Young et al. (2020), Rukonić et al. (2019) and Pernice et al (2021)
13	Regular UX training	Peres et al. (2014) and MacDonald et al. (2022).
14	Esteeming UX skill sets similar to technical skills.	Raza et al. (2012a), Peres et al. (2014), and Sauro et al. (2017).
15	Organizational flexibility	Sauro et al. (2017) and Rukonić et al. (2019)
16	UCD goals predicting UX metrics.	Rukonić et al. (2019) and Jokela and Abrahamsson (2000)
17	Regular review and update of UX metrics	Jokela and Abrahamsson (2000), Pernice et al. (2021), and Chapman and Plewes (2014).
18	UX impacts all project stakeholders.	Pernice et al. (2021), Rukonić et al. (2019) and MacDonald et al. (2022).
19	constantly monitoring UX quality	Namayala et al. (2023), Pernice et al. (2021) and Rukonić et al. (2019),
20	Users' needs	Peres et al. (2014), Chapman and Plewes (2014), and Van Tyne (2009).
21	Consistently tracking UX-related tasks.	Van Tyne (2009) and Sauro et al. (2017).

emanated from other specialties. Nevertheless, 13.33% of selected respondents did not respond to the question regarding their profession. Regarding the respondents' working experience, findings show that 26.67% worked in the FOSS community between zero and five years, 46.67% between five and ten years, 20% between ten and fifteen years, and 6.67% had over fifteen years of working experience.

Since there has never been a consistent method for analyzing interview data (Roulston, 2014), this study performed a content analysis of the interview data using NVivo 12. The findings identified four themes: UX experts' understanding of UX maturity, how stakeholders' descriptions relate to what Nielsen and Norman Group already described, acquired experience in assessing UX maturity, and factors influencing FOSS UX maturity. The presentation and discussion style of the findings mixed deductive and inductive strategies. It adopted the top-down approach that started with developing research theory and progressed to tentative hypothesis testing, observing data patterns and ended with a conclusion by observations. The deductive approach is different from the inductive approach. The former tries to develop a theory, while the latter aims to test an existing idea (Symons, 2019).

Findings from the theme, "UX experts' understanding of UX maturity," show that although each stakeholder has a unique understanding of UX maturity, provided explanations indicate common features. For example, one UX professional said, "….*UX maturity usually describes how an organization transforms from principle-based to UCD.*" Another one said,"…*UX maturity involves users at every stage of organizational product development processes instead of only getting business and technology working.*" We find similarities between the provided definitions in these two sampled descriptions. Nevertheless, stakeholders often used similar words when defining UX maturity and related ideas (see Figure 2).

Findings from the second theme, "How stakeholders' descriptions relate to what Nielsen and Norman Group already described," demonstrate how each stakeholder remarked on the similarities and differences between the given descriptions and Nielsen and the Norman Group's well-known explanation. For example, one stakeholder said, "…*My description and what the Nielsen and Norman group said do not differ noticeably.*" The second said, "….*Every academic has adopted the definition the Nielsen and Norman group offers, and I am likewise at ease.*" One more stakeholder communicated, "…*Although my definition and the Nielsen and Norman group definition contextually present the same thing, however, the two definitions differ significantly.*"

Findings from the third theme, "The acquired experience in assessing UX maturity," show that FOSS stakeholders learn and develop new techniques from experience acquired by assessing UX maturity. However, acquired experiences vary among stakeholders based on their specialties. For example, one stakeholder said, "….*Yes, I have been engaged in UX maturity-related tasks for over six years, particularly designing evaluations that utilize currently accessible UX maturity models. Through years of utilizing the six levels UX maturity model, I have improved my knowledge of UX maturity assessment. However, assessing UX maturity has not always been simple, and it has occasionally been difficult to distinguish between levels.*" A different stakeholder said,

Figure 2. Common terms used to define UX maturity.

"….I have more than ten years of working experience and have been directly or indirectly engaged in assessing UX maturity; however, I have encountered several difficulties. For example, many companies use the only available UX expert to produce logos, banners, or fliers and believe they are their responsibility. Another challenging aspect is the misunderstanding of UX functions. Finally, getting resources for UX-related tasks is challenging in several FOSS projects." One more stakeholder said,"…. *Over ten years, I have gathered several UX and Customer Experience (CX) models. However, the task has been disappointing because many available models are designed for UX teams to assist them in monitoring development progress. They are expensive, use complex languages, and very few are understandable enough for those not knowledgeable in UX."* Finally, one more stakeholder said, *"….Surprisingly, little research is present on the elements that make up a 'mature' UX. Moreover, it has been challenging to explain the link between UX maturity and organizational success and what is the optimal maturity level for a given organization."*

Findings from the final theme, "The factors influencing FOSS UX maturity," show that the FOSS stakeholders have enough knowledge of what factors may positively impact the UX maturity of FOSS projects. For example, one stakeholder said, *"….User-centred design, which I believe is the driving force behind UX maturity, is influenced by many factors, including UX teams, UX research, a defined UX strategy, organization actions aligning with user expectations, and quantitative UX metrics. Others may include adopting artificial intelligence to examine the enormous amount of users' feedback, quality of user interfaces, and simplicity in submitting users' complaints."* Another stakeholder said, *"… As a result of several empirical tests, various unique factors may affect the UX maturity of the FOSS community, including meeting users' requirements, sophisticated ways of collecting and handling users' feedback, UX learning, adoption of UCD methodology, projects' understandability, learnability, operationality, attractiveness, simplicity of bug reporting procedures, UX/usability testing, and proper documentation."* Another stakeholder said, *"….Numerous elements influence UX maturity. including budgets, improved tools, thoughtful design methodology, high-quality user research, and continuity."* Finally, one stakeholder remarked, *"….UX maturity is affected by several key indicators, such as ease of use, speed of use, learnability, consistency, content, accessibility, and flexibility. Others may include aesthetics, recovery from errors, help, brand recall, persuasiveness, differentiation, and the greater good."*

4.4. Analysis of UX experts' agreement on established UXMIF

The thirty-six most important UXMIFs to the FOSS community were established after the literature review, stakeholders' interviews, and consultation with UX experts (see Table 5). The factors were grouped into six themes: the FOSS UX culture, the FOSS UX processes, the FOSS UX outcomes, the FOSS UX strategy, FOSS-adopted technologies, and FOSS usability. The factors were given to the UX experts in response to research question two," What UX maturity influencing factors affect the UX maturity of the FOSS community?"

The FOSS UX culture describes a unique software design and development approach emphasizing collaboration, user-centered design, and openness. The FOSS UX processes describe methods and activities UX designers use to understand and improve the UX of users interacting with a product or service. They are typically iterative and involve activities designed to uncover user needs, preferences, and behaviors to develop and test solutions that meet those needs. The FOSS UX outcomes refer to the design process results and how they impact the overall UX of a product or service. They measure the success of a UX design based on how well it meets the needs and expectations of users and how it achieves the goals of the product or service. The FOSS UX strategy provides a framework for making design decisions and evaluating the design's success over time. It involves defining the target audience, understanding their needs and behaviors, and creating a plan for delivering an optimal UX. FOSS-adopted technologies refer to technologies that enhance UX by making products more engaging, interactive, and effective. They may include artificial intelligence (AI), machine learning (ML), virtual reality (VR), augmented reality (AR), the Internet of Things (IoT), motion design, and mobile and responsive design. Finally, FOSS usability refers to the ease with which users can interact with a product or service to achieve their goals. Usability is a crucial aspect of UX design and involves designing intuitive, efficient, and effective products.

Collected data were analyzed as prescribed in the algorithm for implementing the FDM for screening (see Table 2). Based on the findings from the completed FDM analysis (see Table 6), all threshold values are less

Table 5. Items for free and open-source software user experience maturity influencing factors.

Id.	Items
Usability (U)	
U1	Documentations and support
U2	Ease of use
U3	Speed of use
U4	learnability
U5	Users' feedback
U6	Bugs reporting procedure
U7	UX/usability testing and quality assurance
U8	Meeting users' requirements
U9	User-centered Design Methodology
U10	Operability
U11	Accessibility
U12	Attractiveness
The FOSS Adopted Technologies (T)	
T1	Artificial Intelligence (AI) (
T2	Adopted development methods
T3	Technical infrastructures, such as software development tools, libraries, and frameworks
The FOSS UX Strategy (S)	
S1	UX leadership
S2	Planning of UX-related activities
S3	Allocating adequate financial resources for UX-related works
S4	Dedicating UX staff with specialized UX skills
The FOSS UX Culture (C)	
C1	Developers' UX skillset
C2	Regular training on UX-related activities
C3	Esteeming UX skill sets similar to technical skills.
C4	The organizational flexibility
C5	Considering UX as a professional
C6	Executive understanding and buy-in of UX ideas
C7	Clear UX maturity roles for each stakeholder
C8	UX professionals are part of the decision-makers
The FOSS UX Process Integration (P)	
P1	Regular and systematic use of UX research methods.
P2	Formalize standards for UX design.
P3	Timing to include UX methods, practices, principles, and tools
P4	Consistently tracking UX-related tasks.
P5	Monitor UX quality constantly.
The FOSS UX Outcome (O)	
O1	UCD goals predicting UX metrics
O2	Regular review/update of UX metrics
O3	Early engagement of all stakeholders
O4	Number of errors made by users

than or equal to 0.2, and according to Cheng and Lin (2002), experts' consensus has been reached. The total percentage of agreement is above 75%, and all defuzzification crisp values exceed the α-cut = 0.5. All items are ranked based on priority, where users' feedback and technologies adopted in developing FOSS projects are ranked first, while the speed of use and learnability are ranked last. However, the importance and impacts of UXMIF may vary between projects and user base, making definitive ranking highly challenging.

5. Discussion of the results

The findings reveal that all thirty-six UXMIFs identified have obtained expert consensus (84%) and meet all FDM analysis standards. As a result, they can all be considered when creating new UXCMMs for the FOSS community. The adopted procedure, i.e., the FDM, is reliable and legitimate for information systems research (IS). It has directly asked knowledgeable academics in the area questions about the factors that may impact UX maturity evaluation and iteratively perform ranking and validations.

5.1. Interpreting results

The factors "Users' feedback" and "Adopted FOSS development methods" are at the top of the final ranking list. The participant who initially identified and challenged "User feedback" argued, "… *The quality of user feedback can impact UX maturity. FOSS projects that actively seek and incorporate user feedback tend to have more mature and user-friendly interfaces.*" Likewise, the participant who initially identified and challenged the factor "Adopted FOSS development methods" argued that "… *The FOSS Projects that use modern and flexible infrastructure tend to have more mature UX.*"

Ranking "user feedback" and "adopted development technologies" at the top is not by surprise. The use of modern and flexible technologies in reporting, retrieving, and analyzing user feedback has been the current highly emphasized research area in the community for improving overall UX design (Duffy, 2018). However, current practices in the FOSS community offer less attention to user interfaces and related issues (Raza et al., 2010). They frequently address the requirements of a smaller, more niche audience (Swarts, 2019) and, as a result, cause several UX-related

Table 6. Findings of UX experts' consensus on FOSS UX maturity influencing factors.

	Triangular fuzzy numbers			Defuzzification		
Items	Average of fuzzy numbers	Threshold value (d) by item	Percentage of UX experts' opinions with $d \leq 2$ (%)	Crisp values (Z^*)	Ranking	Status
U1	(0.47, 0.71, 0.88)	0.133	83	0.696	30	Accepted
U2	(0.81, 0.94, 1.00)	0.100	100	0.930	5	Accepted
U3	(0.38, 0.60, 0.81)	0.142	100	0.602	35	Accepted
U4	(0.38, 0.60, 0.81)	0.142	100	0.602	35	Accepted
U5	(0.86, 0.98, 1.00)	0.025	100	0.960	1	Accepted
U6	(0.49, 0.71, 0.88)	0.125	58	0.703	29	Accepted
U7	(0.46, 0.67, 0.85)	0.175	83	0.666	33	Accepted
U8	(0.79, 0.93, 0.99)	0.067	92	0.917	7	Accepted
U9	(0.64, 0.80, 0.94)	0.175	75	0.796	17	Accepted
U1	(0.47, 0.71, 0.88)	0.133	83	0.696	30	Accepted
U2	(0.74, 0.90, 0.97)	0.117	100	0.885	10	Accepted
U3	(0.56, 0.73, 0.90)	0.242	58	0.732	27	Accepted
T1	(0.76, 0.91, 0.98)	0.067	100	0.896	9	Accepted
T2	(0.86, 0.98, 1.00)	0.025	100	0.960	1	Accepted
T3	(0.84, 0.96, 1.00)	0.100	100	0.945	4	Accepted
S1	(0.60, 0.78, 0.91)	0.242	58	0.772	20	Accepted
S2	(0.58, 0.76, 0.91)	0.175	75	0.756	23	Accepted
S3	(0.80, 0.94, 0.99)	0.075	92	0.924	6	Accepted
S4	(0.78, 0.93, 0.98)	0.100	83	0.911	8	Accepted
C1	(0.60, 0.78, 0.91)	0.242	58	0.772	20	Accepted
C2	(0.70, 0.86, 0.97)	0.150	92	0.854	13	Accepted
C3	(0.68, 0.83, 0.96)	0.150	83	0.828	14	Accepted
C4	(0.55, 0.75, 0.90)	0.158	75	0.743	26	Accepted
C5	(0.58, 0.76, 0.91)	0.175	75	0.756	25	Accepted
C6	(0.71, 0.88, 0.96)	0.183	100	0.864	12	Accepted
C7	(0.59, 0.78, 0.93)	0.200	83	0.775	19	Accepted
C8	(0.60, 0.77, 0.92)	0.267	67	0.764	22	Accepted
P1	(0.59, 0.78, 0.93)	0.200	83	0.775	18	Accepted
P2	(0.85,0.97, 1.00)	0.033	100	0.953	3	Accepted
P3	(0.60, 0.81, 0.94)	0.100	100	0.799	16	Accepted
P4	(0.58, 0.76, 0.91)	0.175	75	0.756	23	Accepted
P5	(0.53, 0.74, 0.90)	0.142	75	0.730	28	Accepted
O1	(0.44, 0.65, 0.84)	0.183	83	0.647	34	Accepted
O2	(0.50, 0.70, 0.87)	0.250	25	0.692	32	Accepted
O3	(0.63, 0.83, 0.95)	0.100	100	0.813	15	Accepted
O4	(0.75, 0.89, 0.98)	0.067	92	0.883	11	Accepted
Total construct		0.143	84	N/a	N/a	N/a

problems. For example, reporting and managing users' feedback has been challenging (Nichols & Twidale, 2003; Zhao & Deek, 2005). Among other causes, the FOSS community still faces difficulties developing products with desirable UX because of communication barriers, its nature, limited resources, and lack of standardized reporting channels and incentives. This finding is also confirmed by Yusop et al. (2017). The "user feedback" belongs to the theme "usability." Usability has been critical in developing products with desirable UX. Findings from other studies, such as Hassenzahl (2003), Roto et al.(2010), and Sauer et al. (2020), also confirm the argument. Usability affects the product's reputation because users are more inclined to share negative feedback and discourage others from using the software when they struggle with it or have a bad experience.

Table 7 details the justifications of UX scholars, and other FOSS stakeholders provided when proposing UXMIFs in the usability theme.

The technologies adopted by the FOSS community during the development of its projects belong to the theme "FOSS technology." Adopted technologies being ranked high is not by surprise. The FOSS community is suggested to adopt artificial intelligence (AI) technology due to the massive data increase and embedded complexity when submitting and addressing users' complaints (Zhou et al., 2017). Nevertheless, AI has been an option for quick code production, automatic user behavior analysis, and providing personalized recommendations (Batarseh et al., 2020; Murphy-Hill et al., 2021). Finally, AI tools, such as "Copilot/Codex," primarily contribute to source codes (Pudari & Ernst, 2023).

Table 8 offers participants convincing arguments for each factor in the theme "Adopted technologies"

The theme "The FOSS UX Process Integration" contains five factors argued to influence the UX maturity of the FOSS community. However, the "Formalize standards for UX design" factor has emerged as significant, ranked third among all UXMIFs. This factor may influence the FOSS community's UX maturity by providing a consistent experience to all users across FOSS projects, platforms, and devices, improving users' efficiency in learning and accomplishing their tasks, accessibility, and usability, and encouraging innovations. This conclusion confirms the findings of Kashfi et al. (2019).

Table 9 provides participants' arguments regarding the importance of proposed FOSS UXMIFs in the theme "The FOSS UX Process Integration."

Table 7. UX experts' justifications for proposed FOSS UXMIFs – usability theme.

Factor	Justification(s)
Documentation	*"… May help FOSS develop a devoted user base and a robust community by making the program easier to understand and use, resolving problems, fostering community involvement, and making FOSS available to a wider audience."*
Ease of use	*"… May improve user pleasure, efficiency, accessibility, and overall acceptance, resulting in a good UX that satisfies users' needs."*
Speed of use	*"… FOSS that responds slowly can frustrate users and have a bad UX. While a quick and responsive system might result in a good UX and higher user satisfaction."*
Learnability	*"… A FOSS that is easy to learn and understand for new users will provide a satisfying UX."*
bugs reporting procedures	*"… A FOSS with a robust and efficient bug reporting process can lead to a positive and greater UX maturity by impacting how quickly and effectively developers can identify and address issues that affect users."*
Usability/UX testing	*"… May help find problems and areas where FOSS design needs to be improved, resulting in a better UX overall. UX testing entails assessing FOSS from the viewpoint of its users to comprehend how they interact with it and spot any problems or potential improvement areas."*
User requirements	*"… provide critical insights into the needs and preferences of the users who will be using FOSS and therefore promote UCD, users' satisfaction, and continuous improvement."*
UCD practices	*"… It entails creating FOSS while keeping the user's wants, preferences, and habits in mind. It encourages cooperation, openness, and iterative design, as well as participation from the community."*
operability	*"… It refers to the ease with which users can install, configure, and maintain FOSS. It includes aspects such as system compatibility, installation process, ease of updates and upgrades, and the availability of documentation and support. If users face difficulties installing, configuring, and updating or upgrading the software, they are more likely to abandon it, resulting in a poor UX."*
Accessibility	*"… It refers to the ability of users to access and use software applications regardless of their abilities, disabilities, or impairments. It helps make the FOSS inclusive, compliant, innovative, reputable, and satisfying to all users."*
Attractiveness	*"….It affects the first impression, engagement, brand image, usability, and competitive advantage of FOSS, which may help create visually appealing FOSS, which enhances the UX, increase user engagement, and promote the brand image and their reputation ."*

Table 8. UX experts' justifications for proposed FOSS UXMIFs – adopted technology theme.

Factor	Argument
Artificial Intelligence (AI)	*"… May make FOSS more personalized, predictive, efficient, and user-friendly through understanding the user's behavior and preferences, predictive analytics, Natural Language Processing (NLP), automation and sentiment analysis."*
Technical infrastructures, such as software development tools, libraries, and framework	*"… A well-designed technical infrastructure can facilitate the development of high-quality, user-friendly software that meets users' needs."*

Table 9. UX experts' justifications for proposed FOSS UXMIFs - FOSS process integration theme.

Factor	Provided arguments
Regular and systematic use of UX research methods	*"… May involve collecting data about users' needs, behaviors, preferences, and pain points to inform the design and development of FOSS., leading to better FOSS UX that meets the needs and expectations of users."*
Formalize UX design standards.	*"… May help to create consistency, clarity, and usability across different FOSS projects, creating projects that provide users with a better UX and more likely usable."*
Timing to include UX methods, practices, principles, and tools	*"… May help increase the likelihood of delivering FOSS projects with desirable UX."*
Consistently tracking UX-related tasks.	*"… May help improve UX maturity in FOSS by identifying areas for improvement, measuring progress, encouraging collaboration, enabling data-driven decision-making, and facilitating continuous improvement."*
Monitor UX quality constantly.	*"… May help FOSS developers identify issues and pain points, measure user satisfaction, monitor user engagement, gather user feedback, and encourage continuous improvement that matures to improved UX."*

In "The FOSS UX strategy" theme, the factor "FOSS allocate adequate financial resources for UX-related works" is ranked fifth. According to Levy (2015), UX strategy lies at the nexus of business strategy and UX design. When "the FOSS UX strategy" is empirically created and adopted, it may offer a significantly better probability of creating a successful digital product than simply developing some wireframes and writing many source codes.

Table 10 provides arguments about the UXMIFs in the theme "FOSS UX Strategy."

The theme "The FOSS UX culture" is equally important in the overall FOSS UX maturity. The group ranks "Regular training on UX-related activities" high at the 13th position. Regarding this study, the theme "FOSS UX culture" often refers to the values, beliefs, and practices a FOSS community adopts to prioritize and improve its products or services. It involves creating an environment that encourages and supports the development of UCD practices, user testing, and ongoing UX improvement (Bargas-Avila & Hornbæk, 2011) and must consider the cultural context in which its projects will be used (Norman, 2013). A strong UX culture can improve user satisfaction, increase loyalty, and give a competitive advantage in the marketplace.

Table 10. UX experts' justifications for proposed FOSS UXMIFs – UX strategy theme.

Factor	Arguments
FOSS UX leadership	*"… May prioritize UX design, create a culture of UX maturity, allocate resources, encourage collaboration, and hold teams accountable for UX design to ensure FOSS projects are designed with the user in mind and provide a better UX."*
Planning of FOSS UX-related activities	*"… May help FOSS developers set goals and objectives, conduct user research, plan for user testing, adopt an iterative design process, and foster collaboration to create projects designed with their users' needs in mind and provide a better UX."*
FOSS allocates adequate financial resources for UX-related works	*"… May help FOSS projects hire UX professionals, conduct user research, invest in design tools, conduct user testing, and support the community to create projects with the needs of its users in mind, better UX and improved UX maturity."*
FOSS dedicated UX staff with specialized UX skills	*"… May improve the UX maturity of the open-source software community by ensuring UCD design, design consistency, accessibility, user testing, design documentation, and collaboration."*

Table 11. UX experts' justifications for proposed FOSS UXMIFs – UX culture theme.

Factor	Justification(s)
FOSS developers' UX skillset	*"… May help improve UX maturity in the FOSS community by incorporating design thinking, conducting usability testing, ensuring accessibility, enhancing the visual design, and collaborating more effectively."*
FOSS Regular training on UX-related activities	*"… Can benefit the FOSS community by improving team members' UX skills, keeping them up-to-date with the latest trends and best practices, ensuring consistency, promoting collaboration, and incorporating user feedback."*
FOSS Esteeming UX skill sets similar to technical skills	*"… Can help improve the UX maturity of the FOSS community by increasing recognition of UX expertise, encouraging collaboration, incorporating UX earlier in the development process, improving software usability, and attracting more UX professionals to FOSS projects."*
The organizational level of flexibility in FOSS	*"… Can improve FOSS UX maturity by allowing for quick adaptation to changing user needs, fostering experimentation and innovation, enabling collaboration with diverse contributors, leveraging existing tools and resources, and enabling customization of FOSS projects to meet specific user needs."*
FOSS considering UX as a professional	*"… May help the FOSS community to appreciate the importance of UX better, attract more dedicated UX resources, improve collaboration, establish design standards, and drive innovation."*
Buy-in of UX ideas	*"… May help improve UX maturity in the FOSS community by promoting a UCD approach, facilitating collaboration, encouraging user research and testing, promoting design consistency, and encouraging continuous improvement."*
Clear UX maturity roles for each FOSS stakeholder	*"… May help improve user experience maturity of the FOSS community by encouraging shared ownership, reducing overlap and duplication, promoting accountability, increasing efficiency, and helping to identify gaps and areas for improvement."*
FOSS includes UX professionals as decision-makers	*"….Can improve the UX maturity of the FOSS community by bringing user-centric perspectives, ensuring design consistency, providing expert knowledge, facilitating collaboration, and enhancing user satisfaction and engagement."*

The study's explanation adapts the explanation provided by Hassenzahl and Tractinsky (2006) and Law et al. (2014).

Table 11 provides initial justifications for UXMIFs in the FOSS UX culture theme.

Finally, the theme "The FOSS UX Outcome" is equally important because by focusing on it, organizations can make data-driven decisions to improve the UX and, ultimately, drive business success. Current knowledge ties "the FOSS UX outcomes" to specific goals for a product or service, such as increasing user engagement, improving user satisfaction, or reducing user errors users make when using products (Hassenzahl & Tractinsky, 2006). The theme measures the impact of the UX design on the user and the business (Hassenzahl, 2010). It involves collecting data on user behavior, attitudes, and perceptions through various methods, such as surveys, interviews, usability testing, and analytics (William & Thomas, 2013). Among all the factors in the theme, "Number of errors made by users" is ranked 11th by this study.

Table 12 lists the factors under the theme "The FOSS UX outcome" along with initial justifications from those who proposed them.

5.2. Study's contribution and implications to research and practice

While there has been some research on UX in FOSS projects, limited studies identify factors influencing the UX maturity of the projects (Cheng & Guo, 2018). As a result, the FOSS community still lacks a definitive list of factors influencing its UX maturity, making it difficult to create the right UXCMMs to measure its UX maturity and suggest how to improve the status quo. Generically developed UXCMMs may not apply in the FOS community because FOSS projects have varied priorities, goals, and user groups that accumulate into different dynamics than other software-developing communities.

As a significant contribution to the body of knowledge, this study highlights potential dangers to the accuracy and

Table 12. UX experts' justifications for proposed FOSS UXMIFs – the UX outcome theme.

Factor	Initial arguments
UCD goals predicting FOSS UX metrics	"… *can help improve the UX maturity of the FOSS community by ensuring that design solutions are focused on meeting the users' needs and are more effective in achieving their intended outcomes.*"
Regular review/update of FOSS UX metrics	"… *May contribute to the UX maturity of the FOSS community by providing data-driven insights into the UX, identifying areas for improvement, and promoting accountability and transparency in the design process.*"
FOSS stakeholders' engagements	"… *May ensure that FOSS design solutions meet the needs of their users and stakeholders, build trust and collaboration, and ultimately, improve the overall user experience.*"
Number of errors made by users	"… *When users encounter errors while using FOSS, it can lead to frustration, confusion, and a negative experience, making users less likely to use the application in the future. It can even lead to negative reviews and word-of-mouth feedback that can harm the FOSS's reputation.*"

legitimacy of the FOSS community's UX maturity assessment by drawing a picture showing the absence of UX maturity influencing factors that account for the community's dynamics. Drawing this picture can help identify areas for improvement and provide insights into promoting better UX practices and the broader adoption of FOSS projects. As some of the researchers involved in the panel told us during the study, this discussion is urgent to increase user engagement, improve user satisfaction, reduce user errors, or promote the development of more user-friendly FOSS projects.

The study has used FDM to express the UX experts' consensus and justify the validity of all thirty-six UXMIFs relevant to the FOSS community. The method has also assisted in ranking the factors based on their priorities (see Table 6). However, since the metamorphosis of the FOSS development methods has not ceased and will keep advancing, evaluating whether other UXMIFs emerge periodically is crucial. As a result, the study has pointed out three topics that require more research. First, it has recommended additional empirical research using alternative sampling techniques and other strategies to upsurge analyzed factors and reach a relatively large population of stakeholders and FOSS projects. These studies may help test variables in the broader space and generalize the gathered findings to a large population. They may also uncover variables and other issues not noticed in the completed study. As a different initiative, the study recommends that future studies consult FOSS experts, practitioners, developers, users, and the industry to get their points of view regarding UXMIFs and compare the results for a broader overview.

Second, the study recommends a rigorous exploration of the IS literature on FOSS in search of specific instances of UXMIFs to allow quantifying the extent to which the factors have painted current FOSS research. Finally, the completed study has indicated the need to revise existing UX maturity models and other UX practices to suit the dynamics of the FOSS community, as was also suggested by Terry et al. (2010). This suggestion results from the reality that none of the current UX maturity models was designed for the FOSS community or sufficiently accounted for its UX characteristics and UXMIFs (Namayala et al., 2023).

6. Conclusion

Like many other software-developing communities, the FOSS community must correctly and consistently assess its UX maturity. According to the information corpus, practical UX maturity evaluation approaches must consider organizational dynamics that may vary from one organization or environment to another. To address organizational UX dynamics, it is frequently advantageous to understand the elements that influence UX maturity in a specific organization. However, despite ad hoc interventions, it has been determined that the FOSS community has made little to no effort to analyze the aspects that influence the UX maturity of its projects. Nevertheless, current initiatives lack methodological rigor, are inconsistent, and only cover a few influencing factors. This study aims to fill this gap by conducting an empirical study to assess which UXMIFs influence UX maturity in the FOSS community.

The UXMIFs were established from an exhausted literature review, interviews with FOSS stakeholders, and consultations with other UX assessment experts. It then adopted the FDM to establish factors that may apply in the FOSS community. The results from the experts' consensus accepted all thirty-six factors with a total percentage agreement of 84%. Agreed UXMIFs are supported with justifications on how they are critical in influencing the UX maturity of the FOSS community. This study is the first of its own in the FOSS community.

The discussion of the findings clarified that understanding the UXMIFs is associated with many advantages to the FOSS community. Findings from the completed study may have three immediate impacts or contributions to the body of knowledge. (1) They may provide a scientific way of creating UXMIFs for the FOSS community. (2) They may help the FOSS community's stakeholder plan and adjust course, culture, and policies toward an ideal assessment of UX maturity. (3) They may motivate future researchers to actively discuss UXMIFs specific to the FOSS community to improve its UX maturity assessment.

Finally, like any other study, this study has several limitations. For example, it relies solely on the opinions of UX experts, although highly qualified. It has also used a relatively small sample size and may accommodate unfamiliar participants. Nevertheless, the authors believe that when carrying out this investigation, they may have missed certain crucial factors that significantly influence the UX maturity of the FOSS projects.

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Authors' contributions

The first author developed the concept for the article and created the first draft after reviewing the literature, speaking with FOSS stakeholders, and consulting UX academics. The second author provided recommendations after reviewing early manuscripts and conducting a literature review, as well as additional consultations and interviews. Data cleaning and analysis were helped with by two postgraduate students. All authors read the final draft before being approved.

Disclosure statement

The authors of this research have no apparent conflicts of interest to disclose.

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Appendix A: Interview guide for UX experts in the FOSS community

Dear UX experts,

1. Please indicate your understanding of user experience (UX) maturity and capability.
2. According to the Nielsen and Norman group, UX maturity "measures an organization's desire and ability to deliver user-centered design successfully." Is your understanding different from what Nielsen and Norman's group understand?
3. Have you ever been involved directly or indirectly in planning, executing, or reporting any organization's UX maturity assessment? If yes, briefly share your experiences.
4. Using the experience from question three (3), what factors may influence UX maturity in the FOSS community? If possible, briefly explain how they affect the UX maturity of the community.