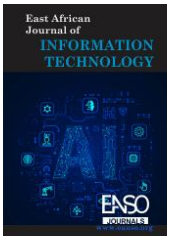


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*Original Article*

# Validation of the usability metrics for evaluating eHealth systems in Tanzania

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## ABSTRACT

The prevalence of eHealth systems in healthcare facilities has experienced significant growth in many countries. Nevertheless, a significant obstacle that has arisen pertains to the usability of the implemented systems. This paper focuses on assessing the usability metrics that are applicable in evaluating eHealth systems in Tanzania's contexts. Data were collected through questionnaires and interviews at six health facilities in Tanzania. The main participants were the health workers who were using the eHealth system in their routine healthcare delivery, including pharmacists, laboratory technicians, doctors, and nurses in their different cadres. The analysis of the findings was performed to obtain usability metrics and contextual issues by computing confirmatory factor analysis (CFA) using structural equation modelling (SEM) for quantitative data and thematic analysis for qualitative data. The results revealed that 11 usability metrics constructs with 54 items and 5 contextual issues constructs with 18 items were applicable in evaluating the usability of eHealth systems in Tanzania.

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## INTRODUCTION

The adoption of eHealth systems in healthcare facilities has rapidly increased in many countries. The main purpose of the adoption of eHealth systems is to improve the quality of healthcare service delivery. Additionally, like other systems, the adoption of an eHealth system depends on the technology's acceptance. Consequently, the acceptance of the system is mainly dependent on the usability of that technology, notwithstanding other factors (Lubua & Pretorius, 2018; Tyllinen, Kaipio, & Laaveri, 2018). Therefore, usability is one of the major factors that should be considered when adopting a technology such as eHealth. This means that if the usability of technology is low, it will lower the efficiency, effectiveness, and dissatisfaction of the service provided through technology, thereby affecting the overall performance and low level of technology acceptance (Kavuta, Msanjila, & Shidende, 2023).

Usability is the degree to which a system, product, or service can be used by specified users to accomplish a set of goals with effectiveness, efficiency, and satisfaction within a specified context of use (ISO, 2018). Usability, in other words, is referred to as "the capability of the software to be understood, learned, operated, attractive to the user, and compliant to standards and guidelines when used under specific conditions" (ISO, 2001, p. 16). For this study, the term usability is defined as the degree to which the user admires using the system due to its simplicity and ability to accomplish the intended task and goals efficiently with tolerable errors. Moreover, the term "eHealth usability" in this study context refers to the ability of healthcare providers and other stakeholders in the healthcare industry to apply the eHealth system to achieve the goal without experiencing difficulties while maintaining efficiency and data integrity. The usability of eHealth systems, like other systems, is measured by using metrics that can reveal the weaknesses of the system that hinder their applicability.

### Usability Metrics

Usability metrics are qualities that are used to measure the usability of a system in its many dimensions. Metrics that are most commonly used to evaluate generic systems include learnability, efficiency, memorability, effectiveness, error correction, and satisfaction (Niranjanamurthy et al., 2014). Learnability examines how simple it is for users to do required tasks when they actually experience the system's design for the first time. Efficiency is a measurement of how quickly a skilled user completes a task. Memorability measures a user's ability to recall how to use a system after some time has passed without using it. Error is a common usability metric that assesses how frequently users make errors, how significant the errors are, and how easy it is for users to recover from such errors. The satisfaction metric is the usability metric that is used to measure the user's enthusiasm or appreciation for the system (Sousa & Lopez, 2017; Broekhuis et al., 2019). These common metrics are used to identify broad usability problems that apply to all information systems in general, not specific problems that are unique to the eHealth context. Therefore, more attention and precise metrics are needed to evaluate the usability of eHealth systems in all their dimensions.

This study grouped the usability metrics for evaluating eHealth systems into three categories: common metrics, specific metrics, and contextual issues. The common usability metrics are those metrics that have been used to evaluate generic systems, products, and services. Recently, studies have used common usability metrics, including error correction, navigation, accessibility, visibility, and perceived ease of use, in evaluating generic information systems (Broekhuis et al., 2020; Islam et al., 2020; ISO, 2018; Hyppönen et al., 2019).

Specific usability metrics are those metrics that are mostly applied in evaluating eHealth systems but are not essentially used to evaluate generic systems. The specific metrics include collaboration, information quality and terminologies, technical qualities, guidance and support, and perceived benefits of the system's internal and external collaboration (Hyppönen et

 

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al., 2019; Broekhuis et al., 2020; Halim, 2019). However, all these studies were conducted in developed countries, including the Netherlands and Finland. Therefore, it is necessary to test their applicability in Tanzania's context. *Table 1* presents a summary of the sources of the usability metrics extracted for evaluating the usability of eHealth systems.

**Table 1: Usability metrics and their sources**

| | Metrics | References |
|---|---|---|
| Common Metrics | Navigation | (Broekhuis et al., 2020; Islam et al., 2020) |
| | Error Correction | (ISO, 2018) |
| | Visibility | (Hyppönen, et al., 2019) |
| | Accessibility | (ISO, 2018) |
| | Perceived ease of use | (Hyppönen, et al., 2019) |
| Specific Metrics for eHealth | Information qualities | (Broekhuis et al., 2020) |
| | Technical qualities | (Broekhuis et al., 2020; Hyppönen, et al., 2019) |
| | Benefits | (Broekhuis et al., 2020; Halim, 2019) |
| | Internal collaboration | (Hyppönen, et al., 2019) |
| | External collaboration | (Hyppönen, et al., 2019) |

### Contextual Issues and eHealth Usability Evaluation

The usability of a system depends on the proper identification of the context in which it is going to be used. Thus, the system developers need to thoroughly study the audience for whom the technology is going to be used so as to consider all contextual issues that directly affect and indirectly affect the usability of the system. This is because one society can differ from another in the level of usability of the system (ISO, 2018). For example, if the users change their characteristics, such as by adding skills, this can change their usability level. Also, the combination of the different activities may lead to a different level of usability.

Contexts include the issues that answer questions like which system is to be used, for whom the system should be designed, what will be used, and where it will be used (Maguire, 2001). The literature exposes that there are specific contexts for healthcare systems, such as culture, interaction between various professionals, social and ideological movements, staff skills, care standards, patient satisfaction, service differentiation, etc. (Bate et al., 2014). Therefore, contexts are a vital attribute in evaluating the usability of eHealth systems. It is recommended that in developing countries, where there are limited resources and the context is quite different from Western culture, the local needs and the social-technical context of the information systems should be considered (Tiihonen et al., 2008).

This study focused on validating the usability metrics and context issues that are necessary for evaluating the usability of the eHealth systems in Tanzania. *Table 2* presents the common contextual issues and their sources from the literature.

**Table 2: Contextual issues and their sources**

| | Contextual issues | Reference |
|---|---|---|
| Context of use | Users characteristics | (Prgomet et al., 2019; ISO, 2018) |
| | Resources & technologies | (Prgomet et al., 2019; ISO, 2018) |
| | Goals &tasks | (Prgomet et al., 2019; ISO, 2018) |
| | Technical environment | (Prgomet et al., 2019; ISO, 2018) |
| | Physical environment | (Prgomet et al., 2019; ISO, 2018) |

## METHODOLOGY

This study collected data from three health facility levels, including regional referral hospitals (RRH), district or designated district hospitals (DH/DDH), and health centres (HC), which are using the locally made eHealth system known as GoT-HoMIS (Government of Tanzania - Hospital Management Information System). Thus, six

 

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health facilities are included: Tumbi Hospital (RRH) – Coast Region; University of Dodoma Hospital (DH) – Dodoma; Chato District Hospital (DH) – Geita; Biharamulo Designated District Hospital (DDH) – Kagera; Makole Health Center (HC) – Dodoma; and Kachwamba Health Center (HC) – Geita. A questionnaire was distributed to 370 participants (who are also healthcare service providers) to collect data. The adequacy of this sample was confirmed using the Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity. The rule of thumb is that a sample size is adequate if the KMO value is greater or equal to 0.7 and Bartlett's test and Sphericity is 0.05 or less (Shrestha, 2021; Hair et al., 2014). These two criteria were met in this study as KMO = 0.939, and Bartlett's Test Sphericity was statistically significant with a p-value of = 0.000, as presented in *Table 3*.

**Table 3: Results for KMO and Bartlett's Test**

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .939 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 18657.883 |
| | df | 3081 |
| | Sig. | .000 |

The questionnaire was formed using a standard questionnaire and a review of the literature. Data were analyzed quantitatively using descriptive analysis for the demographic data, and the model validation was done through CFA using SEM. The CFA tests the model fit of the usability metrics and context issues in evaluating the usability of eHealth systems in Tanzania.

Moreover, the qualitative data were collected through interviews, whereas 21 participants were selected from experienced healthcare professionals and ICT personnel. The purpose of conducting the interview was to identify the usability metrics that could not be involved in quantitative data. The qualitative method also helped to capture the true feelings of the participants about the usability of the eHealth system.

**Reliability**

The reliability of the research tool was measured using Cronbach's alpha coefficient. *Table 3* shows each variable along with its Cronbach's Alpha coefficient. The results of the measurement of reliability show that all variables scored above a 0.7 coefficient. This indicates that the collected data is internally consistent. This gives confidence that the items (questions) used are consistent within each construct and are reliable in obtaining the intended information.

**Table 4: Internal Consistency of variables using Cronbach's alpha Coefficient**

| | Variables | Cronbach's Alpha | No. of items |
|---|---|---|---|
| Common metrics | Navigation | 0.86 | 6 |
| | Error Correction | 0.74 | 7 |
| | Visibility | 0.90 | 3 |
| | Accessibility | 0.73 | 3 |
| | Perceived ease of use | 0.82 | 5 |
| Specific metrics | Information qualities and terminologies | 0.74 | 5 |
| | Technical qualities | 0.74 | 5 |
| | Benefits | 0.81 | 3 |
| | Internal collaboration | 0.84 | 3 |
| | External collaboration | 0.84 | 5 |
| | Guides and support/feedback | 0.75 | 4 |
| Context of use | Users' characteristics | 0.76 | 5 |
| | Resources and technologies | 0.73 | 3 |
| | Goals and tasks | 0.73 | 4 |
| | Technical environment | 0.73 | 7 |
| | Physical environment | 0.85 | 3 |
| | eHealth usability | 0.84 | 4 |

 

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**Demographic Profiles of the Research Participants**

The demographic data involved in this study comprise the gender, age, occupation role, and academic qualifications of the 370 respondents. *Table 4* shows that 44.3% of all respondents were male and 55.5% were female. The ages of the respondents were as follows: 4.6% were aged between 18 and 24, 48.4% were aged between 24-34, 21.9% were between 35 and 44, and 20.8% were aged between 45 and 54. The respondents aged above 55 were 4.3%. Thus, the majority of the respondents were in the group of youths aged between 25 and 34. Respondents were from different healthcare professions, including 29.5% of physicians, doctors, and clinicians (doctors), 9.5% of pharmacists, 11.9% of laboratory technologists, 38.6% of nurses and midwives (nurses), and 10.5% of supporting staff from other departments, including accountants, cashiers, ICT personnel, and data clerks. By academic qualifications, 10% were from ordinary level school, 0.8% from high school, 15.1% from certificate level, 43% from diploma level, 28.9% from bachelor, and 2.2% were masters degree holders.

## FINDINGS AND DISCUSSION

### Validation of the Usability Metrics for eHealth Systems

In this section, the findings are presented in three phases. First, the study conducted convergent and discriminant validity tests to determine whether there are correlations among the items (questions) within a single construct and differences between one construct and another, respectively. Second, the CFA was performed on two different sub-models, including common metrics and specific metrics. The purpose of performing the CFA is to determine the fitness of the constructs (metrics) and their items in the model. The results of the CFA helped to isolate the items that did not support the model fit.

#### *Convergent Validity*

Convergent validity, commonly referred to as "construct validity," is a measure of the coherence of the questions used to assess a certain construct (Hair et al., 2014). The purpose of this method is to establish the validity of a test meant to assess a certain construct by doing a comparative analysis with other tests that also measure the same construct. The assessment of convergent validity involves the evaluation of three key aspects: factor loading, composite reliability (CR), and average variance extracted (AVE) (Gu et al., 2019). The CR and AVE are calculated from the factor loadings. The CRs were calculated using the formula proposed by Netemeyer, Bearden, & Sharma (2003) as follows:

$$CR = \frac{(\sum \lambda)^2}{(\sum \lambda)^2 + \sum Ø}$$

Whereas λ represents the factor loading of an item in a construct, and $Ø = (1 - \sum \lambda^2)$ represents the unique variance of the item

$$AVE = \frac{\sum \lambda^2}{N}$$

N – represents the number of items.

According to previous research conducted by Netemeyer et al. (2003) and Hair et al. (2014), a construct is considered reliable and consistent when the CR value exceeds 0.7. The results show that the values of CRs for all constructs exceeded the predetermined threshold. The CR values obtained in this study range from 0.80 to 0.93, as shown in Appendix 1. This suggests that the items measuring each construct have high internal consistency. Additionally, the range of values for AVE falls between 0.50 and 0.75, indicating the extent to which the questions used to measure the construct precisely convey the essence of the study variable (Srinivasan et al., 2002).

#### *Discriminant Validity*

The discriminant validity shows how distinct a set of items from one construct is from others in other constructs. Unlike convergent validity, which assesses how items from the same construct correlate with one another, discriminant validity assesses how items from different constructs differ from one another. This means that it is expected that the items of one construct have no strong

 

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correlation with those of the other construct. There are two common methods of conducting the discriminant validity test, including cross-loading and the Fronell-Lacker criterion. The cross-loading method measures the discriminant by showing that the items of one construct weakly correlate with the items of another construct. The Fronell-Lacker criterion method compares the square roots of one construct's AVE with the correlations to other constructs, whereas the square root of a construct's AVE should be greater than any correlation coefficients to other constructs to consider that the discriminant exists (Mohammadi & Mahmoodi, 2019).

The results showed discriminants among all constructs, as the square roots of AVE for all constructs are higher than the corresponding correlation coefficients of other constructs, as presented in *Appendix 2*. This indicates that each construct measures a distinctive metric different from others. Thus, the tool was valid for testing the usability of the eHealth system.

**Confirmatory Factor Analysis (CFA)**

This section discusses the confirmatory factor analysis (CFA) of the usability metrics and the context of use. The analysis was computed using the SEM. The CFA is used to show the goodness of fit of the model for validating the variables that meet the requirements for evaluating the usability of eHealth systems. To measure the model fit, basic fit indices, including the goodness of fit index (GFI), adjusted goodness of fit index (AGFI), Turker-Lewis Index (TLI), comparative fit index (CFI), and root mean square error of approximation (RMSEA), were used in this study. The recommended values for CFI, GFI, and TLI are as follows: a value above 0.95 is excellent, a value >0.90 is considered a good fit, and a value >0.8 is an acceptable fit (Hair et al., 2014). For RMSEA, the previous studies suggest that values below 0.05 are considered excellent fits, values between 0.05 and 0.08 are considered good fits, values between 0.08 and 0.10 are considered acceptable fits, and values greater than 0.10 are considered poor fits (Cangur & Ercan, 2015; Schumacker & Lomax, 2016).

**Table 5: Recommended thresholds of the Model Fit Indices**

| Item | Recommended | |
|---|---|---|
| $\chi^2$/df | <5.0 | |
| CFI | >0.95 | Excellent fit |
| | >0.90 | Good fit |
| | >0.80 | Acceptable fit |
| TLI | >0.95 | Excellent fit |
| | >0.90 | Good fit |
| | >0.80 | Acceptable fit |
| GFI | >0.95 | Excellent fit |
| | >0.90 | Good fit |
| | >0.80 | Acceptable fit |
| AGFI | >0.95 | Excellent fit |
| | >0.90 | Good fit |
| | >0.80 | Acceptable fit |
| RMSEA | <0.05 | Excellent fit |
| | <0.08 | Good fit |
| | <0.1 | Acceptable fit |

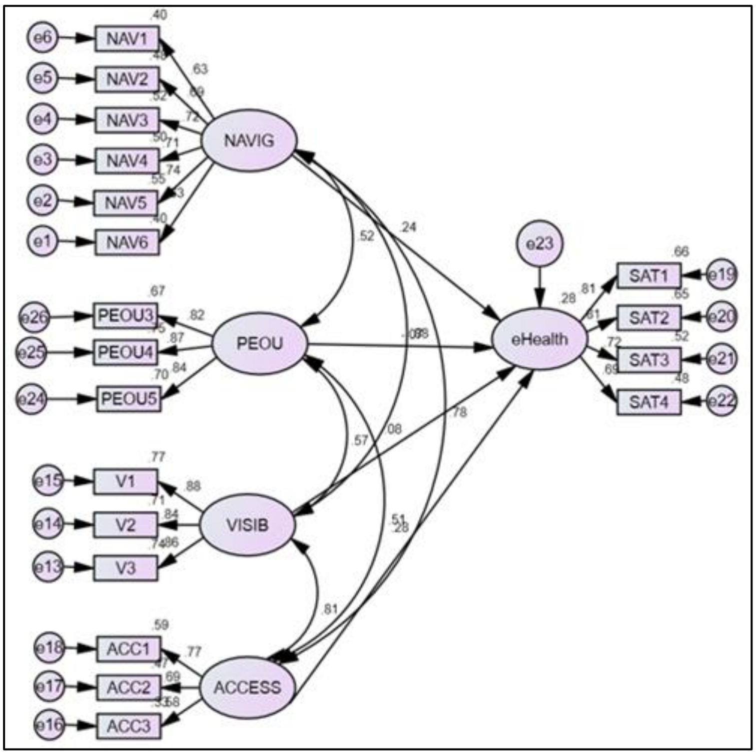
***CFA for common metrics***

In this sub-model of common metrics, the CFA test was conducted with five common usability metrics, including error correction, navigation, accessibility, visibility, and perceived ease of use.

In the first test, the results were very poor, as all fit indices were below the threshold. This study, therefore, decided to review the descriptive results for each common metric construct. When compared to other constructs, error correction had a high number of items with negative perceptions from participants, as the mean values for the majority of items were below the midpoint (i.e., mean <3) of the 5-Likert scale. This prompted us to retest the model by isolating the error correction construct.

Therefore, the model was retested with four constructs and the items of each construct. The result did not satisfactorily fit the model (i.e., GFI =.824, AGFI =.776, TLI = .843, CFI =.865, and RMSEA =.089). According to these findings, the AGFI is weak. Thus, improvement of the model was required. To improve the model, the rules of thumb recommended by Hair et al. (2014) were used. One of the rules recommended by Hair et al. (2014) requires that all items with a factor loading less than 0.6 be eliminated. Therefore, the study inspected all factor loadings of all items, and it was observed that three items in the variable "perceived ease of use" (i.e., PEOU1, PEOU2, and PEOU6) had very low factor loadings; therefore, they were eliminated from the model. The factor loadings for these items were PEOU1 = 0.459, PEOU2 = 0.454, and PEOU6 = 0.282. The results for the goodness of fit of the model after modification are illustrated in *Figure 1*, and the summary is presented in *Table 6*.

**Figure 1: Common usability metrics for evaluating eHealth systems**




The results of the modified model indicate a good fit for CFI >.90, TLI >.90, GFI >.90, and RMSEA < 0.08, while the fit index AGFI resulted in an acceptable fit (i.e., > 0.80). Additionally, the relative chi-square value falls under the recommended range of <5.0 (refer to *Table 5*).

**Table 6: Goodness of fit of the common usability metrics**

| Fit Indices | Results | Remarks |
|---|---|---|
| CMIN/DF ($\chi^2$ /df) | 2.663 | Good fit |
| GFI | .904 | Good fit |
| AGFI | .871 | Acceptable fit |
| TLI | .924 | Good fit |
| CFI | .937 | Good fit |
| RMSEA | .067 | Good fit |

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### *CFA for Specific eHealth Usability Metrics*

This model was tested three times. The first round of testing included five constructs: collaboration (combining all eight items) (COLLABO), benefit (BENEFIT), information quality (INFOQUAL), technical quality (TECHQUAL), and guide support and feedback (GUIDE). The purpose of this first round of model testing was to test whether the items for evaluating collaboration could be combined, as they all deal with collaboration. In this first test, we assumed that the construct error correction, which had been removed from the common metrics model, would not fit in specific eHealth usability metrics, so it was also excluded. The result of the model fit was poor for some fit indices (as presented in *Table 7* in the round 1 test column). This means that the collaboration construct cannot combine items for evaluating internal collaboration with items for evaluating external collaboration. Therefore, they should be separated into two constructs: the internal and the external collaboration.

Round 2 test: In this round, the construct collaboration was divided into two constructs to make a new model with six constructs, including internal collaboration (INTCOL), external collaboration (EXTCOL), perceived benefit (BENEFIT), information quality (INFOQUAL), technical quality (TECHQUAL), and guide support and feedback (GUIDE). The results for the model test were satisfactory since all model fit indices met acceptable fit, good fit, and excellent fit (refer to *Table 7*, column round 2 test). This confirmed that the items for evaluating internal collaboration cannot work together with those for evaluating external collaboration in one construct.

Round 3: In this round, this research introduced construct error correction, which was eliminated from the common metrics model to see if it could be combined with the specific eHealth usability metrics. Therefore, the model in this round included seven constructs (i.e., all the constructs in round 2 plus the error correction). The results were almost similar to the round2 test model and more excellent; thus, they were satisfactory, as the values for all model fit indices ranged from acceptable fit to excellent fit (refer to *Table 7*, column round3 test). These findings suggest that the construct error correction fits into specific eHealth usability metrics better than common usability metrics.

**Table 7: Goodness of fit of the Specific eHealth Usability Metrics**

| Item | Round1Test | Round2Test | Round3Test | Remarks |
|---|---|---|---|---|
| $\chi^2$/df | 3.205 | 1.821 | 1.815 | Recommended |
| CFI | 0.830 | 0.938 | 0.927 | Good fit |
| TLI | 0.809 | 0.929 | 0.918 | Good fit |
| GFI | 0.804 | 0.893 | 0.863 | Acceptable fit |
| AGFI | 0.764 | 0.869 | 0.839 | Acceptable fit |
| RMSEA | 0.77 | 0.057 | 0.047 | Excellent fit |

This research argues that, although error correction is a common metric for evaluating any system, product, or service, it showed a greater impact on the usability of eHealth systems than other common metrics; hence, it was vitally similar to a specific metric for eHealth systems. This could be due to the sensitivity of medical data, where incorrect data could have a significant negative impact on the patient. The literature supports the fact that eHealth systems that cannot prevent errors can lead to severe consequences, such as jeopardizing the patients' information or prescribing the wrong medication or treatment, which then costs patient safety or even life (PEW Charitable Trusts, 2019; Mathews & Marc, 2017; Aljaber et al., 2015; Nabovati et al., 2014). As a result, this study identifies error correction as a specific metric for assessing the usability of an eHealth system.

Based on the results obtained in this test, all fit indices satisfactorily fit the model. Even though not all indices performed excellently, the obtained results are acceptable for the fitness of the model.

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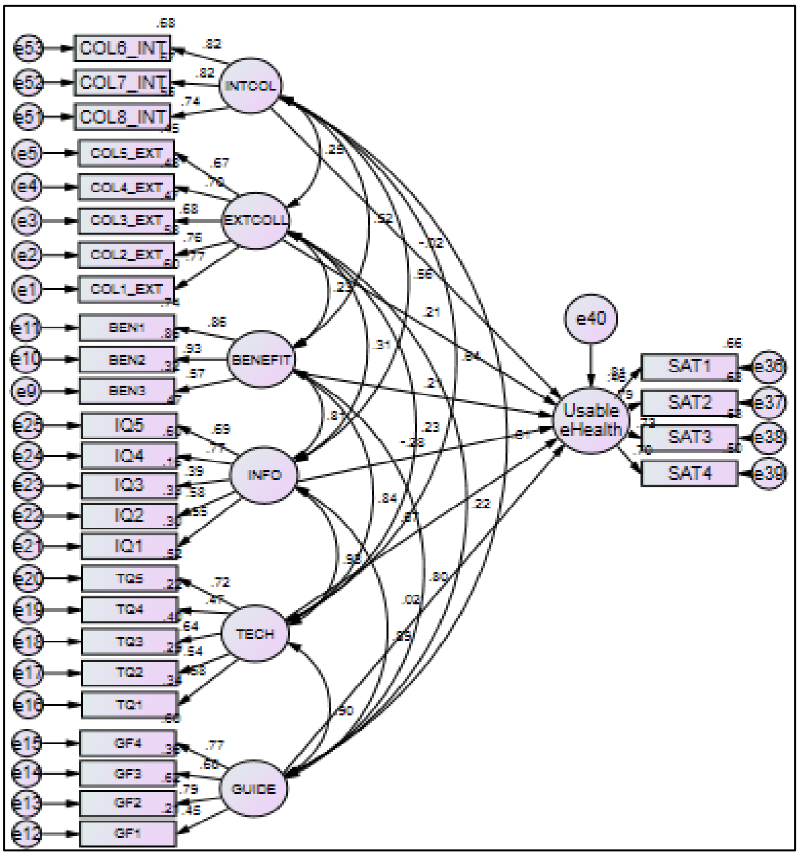
Therefore, there was no need for further modification. Additionally, the construct error correction was found to correlate with the constructs under the category of the specific metrics. This makes the specific eHealth usability model include seven constructs with 32 items for testing the specific usability issues of the eHealth systems, as illustrated in *Figure 2*.

**Figure 2: Specific usability metrics for eHealth systems**



From the quantitative analysis, the final metrics and items (i.e., common and specific metrics) tested for model fit were 11 with 47 items.

### *Contextual Issues in the Usability Evaluation of eHealth Systems*

The contextual issues were embraced into five constructs, including user characteristics (USERCHAR), goals and tasks (GOALS), resources and technology (RESTECH), physical environment (PHYSENV), and technical environment (TECHENV). The initial model was tested for its goodness of fit. The results show that the constructs do not fit in the model, as the fit indices are not good (not acceptable) or are fairly good (acceptable). Thus, the goodness of fit for each index was CMIN/DF = 4.138 (acceptable), GFI =.836 (acceptable), AGFI =.792 (not acceptable), TLI =.795 (not acceptable), CFI =.823 (acceptable), and RMSEA =.092 (acceptable). To increase the level of goodness of the model fit, Awang (2012) and Awang et al. (2015) recommended that all items with a lower factor loading of <0.6 be eliminated from the model in order to yield robust estimates of the model fit. This study examined the factor loadings for all items and revealed five items whose factor loadings were below the thresholds, as follows: TE6 (0.112), TE7 (0.214), and TE2 (0.222) from the construct technical environment (TECHENV). Other items with low factor loadings are UC5 (0.510), UC4 (0.529) from user characteristics, and GT1 (0.574) from goals and tasks.

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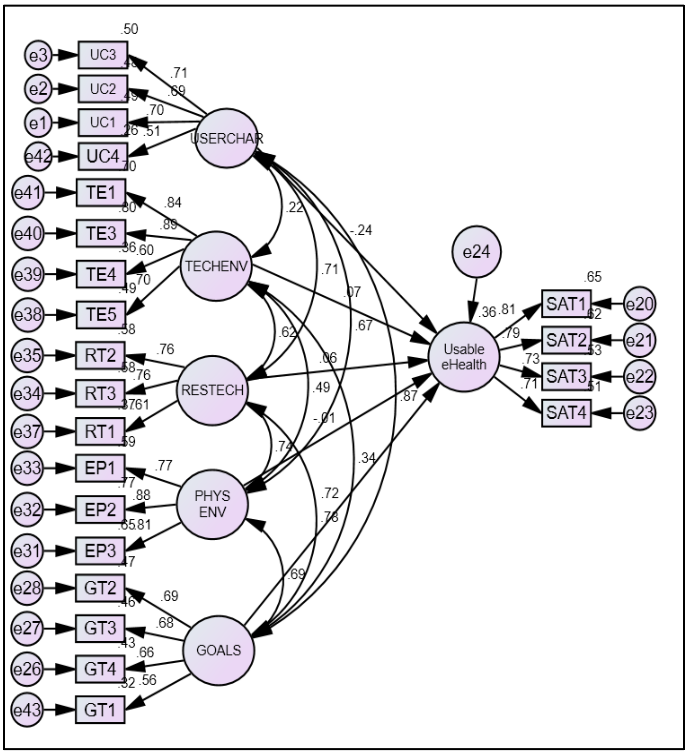
**Figure 3: CFA for contextual issues**



The results of the modified model are illustrated in Figure 3, and the summary of the scores for each fit index is presented in *Table 8*. The results revealed that all fit indices met the recommended values for the model fit. Thus, all goodness of fit indices scored satisfactory values, such as CMIN/DF = 2.823, GFI =.909, AGFI =.874, TLI =.908, CFI =.926, and RMSEA =.0.070. Since the model scored a good level of goodness of fit for almost all indices, as presented in *Table* 8, this study found no need for further modification of the model.

**Table 8: Goodness of fit of the Context issue**

| Indices | Results | Remarks |
|---|---|---|
| Chi-square ($X^2$) | 386.817 | |
| Degree of Freedom (DF) | 137 | |
| $X^2$/DF | 2.823 | Recommended |
| GFI | 0.909 | Good fit |
| AGFI | 0.874 | Acceptable fit |
| TLI | 0.908 | Good fit |
| CFI | 0.926 | Good fit |
| RMSEA | 0.070 | Good fit |

**Findings from Qualitative Data**

This study also conducted an interview to support the quantitative findings. The analysis of qualitative data resulted in six themes, including language used in the system, capability of internal collaboration, ability to give feedback, factors affecting usability, incidents caused by the poor usability of a system, and important issues to maximize usability. Based on the experience and best practices of eHealth system users, the qualitative findings in this research discovered seven issues that were not exposed through quantitative findings. Thus, these issues were considered as new items that could be necessary for evaluating the usability of eHealth systems. These items, as shown in *Table 9 (and plugged in Appendix 1, highlighted with green)*, were sorted and plugged into the existing constructs of the metrics that were validated in quantitative analysis. The addition of 7 items from qualitative

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analysis increased the total number of items for evaluating the usability of eHealth systems to 54. *Table 9* presents the new items from qualitative (qual.) data corresponding to the usability metrics established in quantitative (quant.) data.

**Table 9: Metrics items added from qualitative findings**

| Items from Qual. | Corresponding metrics |
|---|---|
| Ability to maintain data after sending it to another department | Information Quality |
| Ability to eliminate the investigation test for patients who left before treatment | Information Quality |
| Simplifying data entry exercises | Perceived Ease of Use |
| The ability of the OPD doctor to access the IPD patients' information | Accessibility |
| The ability of a lab technologist to communicate pending investigation results to the doctor (e.g., bacteria culture test) | Internal Collaboration |
| The ability of the system to allow collaboration between nurse/midwife and lab technologist when necessary to rescue emergency cases | Internal collaboration |
| The ability of the lab technologist to advise the doctor on the newly discovered disease as a result of the investigation | Internal collaboration |

## CONCLUSION

This study highlighted the usability metrics and context issues that are applicable in evaluating the usability of eHealth systems. The analysis of the findings revealed that the majority of the items (questions) were authenticated for evaluating the usability of the eHealth systems. However, some items of the various constructs scored lower factor loadings, and as a result, they were eliminated from the model, hence not applicable in evaluating the usability of the eHealth systems in Tanzania. Thus, 11 usability metrics constructs with 54 (i.e., 47 from quantitative and seven from qualitative findings) items and 5 contextual issues with 18 items were validated for their applicability in the usability evaluation of eHealth systems in Tanzania.

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## APPENDIX

**Appendix 1: The construct validity of the usability metrics (Factor loadings, CR and AVE)**

| Variable | Items | | Factor Loadings | CR | AVE |
|---|---|---|---|---|---|
| Navigation | NAV1 | Ability to "go back" to the previous screen | 0.75 | 0.88 | 0.55 |
| | NAV2 | Easy to go to the next screen | 0.76 | | |
| | NAV3 | Ability to predict the following procedure | 0.72 | | |
| | NAV4 | The consistency of the system's layout from screen to screen. | 0.73 | | |
| | NAV5 | No need to stop and think about which icon to click | 0.74 | | |
| | NAV6 | Correct icon or link to navigate to correct task | 0.73 | | |
| Perceived Ease of Use | PEOU3 | The system is ease to learn | 0.86 | 0.92 | 0.66 |
| | PEOU4 | It is ease to remember the process in the system | 0.89 | | |
| | PEOU5 | Ease to cope with the system skillfully | 0.86 | | |
| | PEOU7 | Simplifying data entry exercise | | | |
| Visibility | V1 | The interface of an eHealth is attractive | 0.82 | 0.86 | 0.67 |
| | V2 | The fonts (style, colour) are easy to read in on-screen | 0.78 | | |
| | V3 | eHealth system supports the diverse users to accomplish tasks | 0.86 | | |
| Accessibility | ACC1 | Ability to serve patients easily while entering data in the system | 0.77 | 0.80 | 0.57 |
| | ACC2 | The ability to use system without taking away an attention on the patient | 0.70 | | |
| | ACC3 | The ability to use system without taking away an attention on the patient | 0.79 | | |
| | ACC4 | The ability of the OPD doctor to access the IPD patients' information | | | |
| Error Correction | EC1 | Reminders, alerts, and warnings to avoid errors | 0.74 | 0.93 | 0.75 |
| | EC2 | Ability to cancel the process prior to completion | 0.98 | | |
| | EC3 | Default values to select and check for validity | 0.82 | | |
| | EC4 | Ability to undo action to avoid errors | 0.87 | | |
| | EC5 | Popup message to understand what is going on | 0.76 | | |
| | EC6 | Ability to avoids duplicate tests and examinations | 0.70 | | |
| | EC7 | Recover easily from errors and mistakes | 0.71 | | |
| External Collaboration | COL1_EXT | The eHealth system allows the government authorities to access the statistical data influence its usability | 0.77 | 0.87 | 0.58 |
| | COL2_EXT | The system allows the interaction with other health facilities | 0.81 | | |
| | COL3_EXT | The information on medications ordered in other organizations | 0.72 | | |
| | COL4_EXT | I can obtain patients' information from another health facility quickly | 0.77 | | |
| | COL5_EXT | The system support co-operation and communication between doctors working in different health facilities | 0.73 | | |
| Internal Collaboration | COL6_INT | The system support co-operation and communication between healthcare multi-professionals | 0.80 | 0.86 | 0.68 |
| | COL7_INT | I can work together with other members (other health professionals) from other departments through eHealth system | 0.87 | | |

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| Variable | Items | | Factor Loadings | CR | AVE |
|---|---|---|---|---|---|
| | COL8_INT | The work of one user does not interrupts the work of another user in the system | 0.79 | | |
| | COL9_INT | Ability of lab technologist to communicate pending investigation results to the doctor (e.g., bacteria culture test) | | | |
| | COL10_INT | The ability of the system to allow collaboration between nurse/midwife and lab technologist when necessary to rescue emergency cases | | | |
| | COL11_INT | The ability of the lab technologist to advise the doctor on the newly discovered disease as a result of the investigation | | | |
| Perceived Benefits | BEN1 | The systems help to improve quality of care | 0.80 | 0.80 | 0.58 |
| | BEN2 | The system helps to ensure continuity of care | 0.84 | | |
| | BEN3 | The system provides information about the need for and effectiveness of treatment of the patients | 0.63 | | |
| Technical Quality | TQ1 | The system is stable in terms of technical functionality (does not crash, no downtime) | 0.82 | 0.85 | 0.54 |
| | TQ2 | The system has never caused serious adverse event to the patients' safety/health | 0.74 | | |
| | TQ3 | The system responds quickly to inputs | 0.70 | | |
| | TQ4 | Information entered/documented never disappears from the system | 0.70 | | |
| | TQ5 | There is a quick help whenever the problem occurs | 0.73 | | |
| Information Quality | IQ1 | The laboratory and diagnostic imaging results are easily available and logically presented | 0.72 | 0.84 | 0.52 |
| | IQ2 | The patient's medication list is presented in a clear format | 0.74 | | |
| | IQ3 | eHealth system generates a summary view that helps to develop an overall picture of the patients' health status | 0.70 | | |
| | IQ4 | Terminologies on the screen are clear, understandable (e.g., titles and labels) | 0.75 | | |
| | IQ5 | Patients' data are comprehensive, up-to-date and reliable | 0.71 | | |
| | IQ6 | Ability to maintain data after sending to other department | | | |
| | IQ7 | Ability to eliminate investigation test for patients who left before treatment | | | |
| Guide and Support | GF1 | The system provides sufficient information about the patients' progress. | 0.74 | 0.82 | 0.54 |
| | GF2 | The system provides enough information, and instructions, that help to accomplish tasks accurately | 0.77 | | |
| | GF3 | The system monitors and notifies when the orders given to nurses have been completed | 0.64 | | |
| | GF4 | The system clearly informs about what it does (e.g., saving data, message delivery, data updated etc.) | 0.77 | | |
| | | **Contextual issues** | | | |
| User Characteristics | UC1 | The contribution of the previous experience on the current system's usability | 0.73 | 0.86 | 0.55 |
| | UC2 | The contribution of trainings on the usability of eHealth system | 0.73 | | |
| | UC3 | The contribution of the knowledge of computer on using eHealth system | 0.80 | | |
| | UC4 | Training on how to use eHealth system | 0.72 | | |
| | UC5 | Assurance of security and privacy | 0.72 | | |
| Goals and Tasks | GT1 | Ability to perform all healthcare tasks using the eHealth system | 0.70 | 0.80 | 0.50 |
| | GT2 | Routine tasks are performed in a straight forward manner without the need for extra steps | 0.74 | | |
| | GT3 | The tasks are well organized in the system to allow smooth recording and retrieving information. | 0.72 | | |
| | GT4 | Ability to perform healthcare tasks easily compare to manual system | 0.71 | | |

 

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| Variable | Items | | Factor Loadings | CR | AVE |
|---|---|---|---|---|---|
| Resources and Technologies | RT1 | The quality of the hardware and software is good enough to influence the usability of an eHealth system | 0.82 | 0.83 | 0.62 |
| | RT2 | The information is relevant and well understood (use of common language to the user) | 0.75 | | |
| | RT3 | There is a system-support-personnel to solve the problem with the system | 0.79 | | |
| Physical Environment | EP1 | The office has enough space to work with the computer system | 0.76 | 0.85 | 0.65 |
| | EP2 | The working environment is safe to protect the users' physically, legally, confidentiality, and property | 0.85 | | |
| | EP3 | There is enough space, safety and comfortable for working with the system | 0.80 | | |
| Technical Environment | TE1 | The health facility has enough computers | 0.88 | 0.92 | 0.73 |
| | TE2 | No waiting time for the previous user to accomplish the task before the next user | 0.75 | | |
| | TE3 | The speed of the computers available is good enough to accomplish the tasks quickly. | 0.88 | | |
| | TE4 | There is no high frequent of internet outage (internet problem) | 0.81 | | |
| | TE5 | The eHealth system allows working offline (without internet) | 0.86 | | |
| | TE6 | There is no high frequency of electricity power outage | 0.70 | | |
| | TE7 | The electricity power outage and internet outage affect the usability of the eHealth system | 0.64 | | |
| USABLE eHealth | EU1 | Success: The success rate is high (user can perform all tasks successful and meet the goal) | 0.83 | 0.87 | 0.64 |
| | EU2 | Time: Time used to perform tasks is minimal (a user manages to complete tasks timely) | 0.84 | | |
| | EU3 | Error: Error rate is minimized and tolerable (i.e., there is no significant error that can cause damage) | 0.73 | | |
| | EU4 | Satisfaction: The user is satisfied (feel comfortable, confident, and productive) and motivated to use the system | 0.78 | | |

 

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**Appendix 2: Discriminant validity using the Fronell-Lacker criterion**

| CONSTRUCT | NAVIG | VISIB | ACCESS | PEOU | ERROR | TECHQUAL | INFOQUAL | BENEFIT | GUIDE | INTCOL | EXTCOL | USERCHAR | TECHENV | RESTECH | PHYSENV | GOALS | eHealth |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NAVIG | 0.742 | | | | | | | | | | | | | | | | |
| VISIB | .671** | 0.818 | | | | | | | | | | | | | | | |
| ACCESS | .599** | .628** | 0.754 | | | | | | | | | | | | | | |
| PEOU | .443** | .504** | .424** | 0.812 | | | | | | | | | | | | | |
| ERROR | .540** | .478** | .430** | .286** | 0.866 | | | | | | | | | | | | |
| TECHQUAL | .600** | .633** | .591** | .340** | .528** | 0.734 | | | | | | | | | | | |
| INFOQUAL | .588** | .643** | .548** | .364** | .464** | .642** | 0.721 | | | | | | | | | | |
| BENEFIT | .666** | .699** | .592** | .458** | .453** | .671** | .658** | 0.762 | | | | | | | | | |
| GUIDE | .626** | .665** | .537** | .383** | .424** | .639** | .670** | .663** | 0.735 | | | | | | | | |
| INTCOL | .392** | .436** | .437** | .144** | .334** | .492** | .442** | .417** | .470** | 0.825 | | | | | | | |
| EXTCOL | .158** | .139** | .144** | 0.041 | .178** | .179** | .256** | .177** | .194** | .221** | 0.762 | | | | | | |
| USERCHAR | .465** | .494** | .436** | .401** | .322** | .464** | .424** | .489** | .469** | .531** | .125* | 0.742 | | | | | |
| TECHENV | .103* | 0.040 | 0.077 | -0.020 | .110* | .187** | 0.096 | 0.025 | .180** | .356** | .240** | .176** | 0.854 | | | | |
| RESTECH | .472** | .459** | .367** | .210** | .315** | .438** | .437** | .412** | .471** | .471** | .293** | .446** | .568** | 0.787 | | | |
| PHYSENV | .357** | .391** | .339** | .176** | .271** | .440** | .344** | .345** | .418** | .583** | .184** | .551** | .436** | .582** | 0.806 | | |
| GOALS | .439** | .506** | .408** | .309** | .420** | .593** | .480** | .526** | .540** | .537** | .189** | .637** | .235** | .507** | .553** | 0.707 | |
| eHealth | .465** | .462** | .429** | .223** | .438** | .560** | .516** | .570** | .488** | .394** | .272** | .364** | .250** | .431** | .374** | .517** | 0.800 |