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# A Model for Assessing Sustainability of mHealth Systems in Developing Countries: A Case Study of Kenya Health Sector

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**Abstract:** Numerous efforts have been mooted in the attempt to exploit the potential in mHealth towards addressing and tackling the growing global disease burden. A survey of literature indicates that a significant number of mHealth projects in developing countries fail the sustainability test, a measure that evaluates the ability of a solution to continuously meet the primary objective. This study sought to develop a model for evaluating the sustainability of mHealth systems. By adopting the exploratory research design; proposed parameters for evaluating sustainability of mHealth system are identified through review of various categories of literatures: evaluation models, mHealth sustainability evaluation models, mHealth experiences in developing countries. Using these factors, a conceptual model is formulated and statistically validated using Partial Least Squares, a component of Structural Equation Modeling (PLS-SEM) found in the SmartPLS software. The outcome of the study revealed that sustainability of mHealth systems in developing countries is influenced by nine factors; *Management Factors - Ownership*, *Technological Factors – System Quality, System Interoperability, Technology Sustainability, System Relevance, System Scalability* and *Individual Factors – User Support, System Access and User satisfaction.* The nine factors explained 58.2% of the variance in the sustainability of mHealth system. Ownership, User support, Technology Sustainability and User Satisfaction had the stronger influence on Sustainability of mHealth. The factors explained 13.25%, 11.09%, 8.7% and 7.01% of the variance respectively. Management factor (ownership) was found to have the greatest influence on sustainability of mHealth in developing countries. An evaluation score matrix is also proposed.

**Keywords:** *mHealth, Evaluation, Sustainability, Model, PLS-SEM*

## 1. INTRODUCTION

### 1.1 Background – mHealth Overview

The growing global disease burden continues to presents a challenge to realizing sustainable development [1, 2]. The negative effects of the disease burden can be felt on the economy, quality of life, longevity, and productivity. The continued attempts in tackle the disease challenge consume considerable amount of resources that would have otherwise been channeled to address other pressing developmental challenges. Numerous strategies and approaches aimed at addressing the disease burden have been documented. Whereas there have been gains from some of these efforts, the disease burden continues to grow.

Information and communication technologies in healthcare are viewed as tools with potential that could be explored to aid in tackling the global disease burden to enhance healthcare; efficiency, effectiveness and equity in the provision of healthcare [5, 6]. The exponential growth in the adoption of mobile telephony technology particularly in the developing countries presents an opportunity to extend the healthcare services to the disadvantaged, especially those in the remote regions. [3, 4].

There has been a significant growth in attempts to harness the potential provided by the mobile phones towards enhancing healthcare provision [4, 7, 8, 9]. These attempts have been made in the areas that include; monitoring and detecting to enable early reporting of disease outbreak[10], promoting healthy lifestyle through health related promotional messages, a key strategy in the preventive approach to dealing with the disease burden [1], enhancing adherence to medication and treatments regimes through SMS based reminders[11, 12], tracking of medicines distribution and deliveries as well as verifying the authenticity of the delivered consignment[13], sharing information and consultations between healthcare practitioners; nurses in remote locations can share information on a medical case they are handling and receive an expert opinion [14], Community Health Workers who are not medically trained to carry out disease diagnosis have been empowered through mobile phone based applications that enhance their ability to diagnosis and recommend treatment for less complex case, especially in areas with inadequate qualified medical personnel[15].

Although the potential of mHealth towards improving healthcare cannot be doubted, a significant number of implemented solutions and projects in developing countries have failed or been abandoned after a few months or years of utilization and this is despite the promising outcome demonstrated by some of the successful mHealth projects and the numerous pilot projects. When summed up, the issues raised point to *sustainability* challenges for the mHealth solutions. Failed mHealth projects are costly in terms of resources and time.

### 1.2 Sustainability challenges of mHealth Systems/Solutions in Developing countries

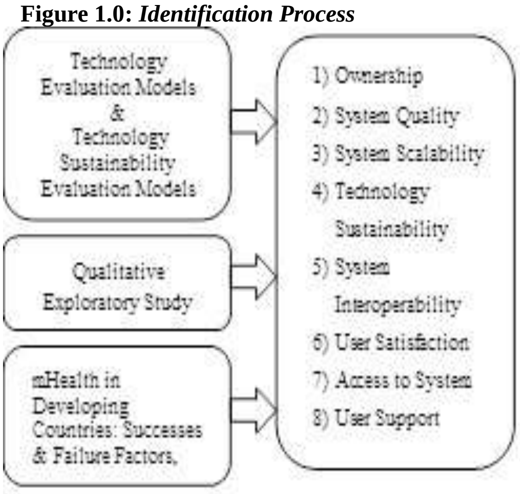
Despite the rapid acceptance and adoption of mobile telephony technology, its geographical coverage has tended to favor urban and near urban areas and thus excludes a significant portion of the population who are far from the communication grid or network connectivity coverage, hence exclusion of this population from mHealth solutions. Access to mobile telephony technology has been found to be a challenge for some part of the population in the developing countries [16, 17]. In some cases, a single mobile phone is available in the family and handled by the head of the family, who in almost all cases is normally the man. In such case, text messages targeting the woman; regarding maternal health, child issues or clinical appointments may not be received or are received much later[18]. Some of the mHealth projects are designed in developed in the western world and deployed in the developing countries without considering the social-technical realities and relevance to developing countries [19, 20]. Where the donor initiates the project and the hosting entity does not make effort to provide a continuity plan; the project is viewed as the agenda of the donor or funding agency and hence no transition plans are made to ensure continuity when the donor exits the scene. In some cases, the host organization does not have surplus resources to sustain the continued utilization of the solution. The design of some mHealth solutions are such that they do not allow for scaling to accommodate future growth requirements.

## 2. METHODOLOGY

The study was informed and motivated by the numerous reports of failed or abandoned mHealth projects across developing countries. The aim of the study was to establish the key parameters and scoring attributes that need to be evaluated in order to ascertain that a given mHealth solution is sustainable hence the need to develop and validate a model for evaluating the sustainability of mHealth solutions in the developing country context.

- The **first step** involved identifying factors that influence sustainability of mHealth systems or solutions in developing countries. To accomplish this, three (**Figure 1.0**) activities were carried out; reviewed literature on mHealth projects in developing countries was carried out. This review covered key areas of utilization of mHealth solutions and extended to cover some of the successful or failed mHealth projects. The review focused on attempting to establish factors or reasons that are attributed to the success or failure of these projects. Secondly, a qualitative exploratory study was also carried out to establish the sustainability challenges experienced by the mHealth stakeholders in developing countries, using Kenya health sector as a case. The stakeholders included users, technical and administrative managers, mHealth Systems administrators, mHealth support staff, designers and developers of mHealth systems. This also included ministry of health officials working in the area of mHealth. The exploratory study findings were analyzed in order to determine the major emerging theme areas, which were further synthesized and condensed into factors. The final activity of identifying additional factors involved review of technology sustainability evaluation models and technology evaluation models [21, 22, 23, 24, 25, 26].

**Figure 1.0: *Identification Process***




- In the **second step**, the factors identified from the three activities were analyzed to generate the final list of proposed factors that were hypothesized to significantly influence sustainability of mHealth applications and systems.

- The **third step** involved the formulation of the proposed study conceptual model and hypothesizing of causal relationships between independent and dependent variables.

- The **fourth step** involved design, development and validation of data collection instruments. The selection and development of the instruments was largely guided by the proposed study conceptual model. The study was designed as a cross sectional-survey and the data collected using tested questionnaires (*n =216*), interview (*n=23*) and focused group discussion (*n=14*).

- The **fifth step** involved analysis of the data, statistical, stakeholder and expert validation of the proposed study model and proposal of scoring elements for various factors. Analysis was done in two steps; first, the respondent's characteristics was established and then the model's causal relationships were validated using Partial Least Squares (PLS), a component of Structured Equation Modelling (SEM) found in the SmartPLS software. In the statistical validation, the adopted the two steps; dividing (Figure 2.0) the model into Measurement and Structural model components [27].

- The **Final step** focused on using the coefficient of determination to create scoring scales and matrix

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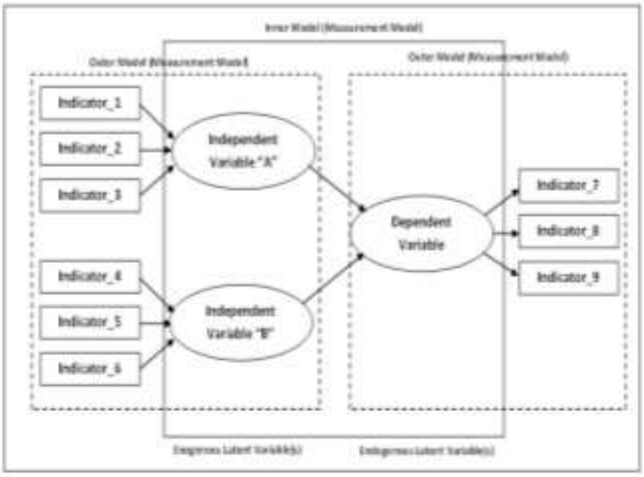
**Figure 2.0** *SEM -Inner and Outer Model Diagram*




(***Source***: *Hair et al., 2011*)

The first steps was assessing measurement model where *Content Validity, model Reliability* and *variable validity* were confirmed. The structural model analysis focused ono establishing the *collinearity* between the constructs in the model by examining the *tolerance* and *Variance Inflation Factor* (VIF) components, analyzing the significance and relevance of the structural model relationships (*Path Coefficients β*), analyzing the variance in the dependent variable through *coefficient of determination ($R^2$)* a value that indicates the proportion of variance in the dependent variable attributed to or that can be explained by a particular independent variable, the *Effect size*, denoted as $f^2$, which measures the impact of each individual independent variable on the dependent variables and the *Predictive relevance* $Q^2$; a statistical quantity the estimate the predictive strength/validity of a proposed model. Further, the model was subjected to three groups of experts; mHealth stakeholders in Kenyan, experts with experience in information system evaluation and mHealth experts with at least 7 years of experience in the design, implementation, management and maintenance of mHealth solutions.

# 3. RESULTS AND DISCUSSION

## 3.1 Respondents Characteristics

The respondents were categorized into two main groups; administration and users. In the administration group, there were a total of 32 female respondents, which accounted for 14.82% of the total respondents while the males were 51 in total, and this accounted for 23.6% of the total number of respondents of the study. The total number of respondents in categorized as belonging to the administration group were 83 as shown in table 1

**Table 1.0**

| Gender | Designation | Number | Percentage |
|---|---|---|---|
| Male | Developers | 17 | **23.6%** |
| | Administrators | 9 | |
| | Managers | 7 | |
| | Owners | 4 | |
| | Technical Support | 14 | |
| | **Sub-Total (Male)** | **51** | |
| Female | Developers | 13 | **14.82%** |
| | Administrators | 3 | |
| | Managers | 5 | |
| | Owners | 2 | |
| | Technical Support | 9 | |
| | **Sub-Total (Female)** | **32** | |
| | **Total** | **83** | **38.42%** |

The distribution of respondents in the users group is shown in Table 2. The males were 36, which represented 16.60% of the total number of respondents in the study. The females on the other hand were 97, representing 44.98% of the total number of respondents.

**Table 2.0**

| Gender | Category | Number | Percentage |
|---|---|---|---|
| Male | Patient | 26 | **16.60%** |
| | Practitioner | 10 | |
| | **Sub-Total (Male)** | **36** | |
| Female | Patient | 86 | **44.98%** |
| | Practitioner | 11 | |
| | **Sub-Total (Female)** | **97** | |
| **Total** | | **133** | **61.58%** |

## 3.2 Proposed Sustainability Evaluation Factors

The factors used to develop the conceptual model were generated from three activities; *literature covering Technology Evaluation Models, Technology Sustainability Evaluation Models, literature on best practices for implanting mHealth systems, an exploratory study on sustainability issues in developing countries,* using Kenya as a case study as well as literature on design, implementation and sustenance challenges of mHealth systems in developing countries.

## 3.3 Categories of Variables identified and working definitions

The factors covered three broad categories: human factors, technology factors and Management Factors as shown in table 3.

**Table 3.0**

| **Category** | **Variable** | **Definition** |
|---|---|---|
| **Individual Factors** | Systems Access **(SA)** | Easy of obtaining, reach, access to a technology |
| | User Satisfaction **(US)** | A measure of the user's response to the system use and focuses on evaluating the level user's satisfaction with the functions available in the system and the perceived user enjoyment in using the system |
| | User Support **(SS)** | A measure of overall level of support by the technical support personnel, evaluated by the attributes; quick responsiveness, assurance and follow up service. |
| **Technology Factors** | System Scalability **(SC)** | The property of a technology to expand and manage an increasing workload |
| | System Relevance **(SR)** | Appropriate mapping of technology features and functions to the task at hand |

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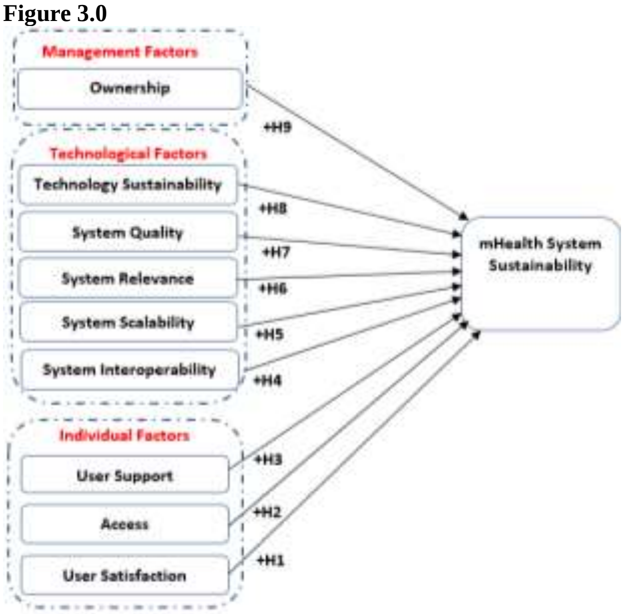
| | | |
|---|---|---|
| | System Quality (**SQ**) | A measure of the inherent features of a system that include ease of use, ease of learning, response time, usefulness, availability, reliability, completeness, system flexibility, and security |
| | Technology Sustainability (**TS**) | The property of a technology to be current and remain productive indefinitely |
| | System Interoperability (**IO**) | Ability of different technologies to interface, communicate and exchange data |
| **Management Factors** | Ownership (**OW**) | Right of possessing, managing, controlling and directing the use something |
| **Sustainability (*Dependent Variable*)** | mHealth Sustainability (SU) | mHealth systems development that meets the needs of the present without compromising the ability of future generations to meet their own needs |

## 3.4 Proposed Conceptual Model with hypothesized relationships

The design of the model involved hypothesizing the causal relationship between the identified factors –*independent variables* and sustainability – *dependent variable*, as shown in figure 3.0

**Figure 3.0**




## 3.5 Model Validation

**Statistical model validation was done in two steps:**

***a) Measurement Model Validation***

The validation of the measurement model component focused on establishing confirming the relationship between the indicators (*measure statements for the variables*) and the independent variables of the model. Here, are the elements were examined (Table 4.0):

i. Evaluation of *Internal Consistency* of the constructs – done through computation of Cronbach Alpha where a value of 0.7 and above is acceptable.

ii. Evaluation of Model Reliability – achieved by assessing two components:
  - *Construct Reliability* – Cronbach Alpha Coefficient equal to or greater than 0.7 and a composite reliability value of 0.5 and above are acceptable
  - *Indicator Reliability* – composite reliability value of 0.5 and above are acceptable

iii. Evaluation of Construct Validity – achieved by assessing:
  - *Convergent Validity* – Average Variance Extracted values of 0.5 and above acceptable.
  - *Discriminant Validity* – outcome of computed cross loading values of 0.5 and above acceptable

**Table 4.0**

| Latent Variable | Indicators | Loadings | Indicators Reliability | Composite Reliability | Cronbach's Alpha | AVE (Average Variance Extracted) |
|---|---|---|---|---|---|---|
| **User Satisfaction (US)** | US1 | 0.753 | 0.767 | 0.862 | 0.836 | 0.900 |
| | US2 | 0.779 | 0.807 | | | |
| | US3 | 0.771 | 0.794 | | | |
| **System Access(SA)** | SA1 | 0.864 | 0.928 | 0.934 | 0.845 | 0.798 |
| | SA2 | 0.853 | 0.846 | | | |
| | SA3 | 0.798 | 0.821 | | | |
| **User Support** (SS) | SS1 | 0.783 | 0.823 | 0.893 | 0.799 | 0.762 |
| | SS2 | 0.761 | 0.698 | | | |
| | SS3 | 0.803 | 0.852 | | | |
| **System Quality (SQ)** | SQ1 | 0.783 | 0.766 | 0.833 | 0.832 | 0.827 |
| | SQ2 | 0.831 | 0.823 | | | |
| | SQ3 | 0.877 | 0.901 | | | |
| **System Relevance (SR)** | SR1 | 0.744 | 0.701 | 0.836 | 0.780 | 0.831 |
| | SR2 | 0.859 | 0.838 | | | |
| | SR3 | 0.802 | 0.798 | | | |
| **System Scalability** | SC1 | 0.778 | 0.760 | 0.801 | 0.829 | 0.774 |
| | SC2 | 0.842 | 0.827 | | | |
| | SC3 | 0.866 | 0.834 | | | |
| **Technology Sustainability (TS)** | TS1 | 0.762 | 0.738 | 0.884 | 0.744 | 0.711 |
| | TS2 | 0.817 | 0.693 | | | |
| | TS3 | 0.811 | 0.811 | | | |
| **Ownership** | OW1 | 0.836 | 0.942 | 0.909 | 0.828 | 0.786 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | OW2 | 0.743 | 0.752 | | | |
| | OW3 | 0.815 | 0.864 | | | |
| **System Interoperability (IO)** | IO1 | 0.773 | 0.746 | 0.825 | 0.817 | 0.801 |
| | IO2 | 0.821 | 0.843 | | | |
| | IO3 | 0.807 | 0.831 | | | |
| **Sustainability (SU)** | SU1 | 0.713 | 0.708 | 0.914 | 0.819 | 0.906 |
| | SU2 | 0.759 | 0.776 | | | |
| | SU3 | 0.858 | 0.933 | | | |

**Note**: The measurement model met the validity and reliability requirements

## *b) The structural Model Validation*

Analysis and validation of the structural component of the model focused on confirming the nature of relationship between the model's independent variables and the dependent variable. This was accomplished through PLS-SEM.

### i. Collinearity between Independent Variables

Establishing collinearity between variables is achieved by computing two key values; the tolerance, which has a threshold of 2.0 and Variance Inflation Factor (VIF), with a threshold of 5. For distinct variables tolerance values should be greater than 2.0 since low values have been found to have a profound negative impact on the outcomes of multiple regression analysis [27, 28], while the corresponding VIF values should be less than 5 because higher values negatively impact on the outcomes of the multiple regression analysis. The outcome of the analysis of the collinearity of the model variables is shown in table 5. The results confirmed that the variables were distinct.

**Table 5.0**

| Construct Pairs | Collinearity Statistics | |
|---|---|---|
| | Tolerance | VIF |
| Ownership (OW) | 0.432 | 1.633 |
| Technology Sustainability (TS) | 0.331 | 1.025 |
| System Quality (SQ) | 0.542 | 2.341 |
| System Relevance (SR) | 0.412 | 1.883 |
| System Scalability (SC) | 0.632 | 1.708 |
| System Interoperability (IO) | 0.434 | 1.333 |
| User Support (SS) | 0.526 | 1.625 |
| System Access (SA) | 0.421 | 1.825 |
| User Satisfaction (US) | 0.341 | 1.823 |

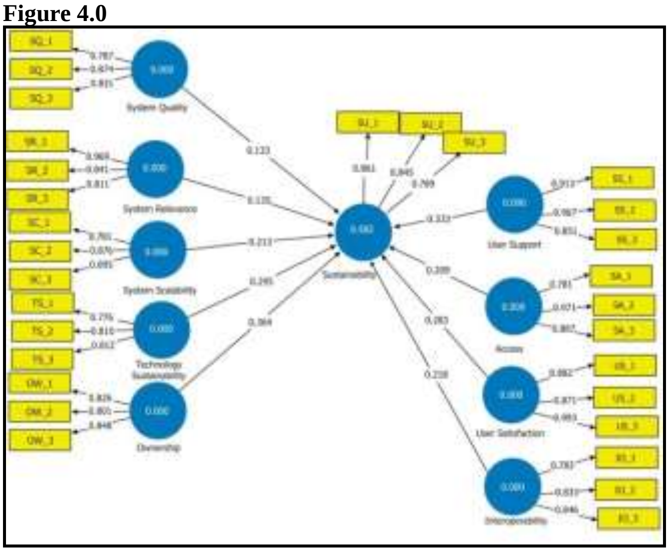
### ii. Path Coefficients (β)

The outcome of the computation of the path coefficient and the t-statistics to determine the strength and significance of the causal relationships between the independent and dependent variables are shown in figure 4.0 and table 6. The path coefficient values reveal the *strength*, *significance* and *direction* of the causal relations between the independent and the dependent variables. Generally, a path with a coefficient of 0.1 or higher is an indication of the existence of a significant causal relationship between the variables. A higher path coefficient value implies that the independent variable associated with such a path has greater influencing effect on the dependent variable. The outcome shows that the causal relationships were all found to be significant but at different levels of significance. The causal relationships OW>>SU, SS>>SU, SA>>SU and SR>>SU were found to hold at significance levels of 1%. US>>SU and SC>>SU were found to hold at 2% and 5% significances respectively. TS>> SU and SQ>>SU were both found to hold at significance levels of 10%

**Table 6.0**

| Causal Relationship | Path Coefficients | Critical Values | Significance Level | Hypothesis |
|---|---|---|---|---|
| **US -> SU** | 0.283 | 2.3011 | 2% | H1 |
| **SA -> SU** | 0.209 | 2.0187 | 5% | H2 |
| **US -> SU** | 0.333 | 2.7694 | 1 % | H3 |
| **IO -> SU** | 0.218 | 1.7392 | 10% | H4 |
| **SC -> SU** | 0.213 | 1.9741 | 5% | H5 |
| **SR -> SU** | 0.135 | 2.6321 | 1% | H6 |
| **SQ -> SU** | 0.133 | 1.9783 | 5% | H7 |
| **TS -> SU** | 0.295 | 2.2462 | 5% | H8 |
| **OW -> SU** | 0.364 | 2.6014 | 1% | H9 |

**Figure 4.0**



### iii. Coefficient of determination ($R^2$)

The path analysis diagram shown in figure 7.0, shows that the $R^2$ (R-squared), the coefficient of determination for the dependent variable Sustainability was 0.582. This therefore means that the 9 exogenous variables; *Ownership, User Satisfaction, User Support, System Access, System Scalability, Technology Sustainability, System Relevance, System Interoperability* and *System Quality* explained 58.2% of the variance in the endogenous variable - *Sustainability*.
Decomposing of the variance and attributing to individual variables, shown in table 7 reveals that the *Ownership* had the highest influence on the sustainability, accounting for the 13.25% of the variance. Furthermore, *Ownership, user support, Technology Sustainability* and *User Satisfaction* constructs accounted for 41.1% of the variance.

**Table 7.0**

| Pathway Considered | Quantity | Variance | Percentage % |
|---|---|---|---|
| OW -> SU > OW | 0.364 * 0.364 | 0.1325 | **13.25** |
| SS -> SU -> SS | 0.333 * 0.333 | 0.1109 | **11.09%** |
| TS -> SU -> TS | 0.295 * 0.295 | 0.0870 | **8.70** |
| US -> SU -> US | 0.283 * 0.283 | 0.0801 | **8.01** |
| IO -> SU -> IO | 0.218 * 0.218 | 0.0475 | **4.75** |
| SC -> SU -> SC | 0.213 * 0.213 | 0.0437 | **4.37** |
| SA-> SU -> SA | 0.209 * 0.209 | 0.0437 | **4.37** |
| SR -> SU -> SR | 0.135 * 0.135 | 0.0182 | **1.82** |
| SQ -> SU -> SQ | 0.133 * 0.133 | 0.0176 | **1.76** |

### iv. Effect size ($f^2$)

Effect size was computed to measure the impact of individual independent variable on the dependent variable, and determine the changes that occur in the dependent variable – *sustainability* coefficient of determination $R^2$, when a specified independent variable is omitted from the model.
The magnitude of $f^2$ was computed using the following formula [29];

$$f^2 = \frac{R^2_{\text{included}} - R^2_{\text{excluded}}}{1 - R^2_{\text{included}}}$$

The outcome of the computation of Effect size ($f^2$) is shown in table 8, against the respective causal relationship and hypothesis. The outcome shows that the most significant factors were user satisfaction and ownership.

**Table 8.0**

| Causal Relationship | Effect of Size | Hypothesis | Effect Size (Magnitude) |
|---|---|---|---|
| US -> SU | 0.165 | H1 | Medium |
| SA -> SU | 0.058 | H2 | Small |
| SS -> SU | 0.091 | H3 | Small |
| IO -> SU | 0.116 | H4 | Small |
| SC -> SU | 0.061 | H5 | Small |
| SR -> SU | 0.026 | H6 | Small |
| SQ -> SU | 0.026 | H7 | Small |
| TS -> SU | 0.106 | H8 | Small |
| OW-> SU | 0.183 | H9 | Medium |

**Table 9.0**
Conceptual Model Hypothesis Analysis

| Hypothesis | Causal Relationship | (β) | Significance (T-Statistics) | Remark |
|---|---|---|---|---|
| H1* | US > SU | 0.283 | 2.3011 | *Supported* |
| H2 | SA > SU | 0.209 | 2.0187 | *Supported* |
| H4 | IO > SU | 0.218 | 1.7392 | *Supported* |
| H5 | SC > SU | 0.213 | 1.9023 | *Supported* |
| H6 | SR > SU | 0.135 | 2.6321 | *Supported* |
| H7 | SQ > SU | 0.133 | 1.9783 | *Supported* |
| H8 | TS > SU | 0.295 | 2.2462 | *Supported* |
| H9 | OW > SU | 0.364 | 2.6014 | *Supported* |

***Note: The** Critical T-values (T-Statistic) thresholds: **2.576** for a significance level of 1%, **2.326** for a significance of 2%, **1.960** for a significance level of 5% are **1.645** for a significance level of 10% and **1.282** for a significance level of 20%*

### v. Predictive relevance Q2

Predictive relevance $Q^2$ of the model was computed using the Cross Validated Redundancy technique in PLS [30], to gauge the predictive strength/validity of a proposed model.

$$Q^2 = 1 - \frac{\sum_D E_D}{\sum_D O_D}$$

*Where*
E = the sum of squares of prediction error
O = the sum of squares error using the mean for prediction
D = Omission distance

This technique defines a threshold of Q2 > 0.5. The computation of the predictive relevance for this model yielded a value of 0.603, which is above the defined threshold of $Q^2 > 0.5$, which confirmed the predictive validity of the model.

**Stakeholder and Expert Validation**

The model was subjected to expert in the field of information system as well as those in the field of mHealth system. The requirement for the expert to participate in evaluating the suitability of the model was that they needed to have had experience of not less seven years in the area of evaluating systems; viability and sustainability. The outcome of the expert opinion is shown in table 10. In summary, the experts endorsed the model.

**Table 10.0**

| Expert Model Validation Interviews Outcome | | | | |
|---|---|---|---|---|
| Stakeholder | Overall Rating on Suitability of the Evaluation Model | | | |
| | Suitable | Neutral | Not Suitable | Overall Comments |
| mHealth Domain | 11 | 0 | 0 | Model is well suited for evaluating the sustainability of mHealth solutions but the significance of each of the factors on sustainability of a particular mHealth system may differ slightly across populations in developing countries dependent on prevailing social economic and political factors and environment |
| Information System Evaluation & auditing - Domain | 6 | 0 | 0 | |
| **Total (10)** | **17** | **0** | **0** | |

## c) *Stakeholder (mHealth) Validation*

The model was also subjected to the stakeholders who included experienced users, managers, administrators, funding agencies and developers. The outcome is shown in table 11.0 The results indicate that 88.89% of the stakeholders were convinced that the model represented the key factors that need to be evaluated when there is a need to establish the sustainability of mHealth systems in the developing countries context.

**Table 11.0**

| Stakeholders Model Validation Interviews Outcome | | | | |
|---|---|---|---|---|
| Stakeholder | Overall Rating on Suitability of the Evaluation Model | | | |
| | Suitable | Neutral | Not Suitable | Overall Comments |
| mHealth Users (**5**) | 4 | 1 | 0 | Fundamental factors that may significantly influence or |
| Systems Administrators (**4**) | 4 | 0 | 0 | |

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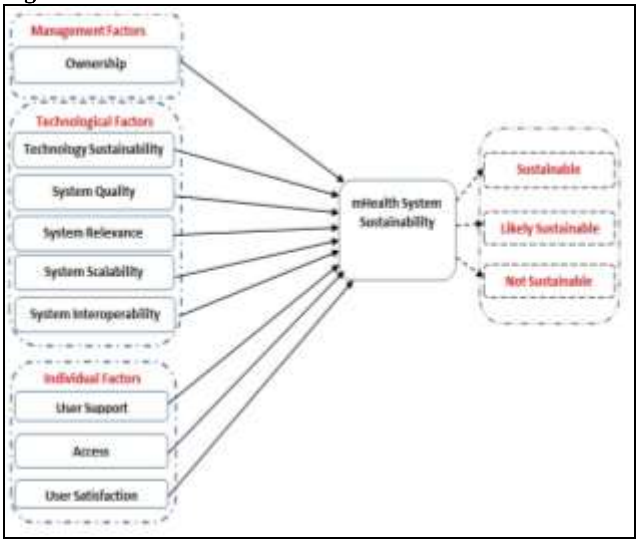
| | | | | |
|---|---|---|---|---|
| Organization Managers (**3**) | 3 | 0 | 0 | impact on the sustainability of mHealth solution in developing countries have been captured |
| mHealth System Developers (**5**) | 5 | 0 | 0 | |
| Funding/Donor Agencies (**3**) | 2 | 1 | 0 | |
| **Total (20)** | **18** | **2** | **0** | |

## 3.6 Final Sustainability Evaluation Model

The final evaluation model shows three categories of factors are critical in determining the sustainability of mHealth systems in the developing country context; management factors, Technology factors and Individual factors (Figure 5.0).

**Figure 5.0**




## 3.7 Model Calibration

In the evaluation of mHealth system based on the validated model, three outcomes are possible; the system may be found Sustainable, Likely sustainable or not sustainable. Through multiple statistical combinations of all possible scenarios, logical reasoning and consultation of experts based on factors validated in the model, a score for the three possible outcome options was developed (Table 11.0).

**Table 11.0**

| **Outcome Option** | **Score Range (Points)** |
|---|---|
| Not Sustainable | < 50 points |
| Likely Sustainable | 50 >= **x** < 80 points |
| Sustainable | Above 80 Points |

## 3.8 Proposed Weightage Contribution of the various factors

The calibration of the model and the allocation of weightage was guided by the outcome of computing the Coefficient of Determination ($R^2$) for individual factors. Using the total Variance of 0.582 as a base, the individual variance was converted to a percentage out of 100% and the percentage converted to point.

**Table 11.0**

| **Factors** | **Decomposed Variance** | **Percentage contribution by the Factor** | **Allocated Points** |
|---|---|---|---|
| Ownership | 0.1325 | 23% | 23 |
| User Support | 0.1109 | 19% | 19 |
| User Satisfaction | 0.0801 | 15% | 15 |
| Technology Sustainability | 0.0870 | 13% | 13 |
| Interoperability | 0.0475 | 8% | 8 |
| System Scalability | 0.0437 | 8% | 8 |
| System Access | 0.0437 | 8% | 8 |
| System Relevance | 0.0182 | 3% | 3 |
| System Quality | 0.0176 | 3% | 3 |
| Total | **0.582** | **100%** | **100** |

## 3.9 Proposed Evaluation Scoring Attributes & Values

| **Factor** | **Coefficient of Determination ($R^2$)** | **Weight out of 100%** | **Assigned Points** | **Elements to be Assessed** | **maximum score for the element** | **Verdict Options** | **Range of Score for the element** |
|---|---|---|---|---|---|---|---|
| Ownership | **0.1325** | **23%** | **23** | Stability & Sufficiency of Financial Resources in the long term | 8 points | Sufficient | 8 |
| | | | | | | Somewhat | 3 - 7 |
| | | | | | | Not Sufficient | 0 - 2 |
| | | | | Governance and Management Structure | 8 points | Clearly defined | 8 |
| | | | | | | Need Improvement | 3 - 7 |
| | | | | | | Not Defined | 0 - 2 |
| | | | | Clear Overall strategy, plan and vision | 7 Points | Clear plan available | 7 |
| | | | | | | Guidelines available but not clear long-term plan | 1 - 6 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | No plan | 0 |
| User Support | **0.1109** | **19%** | **19** | Adequate support personnel | 10 Points | Adequate | 10 |
| | | | | | | Somewhat adequate | 3 - 9 |
| | | | | | | Not Adequate | 0 - 2 |
| | | | | Clear & comprehensive User support plan available | 9 points | Clear plan available | 9 |
| | | | | | | Somewhat ava | 1 - 8 |
| | | | | | | No plan | 0 |
| User Satisfaction | **0.0801** | **15%** | **15** | Degree of user Satisfaction with the mHealth system | 15 Points | Satisfied | 13 - 15 |
| | | | | | | Somewhat satisfied | 5 - 12 |
| | | | | | | Not Satisfied | 0 - 4 |
| Technology Sustainabilit y | **0.0870** | **13%** | **13** | Measures to guarantee sustainability of the technology | 13 points | Sufficient Measures | 13 |
| | | | | | | Measures not adequate | 1 - 12 |
| | | | | | | No Measures in place | 0 |
| Interoperabil ity | **0.0475** | **8%** | **8** | Adequacy of design to guarantee interoperability | 8 points | Adequate Features | 8 |
| | | | | | | Need improvement | 1 - 7 |
| | | | | | | No features | 0 |
| System Scalability | **0.0437** | **8%** | **8** | Inbuilt capabilities to guarantee system to Scale | 8 Points | Fully scalable | 8 |
| | | | | | | Require improvement to scale | 1 - 7 |
| | | | | | | Not scalable | 0 |
| System Access | **0.0437** | **8%** | **8** | Appropriate system Access Devices available | 2 Points | Available | 2 |
| | | | | | | Have some challenges | 1 |
| | | | | | | Not available | 0 |
| | | | | Recharging Devices available | 2 Points | Chargers available | 2 |
| | | | | | | Have some challenges | 1 |
| | | | | | | Not Available | 0 |
| System Access | **0.0437** | **8%** | **8** | Adequacy of Airtime Charge available | 2 Points | Adequate | 2 |
| | | | | | | Available but has challenges | 1 |
| | | | | | | No Available | 0 |
| | | | | State of Network Connectivity | 2 Points | Good | 2 |
| | | | | | | Fairly good but has challenges | 1 |
| | | | | | | Significant challenge | 0 |
| System Relevance | **0.0182** | **3%** | **3** | System functional features relevant to the tests and needs | 3 Points | Relevant | 3 |
| | | | | | | Somewhat relevant | 1.5 |
| | | | | | | Not relevant | 0 |
| System Quality | **0.0176** | **3%** | **3** | Accuracy | 1 Point | Accurate | 1 |
| | | | | | | Somewhat Accurate | 0.5 |
| | | | | | | Not Accurate | 0 |
| | | | | Stability and reliability | 1 Point | Stable & Reliable | 1 |
| | | | | | | Somewhat stable and reliable | 0.5 |
| | | | | | | Not Stable or reliable | 0 |
| | | | | Security of the system | 1 point | Secure | 1 |
| | | | | | | Somewhat secure | 0.5 |
| | | | | | | Not Secure | 0 |

## 4. CONCLUSION & RECOMMENDATIONS

Sustainability of mHealth system is critical if the system is to realize the original objects. In the developing country context, Access to the system, effective user support and a high degree of user satisfaction are the individual factors that need to be addressed in order to ensure sustainability. In addition, technology issues that must be addressed include the relevance of the system to the tasks at hand, the quality of the system, which addresses the issues of reliability accuracy of the system outcome and timeliness, the interoperability of the system – a component that focuses on ensuring that the mHealth system can interface and communicate with existing system must be considered. Other technology issues that are critical to sustainability include the ability of the mHealth system to scale include the ability as well as the sustainability of the technology. On the management side, the owners of system must play the critical role of providing a sustainable financial plan, human resources to support users and a continuity plan in cases where the mHealth system in donor initiated.

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