A Systematic Mapping of ICT4D Adoption Research in Developing Countries

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Abstract. While the use of theories and models in Information and Communication Technology for Development (ICT4D) is important and has been studied, the scope of these theories has not been sufficiently researched. With the aid of systematic mapping, this study provides an overview of the research on ICT4D adoption in developing countries to determine the research gaps and trends in the theories used. The study presents research published in ICT4D journals between 2015 and 2019. The results indicate that the understanding of the conceptualisation of the constructs of the theories used in ICT4D research remains sparse. In addition, the statistical techniques (Regression, Partial Least Squares Structural Equation Modeling, amongst others) used to assess the constructs in the selected studies may need more scrutiny. The study recommends that further studies be conducted using other qualitative methods of inquiry to identify any gaps that could have been missed.

Keywords: Theory · Model · Information and communication technology for development · ICT4D · Adoption · Developing countries

1 Introduction

Recently, there has been an increase in the systematic mapping of theories and models used in Information and Communication Technology for Development (ICT4D) research [1–3]. In many instances, ICT4D journals demand that researchers provide a theoretical background for their work. This has compelled ICT4D researchers to embark on research that provides theoretical contributions. However, the literature still points to a lack of in-depth understanding and learning of the change, transformation and impacts in ICT4D research [3] due to, amongst other reasons, the lack of theory building. Theory helps in gaining an in-depth understanding of the issues at hand and provides a solid foundation for further inquiry [4]. It is, therefore, important to investigate the theories and models related to ICT4D studies. While previous studies have attempted to explore ICT4D research using the Activity Theory [3], studies on the systematic mapping [5] of the theoretical foundations of ICT4D research [6] are scant.

This study aimed at presenting a systematic mapping of theories and models used in ICT4D research in developing countries. It was anticipated that the study would provide a better understanding and contextualisation of the theories and models used in ICT4D

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research in these countries. In doing so it will possibly provide a basis for information and communication technology (ICT) to achieve its development goals as suggested by Sein, Hatakka, and Sæbø [6]. The authors argued that technology needs to be designed to operate in a complex social, political, economic and cultural context. Hence, it is important to understand the theories and models used in designing and implementing such technology.

Mapping studies remain sparse in the ICT4D literature and few studies have been conducted in developing countries. For instance, Zewge and Dittrich [5] conducted a systematic mapping of information technology in developing countries while Kante and Ndayizigamiye [7] investigated the adoption of the Internet of Things in healthcare services. These studies have some gaps which need to be dealt with for a better understanding of ICT4D adoption in developing countries. Firstly, the two studies did not look at the conceptualisation of the variables used to study the adoption. According to Müller-Bloch and Kranz [8], this is a knowledge void which needs to be addressed. Secondly, the mapping studies did not reveal the statistical techniques used in analysing the data and this could be a methodological gap to be dealt with. Finally, the growing literature needs to be further mapped to determine if the recommendations and suggestions of the previous mapping studies have been given due consideration.

A theoretical lens is a basis for "the description, explanation, and prediction of the phenomena it relates to – that is, offer an understanding of the what, how, and why behind the scenes" [9]. The phenomena in this study were technology and development. The understanding, in turn, will help policymakers, researchers, development practitioners and other development stakeholders appreciate the underlying conceptual structures that ultimately enable purposeful and meaningful actions [9].

In this study, developing countries are referred to as low-income, lower-middle-income and upper-middle-income economies as defined by the World Bank [10]. Heeks [11] reported ICT4D as the use of technology "to help deliver on the international development agenda" and that agenda, according to the scholar, comprises the Sustainable Development Goals (SDGs). Thus, in this study, any paper that used ICT linked to any of the SDGs was of interest.

This paper covers research published in ICT4D journals between 2015 and 2019. It is part of an ongoing study and data covering the period of January 2020 to May 2022 are currently being gathered. Furthermore, other criteria such as digital development, among others, are being incorporated to retrieve more studies.

2 Search Procedures and Strategies

Systematic mapping or scoping studies are designed to provide an overview of a research area by classifying and counting the contributions of the categories within each classification. Hence, they can provide an overview of the theories and models used in ICT4D research in developing countries by classifying and counting contributions. Doing so results in structuring the ICT4D research with regard to theories and models (as suggested by Petersen, Vakkalanka and Kuzniarz [12]) thereby providing the basis for ICT to be contextualised and deliver its intended objective of development.

Systematic mapping involves searching the literature to get acquainted with topics that have been covered in a specific research area and to ascertain where the literature has been published [12, 13]. This study followed the guidelines for conducting a systematic mapping as stated by the World Bank [10] and Petersen, Vakkalanka and Kuzniarz [12]. According to these guidelines, systematic mapping is conducted in three phases: a) scoping of the systematic mapping, b) study identification and selection, and c) data extraction and analysis. Each of the phases is described below and the results of the mapping are reported in the "Results and Discussion" section.

2.1 Scoping of the Systematic Mapping

The specific research questions (RQs) of this systematic mapping were:

RQ 1. What are the current models and theories used in ICT4D adoption studies in developing countries?
RQ 2. What are the statistical techniques used to measure technology adoption?

As noted above, this systematic mapping reviewed ICT4D literature published between 2015 and 2019 in a developing country context. The following keywords were generated from the research questions and used as search terms: Theory OR Model OR Adoption OR Use OR Acceptance.

A theory, in general, is a system of constructs (or concepts or variables) and the interrelationships among them that jointly explain the constituent elements of a phenomenon and show how and/or why it occurs [9]. Sometimes a researcher may combine different constructs from various theories and test them in a data-driven study. Such combinations in the field of information systems can be considered models. "Adoption" is the decision of a user (for example, a farmer or a health practitioner) to start using an ICT-based service [14] and, in most cases, studies looking at adoption use adoption and "acceptance" interchangeably to specify that decision. The term "use" of an ICT-based service refers to its continuous use [15], which comes after adoption/acceptance.

2.2 Study Identification and Selection

Three main activities were done during this stage: a) deciding on the search strategies to be followed, b) developing and evaluating the search, and c) applying the inclusion and exclusion criteria.

Search Strategies Followed
A dual search strategy (snowball and a manual search) was developed in relevant ICT4D journals and conferences [5, 12]. Evidence has shown that a manual search can be more effective in identifying relevant studies than an automated one [12]. A snowball search has also been identified as an appropriate search strategy [12] for systematic mapping.

Developing and Evaluating the Search
The manual search to select appropriate journals was based on the ranking of ICT4D journals as defined in the study by Heeks [16] and used in a mapping study by Zewge

and Dittrich [5]. Based on the manual search, the three highest-ranked journals, namely, the Electronic Journal of Information Systems in Developing Countries (EJISDC), the Information Technologies and International Development (ITID) Journal, and the Information Technology for Development (ITD) Journal were targeted. Any paper published in these journals was presumed to be related to ICT4D. In addition, other relevant papers were selected based on the snowball strategy. In snowballing, the reference list and citations of relevant papers are reviewed to identify new papers whereas, in a database search, different databases are searched using predefined search strings to identify new papers [17]. Table 1 displays an overview of the journals and conferences selected in the study.

Table 1. Publications by selected journals/conferences

Acronym	Journal/Conference name	Search strategy	Ranking source	Total number of publications	Total number of selected papers
ITID	*Information Technologies and International Development Journal*	Manual	Richard Heeks (2010)	15	1
EJISDC	*Electronic Journal of Information Systems in Developing Countries*		Richard Heeks (2010)	130	10
ITD	*Information Technology for Development Journal*		Richard Heeks (2010)	20	0
Other	*African Journal of Information Systems (AJIS)*	Snowball		66	6
	Information Processing in Agriculture			1	1
	AIS Transactions on Replication Research			29	1
	Journal of the Midwest Association for Information Systems			22	0
	AMCIS 2016			1	

(*continued*)

Table 1. (*continued*)

Acronym	Journal/Conference name	Search strategy	Ranking source	Total number of publications	Total number of selected papers
	MWAIS 2018			1	
	Education Research International			1	0
	African Journal of Hospitality, Tourism and Leisure			1	0
	International Journal of Business and Management			1	0
	Journal of Management Research			1	0
	European Journals of Business Management			1	0
				290	19

As noted above, the search was performed in each of the journals using the key terms Theory OR Model OR Adoption OR Use OR Acceptance and the date range 2015 - 2019. Papers containing the search terms were downloaded from the three journals and conferences regardless of their relevance to developing countries or ICT4D. It should be noted that only papers available for downloading (open access) were selected for further analysis. Exclusion and inclusion criteria were then applied.

Inclusion and Exclusion of Papers

Any article that did not focus on a developing country was excluded from the review. The distinction between developed and developing countries was drawn from the World Bank [18]. Through a word search, any paper that focused on a developing country was tagged accordingly. As we (the authors) were only interested in papers that collected primary data and analysed data through quantitative methods, a second criterion was applied, that is, any paper with the term "review" in the title was removed from further analysis. Additionally, any paper with an abstract that did not contain the terms "survey" OR "quantitative" was also excluded. The inclusion and exclusion criteria are summarised in Table 2.

Table 2. Inclusion and exclusion criteria

Description	Inclusion	Exclusion
Research paper sources	Ranked [16] OR Identified through the snowball search strategy	Not ranked [16] OR Not identified through the snowball search strategy
Publication year	Published between 2015 and 2019	Published before 2015 and after 2019
Country of focus	Developing countries (lower-income and upper-income) as defined by the World Bank [18]	Developed countries as defined by the World Bank [18]
Words (Strings) in the title of the paper	Does not contain "Review OR Reviews"	Does contain "Review OR Reviews"
Words in the abstract	Quantitative OR Survey	Absence of Quantitative OR Survey

A systematic review of the selected papers was then performed. The Overview Quality Assessment Questionnaire (OQAQ) reported in the study by Lwoga and Sangeda [19] was modified to fit the quality assessment of theory according to Mueller and Urbach [9]. A paper was included for further analysis only if its OQAQ score was six or above (from a range of 0–10). The OQAQ was used to assign points to the paper according to various criteria. The questionnaire consisted of 15 questions divided between 1) definitions, 2) domains, 3) methodology and 4) overview, and the points were distributed amongst these categories. For instance, in the definition subsection of the OQAQ, there were three questions one of which was: "Were many theories stated and used by the study?" If the response was "Yes", the paper received two points and if the response was "No", the paper received zero points. The search strategy and selection process are depicted in Fig. 1.

Data Extraction and Analysis Process

To extract data from the identified primary studies, we developed a template as shown in Table 3. A variable (data extraction), named an "extraction variable, consisted of a data item and a value. The extraction was performed by the first author and reviewed by the second author as suggested by Badampudi, Wohlin and Petersen [17]. The extraction variables were purposefully defined to answer the research questions.

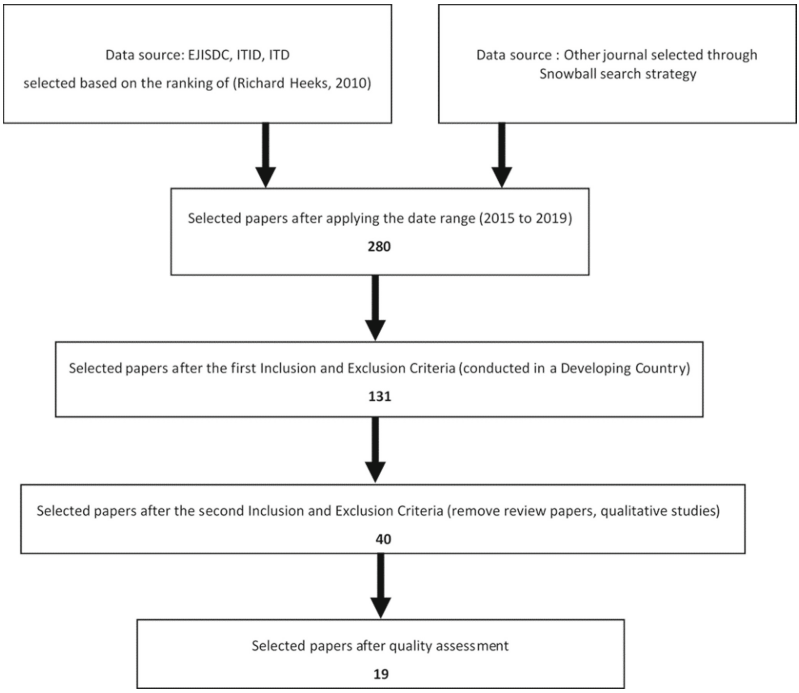

Fig. 1. Search strategy and selection process

Table 3. Data extraction form

Data item	Value	Research question
Article title	Name of the article	
Author name	Set of names of the authors	
Country	In which country has the study been done	
Field of study	What was the field of study	
Population	Whose adoption was studied	
Research questions	What were the research questions	
Main theory	What was the main theory/model of the study	RQ 1
Other theories	What other theories/models have been used	
Statistical technique	What was the statistical technique used	RQ 2

2.3 Tools Used in the Analysis Process

The selection process of the papers was managed using the open-source desktop-based application Mendeley – a database used to classify, tag and reference papers using various attributes. The application can be synchronised with the Cloud Vision API (it works with

a cloud library that is loaded into the add-in function, so there is no need to switch between applications when citing) as used and suggested in the study by Zewge and Dittrich [5]. After the selection and pre-processing phases, articles that were selected for further analysis were exported to a Microsoft Excel 2016 file. The extraction process from Mendeley to Microsoft was done using JabRef, an open-source bibliography reference manager.

3 Results and Discussion

This section reports and discusses the results. It starts by characterising the data in terms of publications per year and per country and the focus areas of the studies. The section then provides an overview of the theoretical lenses (RQ 1) and finally discusses the statistical techniques used to assess the adoption models of the selected studies (RQ 2).

3.1 Publication Per Year and Per Country

Fifty-nine percent of the selected papers were published in the *Electronic Journal of Information Systems in Developing Countries* (*EJISDC*), 5% in the *Information Technologies and International Development Journal* and 36% from other sources (*African Journal of Information Systems*, *Information Processing in Agriculture*, *AIS Transactions on Replication Research*, *Journal of the Midwest Association for Information Systems, AMCIS* 2016, *MWAIS* 2018, *Education Research International*, *African Journal of Hospitality, Tourism and Leisure*, *International Journal of Business and Management*, *Journal of Management Research*, and the *European Journal of Business Management*). Table 4 provides an overview of the publications per year and per country. It was found that there was at least one paper on ICT4D adoption each year from 2015 to 2019 in the *EJISDC*. However, in accordance with the literature [5], there is no consistency of publications related to ICT4D adoption in the selected journals over time.

Table 4. Publications per year

Journal	2015	2016	2017	2018	2019	Total
EJISDC	1	1	2	4	2	10
AJIS		1	2		4	6
ITID		1				1
Snowball				2		2
Total	1	3	4	6	6	19

Concerning the countries where the studies were conducted, the analysis revealed that Tanzania accounted for 18% of the total studies; South Africa and Nigeria accounted for 28% (14% each); while India, Ghana, Fiji, Uganda, Kenya, Burundi, Congo Brazzaville and Vietnam represented approximately 50% of the selected studies. One study could

not be linked to any country as it was an online survey. Over 86% of the studies were conducted in Africa. Thus, in the context of this study, most of the ICT4D adoption research is being conducted in Africa. This can be explained by the fact that Africa's ICT penetration is rising and, consequently, new technologies related to health, agriculture and governance, among others, are being implemented in African countries.

3.2 Focus Areas of the Studies

ICT4D is a multidisciplinary research area [20] that encompasses three study fields: computer science, information systems, and development studies [21]. As this research was concerned with adoption, only studies relevant to the adoption of information systems and, to an extent, development studies were considered. The studies were broken down according to their focus such as e-government, agriculture and others. Table 5 provides a breakdown of the studies according to their focus areas per country and year.

Table 5. Studies' focus area per country and per year

Focus area	2015	2016	2017	2018	2019	Total
Agriculture	No data	No data	1: [22] in Mali	1: [14] in Mali	2: [23] in Nigeria and [24] in Tanzania	4
E-government and e-governance	No data	1: [25] in India	No data	2: [26] in Nigeria and [27] in Ghana	1: [28] in Nigeria	4
Internet services	1: [29] in South Africa	No data	1: [30] online survey	1: [31] in Vietnam	1: [32] in Kenya	4
Education	No data	1: [33] in South Africa	1: [34] in Nigeria	No data	No data	2
Mobile money	No data	No data	1: [35] in Tanzania	1: [36] in Fiji	1: [37] in Uganda	3
Healthcare	No data	No data	1:[38] in Burundi	No data	No data	1
Tourism	No data	No data	No data	No data	1:[40]in Tanzania	1
Total	1	2	5	5	6	19

As shown in Table 5, the subfields of agriculture (including related studies), e-government (including related studies) and internet services (including related studies) were the main focus areas of ICT4D adoption research studies. The fact that many of the papers focused on agriculture is not surprising as agriculture represents the backbone

of the economies of developing countries [40, 41]. Similarly, studies investigating the adoption of e-government and e-governance by rural dwellers are not surprising as many people in developing countries (especially in Africa) live in rural areas and governments need to provide services to them [42]. On the other hand, studies related to internet services tended to look at internet coverage, internet skills and 3G adoption amongst others. These subfields have received much attention in the literature when compared to healthcare, tourism, social media and education. More studies are thus needed in developing countries on the adoption of e-health technologies and the adoption of technology in the tourism industry and education.

3.3 Theories Used and Theoretical Gaps

As pointed out earlier, a (scientific) theory can be defined as a set of variables (constructs) and relationships between these variables [9]. The main theories revealed by the dataset were:

1. The Technology Acceptance Model (TAM). Adapted from the Theory of Reasoned Action, the TAM is an information system theory that models how users come to accept technology and how they use that technology [43].
2. The Unified Theory of Acceptance and Use of Technology (UTAUT). Venkatesh, Thong and Xu [44] formulated a model that integrates and unifies the characteristics and elements of eight models and labelled it as UTAUT.
3. The Diffusion of Innovation Theory (DOI). Also referred to as Innovation Diffusion Theory (IDT) [45], it is one of the theories used in information systems to study the adoption or use of ICT services by users.
4. Technology-Organisation-Environment (TOE) Theory. This theory provides three key factors, namely, technological, organisational, and environmental [25] all of which are vital for implementing technological innovations.
5. The Theory of Planned Behavior (TPB). The TPB implies that individuals make decisions on the basis that they carefully consider all the information available [46].
6. The DIKDAR Model. This model proposes an information needs/mapping approach in which the lack of access to information exposes individuals and communities to vulnerabilities [47].

The following section discusses the theories used, how the constructs were formed and what the theoretical gaps are.

TAM

The results of the study revealed that the TAM was the most used theory. It was used in five studies (27%) as the main theory [23, 30, 31, 35, 36]. The approach of the studies using the TAM was inductive in that they were data-driven. In other words, they were, in the main, testing the theory and some had included constructs from other theories to form a conceptual framework and thus a model.

The TAM was used in the Tanzanian study by Lwoga and Lwoga [35] to investigate user acceptance of mobile payments. In addition to the TAM, the study borrowed constructs from the UTAUT and the DOI Theory/IDT. As in many studies that use the

TAM, the DOI Theory and the UTAUT, some gaps in the conceptualisation of certain constructs in the study were found. One such construct is "compatibility". As suggested by Heeks [11], compatibility should include an item on cost. Therefore, in the case of the study by Lwoga and Lwoga [35], the cost of withdrawing or depositing money, for example, should have been included as a compatibility variable. The authors of the study acknowledged that perceived cost should be included in future studies. Thus, the conceptualisation of the compatibility construct was problematic in the study.

The TAM was also used in the study by Silic, Barlow and Black [30] to evaluate the role of trust in the adoption of an open-source system. The authors added some empirical constructs to the model. These empirical constructs were "perceived reputation", "perceived opportunism", "perceived environmental risk", "perceived structural assurance", and "consumer trust" in mobile payment (M-payment) systems and internet banking. According to Müller-Bloch and Kranz [8], any empirical construct should be supported by a theoretical one which was not the case with the study by Silic, Barlow and Black [30]. This points to a methodological void as the above-mentioned constructs were not grounded in theory. While these "new" constructs did not have any reported theoretical basis, they were supported by the literature. The findings described here shed new light on the use of the TAM in adoption studies and would be relevant for future studies in addressing these highlighted gaps. One such gap could be the conceptualisation of constructs (both theoretical and empirical).

The third study using the TAM was that of Uduji, Okolo-Obasi and Asongu [23] who used the model to investigate the adoption of e-wallet amongst informal farm entrepreneurs in Nigeria. The conceptualisation of the constructs in the study was unclear as none of the constructs used could be linked to the TAM. This suggests that the validity of the study can be queried. Questions such as "Where did the study get the constructs?", "How were they formulated?" and "Were they tested before being used in the study?" need to have been asked and answered.

The TAM was employed in the study by Tapanainen, Dao and Nguyen [31] which investigated the adoption of 3G services in Vietnam. The authors extracted the constructs "intention to adopt" and "social influence" from the UTAUT and the constructs "IT self-efficacy" and "service quality" from the TPB. However, while some empirical factors were added to the study the theoretical evidence of these was not reported. This again poses the question of how the constructs were formed and thus the validity of the constructs.

In Fiji, the TAM was used to study the factors influencing the intention to use mobile value-added services by women-owned microenterprises [36]. Some constructs were borrowed from the UTAUT and TAM 2 (TAM 2 is an extension of TAM). These constructs were "social influence" and "intention to use". We were not able to find a gap in the way the constructs of this study were formed.

In summary, most of the studies using the TAM have gaps in the conceptualisation of the constructs of the theory. This may be attributed to these studies not conducting a pilot or pre-study to operationalise and better capture the intended question. Furthermore, one may link these gaps in the use of the TAM to the philosophical approach that these studies employed, namely, positivism. If they were to have used a pragmatist approach, they may have been forced to conduct a qualitative and quantitative study sequentially.

Doing so may have filled the gap in the conceptualisation of the construct. Furthermore, the TAM itself might be the source of the problem. Perhaps, that is why TAM has been extended to TAM 2 and TAM 3 and later incorporated into the UTAUT.

UTAUT and DOI

The DOI Theory was used in 16% of the selected papers as the main theory. The same applies to the UTAUT. The DOI Theory was used in the context of Mali [14] and Burundi [38]. The former entailed the adoption of ICT-based agricultural (input) information by farmers while the latter pertained to the adoption of mHealth in the country. Again, in the conceptualisation of the "compatibility" construct, the cost factor was not considered. The Mali studies included some constructs from the DIKDAR Model [47] and the Theory of Knowledge [48]. The lack of inclusion of the cost factor in the conceptualisation of the compatibility construct was also observed in the study of Ndayizigamiye and Maharaj [38] in Burundi.

Studies that used the UTAUT as the main theory were those of Chopra and Rajan [25], Malinga and Maiga [37] and Olaleye [28]. Chopra and Rajan [25] investigated the adoption of e-government technologies for food distribution in India. Although no theoretical gaps could be identified, the study did have some methodological gaps. For instance, the authors used the Average Variance Extracted (AVE) of PLS-SEM to measure discriminant validity instead of construct validity.

Malinga and Maiga [37] used the UTAUT to determine the factors that influence the adoption of mobile money by traders in Uganda. The study extended the UTAUT by adding two new factors brought from empirical studies that were not supported by any theory. As suggested by Mueller and Urbach [9], empirical constructs should be supported by theoretical ones.

The third study using the UTAUT was that of Olaleye [28] which investigated the determinants of electronic invoicing in Nigeria. It used "social influence" as well as the "image" as two distinct constructs. However, literature [15, 31, 49] suggests that the image construct from the DOI 2 Theory (an extension of the DOI Theory) is the same as the "social influence" construct of the UTAUT. Moreover, the author did not provide the items used to measure the image construct. Thus, one could not ascertain the face validity of the construct. The findings reported here shed new light on the use of the UTAUT and the DOI Theory in adoption studies and would be relevant for future studies in addressing these gaps.

Other Theories

Other theories that were used included the Institutional Theory in Nigeria [34] and Kenya [32]; the Theory of Reasoned Action in South Africa[33]; the TAM 2 in Tanzania [24]; the Green IT Adoption Model in Tanzania[39]; the Technology-Organisation-Environment (TOE) Framework in Nigeria [26] and South Africa [29]; the Process Virtual Theory [50] in Ghana; the Theory of Information Systems Improvisation [51] in Congo Brazzaville; and the United Nations Development Programme (UNDP) Framework in Tanzania[52]. The conceptualisation of the constructs is the most pertinent gap in the majority of these studies. For example, Ofoeda, Boateng, and Asmah [50] used three variables, that is, "ICT infrastructure", "internet access" and "communication" to measure the technological factors construct. However, ICT infrastructure could have been measured as a latent

variable instead of an observed variable. Another example of a gap comes from the study of Omotayo [34] in which it was hypothesised (page 12) that "there is a significant relationship between Normative Pressures [NPs] and attitude of teachers towards the use of e-learning." However, the author did not specify whether the relationship was positive or negative. Similarly, the same gap was observed in the study conducted by Oredo, Njihia and Iraki [32] in Kenya. Using the Institutional Theory, the authors hypothesised (page 138) that "there is a relationship between coercive pressures and cloud computing adoption by Financial, ICT and Manufacturing firms in Kenya." However, the study did not mention whether the relationship was significant, positive or negative.

A further theoretical gap comes from the study of Gareeb and Naicker [29]. This study used the TOE Framework as the main theory to determine the factors that influence the adoption of broadband internet technologies in South Africa. The study grouped distinct constructs, that is, "relative advantage", "perceived ease of use", "service quality", "availability", "compatibility" and "observability" under a single construct called "technology context". However, relative advantage, for example, is a construct on its own and is measured using many items (observable variables). Hence, as the study did not provide the items used to measure relative advantage, the face validity could not be assessed.

Regarding the qualitative/mixed studies [51, 53], no theories were identified as having been used. Rather, the studies gathered empirical factors from the literature and conducted interviews around these factors. The study of Momo and Twum-Darko [53] for instance, examined the "acceptance factors" of health information systems in the Congo-Brazzaville with 18 key informants. The authors could have matched their empirical factors with theoretical ones from the TAM or the UTAUT. This may be a gap as they could have grounded these factors in theory as recommended in the field of information systems research [6, 9].

3.4 Methodological Gaps

A methodological gap appears when new research methods are necessary to provide new insights or to avoid distorted findings [8]. In this study and following the framework suggested by Müller-Bloch and Kranz [8] on how to identify methodological gaps, we only assessed the statistical techniques that the selected studies used to generate their findings.

Approximately 45% of the selected studies used Structural Equation Modeling (SEM) (Partial Least Square (PLS) component) to assess relationships between variables. This is not surprising as the literature [54–56] reports that SEM (and mostly its PLS component) is the statistical technique most used in information systems research. SEM allows researchers to answer a set of interrelated research questions by modeling the relationships among many variables in a single, systematic, and comprehensive analysis [57]. The capability of PLS-SEM to simultaneously analyse a set of variables differs greatly from most first-generation regression models such as linear regression, LOGIT, ANOVA and MANOVA which can only analyse one layer of linkages between independent and dependent variables at a time [57, 58]. The use (and overuse) of PLS as a method to test one's hypotheses may have resulted in the publication of a large

number of studies the findings of which are invalid [59]. However, this contention has been countered in the study by Henseler et al. [60].

Another methodological gap emanated from the fact that most of the selected studies used either the Fornell-Larcker or the cross-loadings criteria to establish the discriminant validity of their constructs. While these criteria can be used, the literature [61, 62] suggests that the heterotrait-monotrait ratio (HTMT) better detects the existence or lack of discriminant validity than the other two criteria (Fornell-Larcker or the cross-loadings). Hence, this is a methodological gap as a second study with the same data may indeed find that the constructs' discriminant validity may not be established using the HTMT. Furthermore, some gaps in a composite variable were measured in a few studies. For example, the variable "green ebusiness adoption and use" was measured as a single latent variable in the study by Masele [39]. However, adoption and use are two variables that should not be measured as a single variable. Consequently, the R^2 (the measure of the extent of the variance of the dependent variable explained by the independent variables) generated from Masele's study may not reflect adoption and use at the same time but rather adoption or use. Hence, further analysis of the data generated through this study may lead to new insights.

The remaining studies used regression analysis [26, 33, 37]; principal component analysis[38]; multiple regression [27, 34]; the Bivariate Probit Model [23]; content analysis [51]; descriptive statistics [51, 52]; and ANOVA statistical tests [24, 53].

A methodological gap in the study by Omotayo [34] was identified. While the study presented some controlled variables (age, gender and income), a closer look at the model generated by the study revealed that these variables were independent ones having a direct effect on the dependent variable and thus were not controlling variables. A controlled (monitored or constant) variable is maintained in the model to observe if it has a minimal impact on the relationship between the independent variable and the dependent variable [63]. The controlled variable is not usually hypothesised, which was not the case in Omotayo's [34] study.

The findings reported here shed new light on the use of PLS-SEM and other statistical techniques in adoption studies and would be relevant for future studies addressing these gaps.

4 Conclusion

The purpose of this study was to identify the gaps in the theories and methodologies used in ICT4D adoption research in the context of developing countries. The study found that TAM was the most used theory (27%) in ICT4D adoption research, followed by the DOI Theory (16%), the UTAUT (16%) and lastly the Institutional Theory (11%). The remaining theories used were the TAM 2 (6%), the Green IT Adoption Model (6%), the TOE Framework (6%), the Process Virtual Theory (6%) [50], and the United Nations Development Programme (NDP) Framework (6%) [52]. The major theoretical gaps identified in this systematic mapping were related to the conceptualisation of the theories' constructs. The identified methodological gaps were related to the way variables were grouped and the type of statistical tests used to establish the discriminant validity. Overall, the results from this mapping study suggest that there is a need to undertake

more studies on the contextualisation and conceptualisation of the established theories such as the TAM, the DOI Theory and the UTAUT so that ICT4D adoption research can deliver its intended goal in the context of developing countries.

The authors acknowledge that the selection process may have left out papers that qualified to be analysed. In addition, some gaps could have been missed during the analysis process. It is, therefore, recommended that further studies using other qualitative or quantitative methods of inquiry be conducted to identify any gaps that could have been missed. Finally, as noted, this paper is part of an ongoing study and data from studies published from January 2020 to May 2022 are currently being analysed.

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