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# Broadband Assessment Index: A Framework and Composite Metric for Measuring Broadband in Developing Countries

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## ABSTRACT

This paper presents a framework, and a composite broadband metric, the Broadband Assessment Index (BAI) that scores the state of broadband of a developing country based on three sub -indices namely, broadband readiness (BR), broadband intensity (BI), and broadband adoption (BA), respectively across 13 constructs. The 13 constructs were found to significantly explain the variation of the sub-indices in studies earlier undertaken by the author. This is the first composite broadband assessment instrument across the three domains of the broadband eco-system, namely readiness, intensity and adoption specifically designed for use in developing countries. Currently, some of the available proxy benchmarks for the assessment of the state of broadband are the ITU's ICT development index (IDI), and the World Economic Forum's Networked Readiness Index (NRI) which globally rank countries on ICT development and Networked readiness respectively. Compared to the IDI, and the NRI frameworks, the BAI framework introduces additional constructs such as Age, Income, Digital literacy, and access to mobile broadband that are crucial for assessing the state of broadband in developing countries. Using real-world hard data from re-known international organisations including the International Telecommunication Union (ITU), the World Bank, the United Nations, and the World Economic Forum (WEF), the top ranked Sub-Saharan Africa countries in the 2011 ITU's IDI, and World Economic Forum's NRI rankings are evaluated using the BAI framework. The results appropriately validate the BAI framework, and show distinct advantages of the BAI framework over the IDI and NRI frameworks when applied to developing countries. This is due to the emphasis placed on "access to fixed broadband" by the former frameworks, and their failure to put more emphasis on mobile broadband access, digital literacy, age, income, and the individual as the unit of investigation. The BAI framework incorporates measures to correct for these anomalies. In addition to improving their international ICT performance rankings, the BAI framework recommends that developing countries identify BAI factors that best align with their short term and long term development strategies, such as the development of national broadband policies or strategies. The BAI computation algorithm can be easily automated, and the sub-index and construct weights varied to reflect the priorities of a particular decision modeler to suit a given country's special requirements. Furthermore, although designed with special focus on developing country characteristics, the BAI can be used in international broadband benchmarks with results that will relatively score developing countries higher up than with current international benchmarking frameworks. The paper[3] proceeds to outline the methodology of the BAI framework and index, it's evaluation and validation, comparison with the IDI and NRI frameworks, and finally outlines recommendations to stakeholders in the broadband eco-system.

**Keywords:** Broadband *Assessment Index, BAI, Broadband, Framework, Metric, Broadband Measurement, Developing countries.*

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## 1. INTRODUCTION

The recent tremendous growth in the information and communication technology (ICT) sector has brought alongside it the need for specific, timely and reliable metrics to support and inform users, industry, policy makers, and other stake holders in the sector [1].

Techniques for measuring ICT have evolved in roughly three stages beginning around the year 2000 [2]. Initial efforts such as those of the Center for International Development (CID) at Harvard, APEC's e-Commerce Readiness Assessment Guide (2002), and Mosaic Group's Framework for Assessing the Global Diffusion of the Internet (2001) focused on self assessment and policy development especially in the areas of e-readiness and internet penetration [2]. There was relatively inadequate comparative analyses of countries, and where available, developing countries were often excluded from the studies due to lack of data [3]. In 2002, the World Economic Forum introduced the Networked Readiness index (NRI), and evaluated 82 economies on ICT use by individuals, businesses, and Governments [2][3].

After the World Summit on the Information Society (WSIS) in Geneva in 2003, key stakeholders involved in the statistical measurement of the Information Society, including the International Telecommunication Union (ITU), the Organisation for Economic Co-operation and Development (OECD), Eurostat, the United Nations Conference on Trade and Development (UNCTAD), the UN ICT Task Force, the UN Regional Commissions, the UNESCO Institute for Statistics (UIS), and the World Bank, created a global Partnership for Measuring ICT for Development (ICT4D). This gave birth to the second generation of ICT measurement frameworks with wider scopes that included

developing countries [4]. Benchmarking tools such as the ITU's Digital Opportunity Index and ICT Development Index (IDI) were also introduced [5].

The third generation of benchmarks such as the World Economic Forum's NRI, the Economist's Intelligence Unit (EIU)'s Digital Economy Rankings, and the current International Telecommunications Union's IDI have expanded measurements beyond ICTs, and now include internet access and some variables on broadband assessment as well [6]. However, despite efforts by international organisations and academic institutions to improve broadband measurements, [7][8] specific studies on broadband metrics in developing countries remain limited.

Increasing access to broadband via mobile and nomadic devices in developing countries, and the remarkable differences in demographic factors among others, point to the possible disadvantaging of developing countries when evaluated against measures such as the IDI and the NRI which heavily rely on variables such as fixed broadband subscriptions, and percentage of households with internet access [2][6][9]. In the first attempt to address the disparities in the traditional international broadband rankings , [9] proposed the Broadband Performance Index (BPI), a policy-relevant methodology of comparing broadband among countries by measuring the actual broadband penetration in a country against expected performance. According to [9], the BPI is applicable to broadband adoption, and not the entire broadband eco-system [10][11][12][13][14].

This research, based on a model of broadband readiness, intensity and adoption [12][13][14] sought to fill the identified knowledge gap by firstly developing a composite metric for measuring broadband across the entire broadband eco-system, and secondly contributing to the body of knowledge on broadband metrics in developing countries. The research, using Kenya as a representative of developing countries, sought to address the following objectives.

1. To identify the factors that contributes to increase broadband readiness of a developing country.
2. To identify the factors that contributes to increase broadband intensity in a developing country.
3. To identify the factors that contributes to increase broadband adoption in a developing country.
4. To specify an algorithm to calculate an overall broadband metric for assessing the state of broadband for a developing country based on the above framework.

Objectives 1-3 were already addressed in previous studies [12][13][14]. The current study therefore sought to develop a framework and specify an overall composite metric, in this case the Broadband Assessment Index (BAI) to measure the state of broadband in a developing country.

The rest of this paper is structured as follows: Section 2 gives a theoretical underpinning of the BAI framework, Section 3 provides a brief discussion of the BAI framework and metric methodology. The data analysis and findings are presented in Section 4 followed by discussions and recommendations in Section 5. Finally, limitations of the research, future work, and conclusion are provided in the last two sections.

## 2. BROADBAND ASSESSMENT INDEX (BAI) FRAMEWORK

The purpose of the proposed framework is to develop a composite metric across the entire broadband ecosystem to measure the state of broadband in developing countries. The BAI framework, which is used to specify the BAI index is divided into the following three sub-indices:

- *Broadband readiness sub-index (BR)*: Concerned with the policy, regulatory, technical, commercial and physical infrastructures necessary to support broadband [12].

- *Broadband intensity sub-index (BI)*: Concerned with the state of broadband use, value and nature of broadband transactions [13].

- *Broadband adoption sub-index (BA)*: Concerned with the attitudinal, normative and control factors that influence intentions to adopt broadband [14].

The BAI framework postulates that the overall state of broadband, measured by the Broadband Assessment Index (BAI) in a developing country is affected in similar or different proportions, $n_x$, by the three sub-indices, BR, BI, and BA, Figure 1. The sub-indices are derived from 13 constructs, Table 1. Separate studies were first carried out to determine the constructs that most significantly influenced each of the sub-indices, [12][13][14],Table 1.

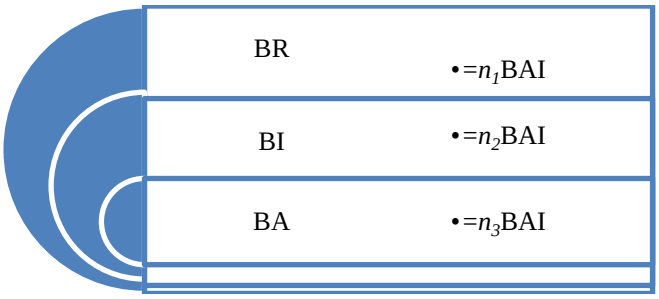


**Figure1. The BAI concept**

Source: Author

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**Table 1: Significant constructs for BR, BI, and BA**

| Sub-Index | Significant Constructs |
|---|---|
| Broadband Readiness (BR) | Demand Side (DS), Policy (POL), Digital Literacy (DL), Regulatory (REG) [12]. |
| Broadband Intensity (BI) | Age (AG), Education (ED), Income (IN), Mobile broadband awareness (MBA), Mobile broadband use (MBU) [13]. |
| Broadband Adoption (BA) | Self Efficacy (SE), Relative Advantage (RA), Facilitating Conditions (FC), Perceived Knowledge (PK) [14]. |

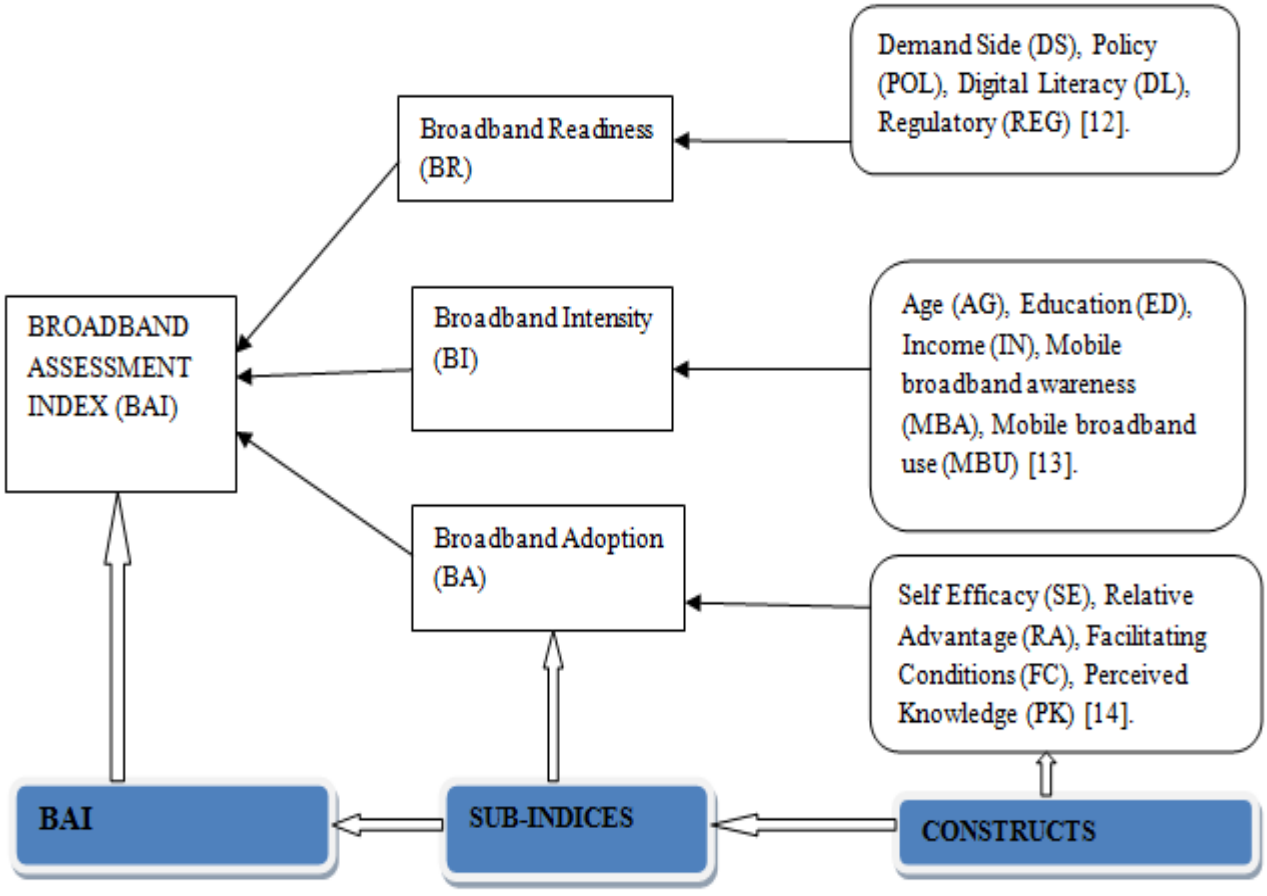


**Figure 2: The BAI Framework**

Source: Author.

# 3. BAI METHODOLOGY

## 3.1 BAI Composition

The three BAI framework sub-indices are derived using 13 constructs according to the following structure (see also Figure 2):

A. Broadband Readiness (BR) sub-index

1. Demand Side (DS)
2. Policy (POL)
3. Digital Literacy (DL),
4. Regulatory (REG)

B. Broadband Intensity (BI) sub-index

1. Age (AG)
2. Education (ED)
3. Income (IN)
4. Mobile broadband awareness (MBA)
5. Mobile broadband use (MBU)

C. Broadband Adoption (BA) sub-index

1. Self Efficacy (SE)
2. Relative Advantage (RA)
3. Facilitating Conditions (FC)
4. Perceived Knowledge (PK)

## 3.2 BAI Equation

From Figure1, Assuming a linear relationship,

$BAI_j=n_1BR_j + n_2BI_j + n_3 BA_j$……...(i)

Where $n_1$, $n_2$, and $n_3$ are the weightings for BR,BI, and BA sub-indices respectively, j= country, And

BR (or BI or BA)= $\sum_{i=1,m} w_{ij} e_{ij} /m$…….(ii)
where
*BR or BI or BA*: respective sub-index
*j:* country
*i:* each of the constructs used in computing the sub-index
$w_{ij}$: relative weights assigned to the construct (i)
$e_{ij}$ : individual score for each construct on a scale of 1
m: number of constructs per sub-index.

In the BAI, the three sub- indices are given equal weights, i.e $n_1 = n_2 = n_3 = n$. The construct weightings $w_i$ are also equal. Thus equation 1 becomes

$BAI_j=(BR_j + BI_j + BA_j)/3$……..…..(iii)

On a scale of 10, for country j, the Broadband Assessment Index, BAI is specified as follows:-

**$BAI = 10 (BR + BI + BA)/3$…….....(iv)**

## 3.3 General observations in specifying BAI

A number of approaches may be used to collect data for the determination of the constructs involved in the computation of the sub-indices [2], the major ones being,

i. Questionnaire data collected based on opinions of key decision makers and leaders in the ICT sector.
ii. Hard data, from sources such as the World Bank, World Economic Forum , ITU, and so on, collected from country designated representatives such as industry regulators who in turn gather the data from industry players.
iii. Individual country self-assessment tools

The collected data for a given country has to undergo certain processes before being used in the determination of the constructs [6][9]. These are:

- *Data Normalization*: Necessary in order to transform the values of the constructs into the same unit of measurement [6][15][16].
- *Data Rescaling*: Rescaling of the data on a suitable scale to enable comparison of the values of the constructs and the sub-indices [17][18].
- *Constructs and sub-indices weighting*. The construct and sub-indices weights may be chosen based on various statistical methods [19][20][21] or equal weighting may be employed [15].

Due to time and resource constraints, and in order to reduce self reporting bias inherent in questionnaire data based on opinions of key decision makers, and individual country self-assessment, [9][15][16][17],the BAI framework used the latest hard data collected by the ITU, the World Bank, the UN, and the World Economic Forum in the computation of the BAI. An added advantage of the hard data is that it has already undergone the data preparation phases listed above and is therefore readily available for application [22].

# 4. DATA ANALYSIS AND FINDINGS

## 4.1 Data Sources

The first step in the data analysis was to match the constructs, their measures, and the corresponding data sources used to compute the BAI, Table 2.

**Table 2: Constructs, Measurement and Data Sources for the BAI**

| Code | Construct | Measurement | Data Sources |
|---|---|---|---|
| **BROADBAND READINESS (BR)= (R1 +R2 +R3 +R4)/4** | | | |
| R1 | Demand Side (DS) | Total (Fixed + Mobile) broadband subscriptions per 1000 inhabitants | ITU, 2011 |
| R2<br>=Dummy/2 | Policy (POL) | Dummy (0= No Policy, 1= ICT Policy only, 2= ICT Policy & Broadband Policy or Strategy) | ITU, 2011 |
| R3<br>=(R31+R32+R33)/3 | Digital Literacy (DL) | R31. Literacy rate<br>R32. Secondary Gross Enrolment ratio<br>R33. Tertiary Gross Enrolment ratio | ITU, 2011 |
| R4 | Regulatory (REG) | Dummy (1 for competition in broadband markets, 0 for otherwise) | ITU, 2011 |
| **BROADBAND INTENSITY(BI)= (I1 +I2 +I3 +I4)/4** | | | |
| I1 | Age ( AG) | Percentage of Population between 15 and 60 years | UN, 2011 |
| I2 | Education (ED) | Tertiary Gross Enrolment ratio | ITU, 2011 |
| I3 | Income (IN) | GDP per capita (Data transformed, $\log(I_3)/5.61$) | World Bank, 2011 |
| I4 | Mobile Broadband Awareness (MBA)<br>Mobile Broadband Use (MBU) | Number of Mobile broadband subscriptions per 1000 inhabitants | ITU, 2011 |
| | **BROADBAND ADOPTION (BA)= (A1 +A2 +A3)/3** | | |
| A1 | Self Efficacy (SE)<br>Perceived Knowledge (PK) | Literacy rate | ITU, 2011 |

| | | | |
|---|---|---|---|
| A2 | Relative Advantage (RA) | International Bandwidth per Internet user(Data transformed, $\log(A_2)/5.61$) | ITU, 2011 |
| A3<br><br>= (A31 +A32)/2 | Facilitating Conditions (FC) | A31. Percentage of Individuals using the Internet | ITU,2011 |
| | | A32. Number of Secure Internet Servers per 1,000,000 inhabitants | World Economic Forum, 2011 |
| **BROADBAND ASSESSMENT INDEX (BAI)= 10(BR +BI +BA)/3** | | | |

## 4.2 Computation of BAI

Having determined the constructs, their measures and respective data sources, Table 2, the next step was to evaluate the BAI. From ITU's, " Measuring the Information Society, 2012" [6], the top 10 ranked countries from Sub-Saharan Africa in the ICT Digital Index (IDI) were chosen. The choice of countries from the same region made it easier to evaluate BAI scores and rankings against scores and rankings of the IDI and the World Economic Forum's Networked Readiness Index (NRI). The top 10 Sub-Saharan Africa countries in the ITU's 2011 IDI rankings are Mauritius, South Africa, Botswana, Namibia, Gabon, Kenya, Zimbabwe, Ghana, Nigeria and Senegal respectively, while the top 10 Sub-Saharan Africa countries in the WEF's 2011 NRI rankings are Mauritius, South Africa, Rwanda, Botswana, Kenya, Ghana, Senegal, Gambia, Namibia, and Zambia respectively. The ITU list was chosen for evaluating the BAI. For consistency, Rwanda and Gabon were dropped from the final list because of the large disparities in their IDI and NRI rankings, and were replaced by Gambia, which was ranked $11^{th}$ and $8^{th}$ in the IDI and NRI rankings respectively. Table 3, shows the populated data for the countries from the various data sources. For the explanation for the construct codes, refer to Table 2. Table 4 shows the computed Broadband Readiness (BR), Broadband Intensity (BI), Broadband Adoption (BA), and the composite Broadband Assessment Index (BAI) for each country.

**Table 3: Construct Data for Selected Sub-Saharan Africa Countries**

| COUNTRY | R1 | R2 | R31 | R32 | R33 | R4 | I1 | I2 | I3 | I4 | A1 | A2 | A31 | A32 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MAURITIUS** | .213 | 1 | .894 | .249 | 0.879 | 1 | .56 | .249 | .879 | .124 | .684 | .728 | .35 | .866 |
| **SOUTH AFRICA** | .216 | 1 | .938 | .158 | 0.887 | 1 | .55 | .158 | .887 | .198 | .671 | .762 | .21 | .626 |
| **GHANA** | .233 | .5 | .581 | .088 | 0.666 | 1 | .5 | .088 | .666 | .23 | .503 | .419 | .141 | .017 |
| **ZIMBABWE** | .152 | .5 | .41 | .062 | 0.919 | 1 | .5 | .062 | .919 | .149 | .459 | .578 | .157 | .01 |
| **BOTSWANA** | .023 | .5 | .8 | .074 | 0.841 | 1 | .55 | .074 | .841 | .018 | .679 | .7 | .07 | .085 |
| **NAMIBIA** | .044 | .5 | .64 | .09 | 0.885 | 1 | .52 | .09 | .885 | .036 | .652 | .6008 | .12 | .14 |
| **KENYA** | .004 | .5 | .602 | .04 | 0.87 | 1 | .49 | .04 | .87 | .003 | .528 | .652 | .08 | .026 |
| **NIGERIA** | .029 | .5 | .44 | .103 | 0.608 | 1 | .47 | .103 | .608 | .028 | .545 | .457 | .284 | .012 |
| **ZAMBIA** | .005 | .5 | .455 | .024 | 0.709 | 1 | .44 | .024 | .709 | .001 | .541 | .473 | .115 | .012 |
| **GAMBIA** | .005 | .5 | .541 | .041 | 0.465 | 1 | .49 | .041 | .465 | .005 | .471 | .576 | .109 | .029 |
| **SENEGAL** | .022 | .5 | .374 | .079 | 0.417 | 1 | .49 | .079 | .417 | .015 | .534 | .617 | .175 | .011 |

**Table 4: Computed Broadband Readiness (BR), Broadband Intensity (BI), Broadband Adoption (BA) sub-indices, and the composite Broadband Assessment Index (BAI) for each Country**

| COUNTRY | Broadband Readiness Sub-Index (BR) | Broadband Intensity Sub-Index (BI) | Broadband Adoption Sub-Index (BA) | Broadband Assessment Index (BAI) |
|---|---|---|---|---|
| MAURITIUS | 0.722 | 0.453 | 0.673 | 0.616 |
| SOUTH AFRICA | 0.719 | 0.448 | 0.617 | 0.595 |
| GHANA | 0.545 | 0.371 | 0.334 | 0.416 |
| ZIMBABWE | 0.529 | 0.408 | 0.374 | 0.437 |
| BOTSWANA | 0.524 | 0.371 | 0.486 | 0.460 |
| NAMIBIA | 0.521 | 0.383 | 0.461 | 0.455 |
| KENYA | 0.502 | 0.351 | 0.411 | 0.421 |
| NIGERIA | 0.478 | 0.302 | 0.383 | 0.388 |
| ZAMBIA | 0.475 | 0.294 | 0.359 | 0.376 |
| GAMBIA | 0.464 | 0.250 | 0.372 | 0.362 |
| SENEGAL | 0.453 | 0.250 | 0.415 | 0.373 |

## 4.3 Validation

This research utilised pre-validated [21] hard data from re-known sources including the World Bank, the International Telecommunications Union, the United Nations, and the World Economic Forum. Furthermore, in each of the studies leading to the selection of the significant constructs for the measurement of each sub-index BR, BI, and BA [12][13][14] respectively, the internal consistency of the constructs was confirmed using Cronbach's coefficient (alpha) values. In all the three studies, the constructs possessed acceptable levels of reliability, hence also validating the BAI framework.

Since no framework or composite metric has been previously developed to assess the state of broadband in developing countries in the domains of readiness, intensity and adoption, the researcher attempted to further validate the BAI framework and index by comparison with the published ITU's IDI and World Economic Forum's NRI 2011 indices for the selected Sub-Saharan Africa countries.

According to [6], the ICT Development Index (IDI) ranks countries' performance with regard to information and communication technology (ICT) infrastructure and uptake. It is based on three sub -indices, ICT readiness (reflecting the level of networked infrastructure and access to ICTs), ICT intensity (reflecting the level of use of ICTs in the society), and ICT impact (reflecting the result or outcome of efficient and effective ICT use) [6].

The World Economic Forum's Networked Readiness Index (NRI) [2], measures the degree to which economies leverage ICT for enhanced competitiveness. The NRI comprises four sub-indices that measure a country's environment for ICT, the readiness of a society to use ICT, the actual usage of ICT by the main stakeholders, and the impacts that ICTs generate in the economy and society. Whereas the IDI is based mainly on questionnaire based data collected using individual country self-assessment tools [6], the NRI is based on a combination of questionnaire data based on opinions of key decision makers, hard data, and individual country self-assessment tools [2].

The rationale for choosing the IDI and NRI for comparison with the BAI is two- fold. Broadband, the subject matter of the BAI framework, is probably the most disruptive form of ICT [7][8][10] , which both IDI and NRI claim to measure. Further, the three indices, namely, BAI, IDI, and NRI respectively utilise a number of common constructs, and therefore variations in the application of these constructs in the calculation of the respective indices can easily be compared [23]. The selected countries' rankings according to the three indices , and their individual scores on a scale of 10 are shown in Table 5. (Note: NRI was originally scored out of a scale of 7 [2], and the figures in Table 5 have been translated to a scale of 10 for comparison purposes).

The researcher also compared the measures used in developing the BAI framework with those used in the IDI and the NRI frameworks.Table 6 shows the comparisons for the measures used in the BAI, IDI, and NRI frameworks respectively.

**Table 5: Comparison Scores and Rankings of Selected Countries BAI, IDI, and NRI**

Note: NRI initially scored on a scale of 7 [2], but converted to a scale 10 in Table 5 for uniformity.

| COUNTRY | BAI SCORE | BAI RANK | IDI SCORE | IDI RANK | NRI SCORE | NRI RANK |
|---|---|---|---|---|---|---|
| **MAURITIUS** | 6.16 | 1 | 4.18 | 1 | 5.80 | 1 |
| **SOUTH AFRICA** | 5.95 | 2 | 3.42 | 2 | 5.53 | 2 |
| **BOTSWANA** | 4.60 | 3 | 2.67 | 3 | 5.51 | 4 |
| **NAMIBIA** | 4.55 | 4 | 2.51 | 4 | 4.79 | 9 |
| **ZIMBABWE** | 4.37 | 5 | 2.24 | 7 | 4.20 | 18 |
| **KENYA** | 4.21 | 6 | 2.32 | 6 | 5.01 | 5 |
| **GHANA** | 4.16 | 7 | 2.23 | 8 | 4.91 | 6 |
| **NIGERIA** | 3.88 | 8 | 1.93 | 9 | 4.60 | 12 |
| **ZAMBIA** | 3.76 | 9 | 1.65 | 15 | 4.66 | 10 |
| **SENEGAL** | 3.73 | 10 | 1.85 | 10 | 4.89 | 7 |
| **GAMBIA** | 3.62 | 11 | 1.84 | 11 | 4.87 | 8 |

**Table 6:Comparison of the Measures used in the BAI, IDI, and NRI. (Note: X indicates measure is used)**

| MEASURE | BAI | IDI | NRI |
|---|---|---|---|
| Total (Fixed + Mobile) broadband subscriptions per 1000 inhabitants | X | - | - |
| ICT Policy | X | - | X |
| ICT Regulatory | X | - | X |
| Literacy rate | X | X | X |
| Secondary Gross Enrolment ratio | X | X | X |
| Tertiary Gross Enrolment ratio | X | X | X |
| Percentage of Population between 15 and 60 years | X | - | - |
| GDP per capita | X | - | - |
| Number of Fixed broadband subscriptions per 1000 inhabitants | - | X | X |
| Number of Mobile broadband subscriptions per 1000 inhabitants | X | X | X |
| International Bandwidth per Internet user | X | X | X |
| Percentage of Individuals using the Internet | X | X | X |
| Number of Secure Internet Servers per 1,000,000 inhabitants | X | - | X |

## 5. DISCUSSION AND RECOMMENDATIONS

Comparison of the measures used in the BAI, IDI, and NRI frameworks is shown in Table 6. It should be noted, however, that attempting to make a comparison between the different methodologies is not without difficulty, since often similar indicators by different institutions may be measured quite differently, or may be used to score quite different constructs [15]. Examples are the Policy and Regulatory constructs which are based on hard data in the BAI, while in the NRI, the two measures are based on data collected based on the opinion of key stake holders in the respective countries. Further, in the NRI, the Policy construct is measured by "effectiveness of general law making", while in the BAI, the Policy construct is scored based on the presence of an ICT policy or Broadband policy/strategy or both. The IDI framework does not use the Policy and Regulatory constructs.

Again, some measures are only partially comparable, since one approach may differ in focus from the other. This is the case with the measures "Adult literacy", "Gross secondary

enrolment ratio", and "Gross tertiary enrolment ratio". In the IDI, the three measures are used to score the "ICT skills" sub-index. In the NRI, "Adult literacy" and "Gross secondary enrolment ratio" are used to score ICT skills while "Gross tertiary enrolment ratio" is used to score the business and innovation environment. In the BAI, the three measures are used to score "Digital literacy" while "Gross tertiary enrolment ratio" alone is used to score the "Education" construct. Another difference is seen in the measure "Number of secure internet servers" which scores infrastructure and content in the NRI, the same measure being used to score facilitating conditions in the BAI. Further, the measures "Fixed broadband subscriptions", and "Mobile broadband subscriptions" are used to score ICT use in both the IDI and NRI frameworks. In the BAI framework, however, the "Total (Fixed + Mobile) broadband subscriptions" is used to score the broadband demand side construct, whereas "Mobile broadband subscriptions" is used to score mobile broadband awareness and mobile broadband use constructs.

However, on the overall, Table 6 shows that the BAI framework covers more measures than either the IDI or NRI frameworks. It also gives prominence to constructs such as mobile broadband [10][11] and digital literacy [12][13][14], which have been shown to be critical for broadband adoption, intensity, and readiness in developing countries [12][13][14][20][22][24][25].Furthermore, the constructs of Age and Income are only used in the BAI framework. Recent studies point to increasing adoption of broadband at the individual level, rather than at the household [10][13][14][25][26][27]. The use of the two constructs therefore give the BAI framework a distinct advantage over the IDI and the NRI frameworks respectively for the assessment of the state of broadband in developing countries [28][29]. The BAI framework dataset also includes more "developing countries" specific measures than either the IDI or the NRI frameworks. Although the NRI framework uses nearly all the measures in the BAI framework, the NRI suffers the disadvantage that nearly half of it's data set (47 percent) is based on expert opinion. Respondents' self bias cannot be ruled out given the collected data is used in international country rankings. The BAI framework uses expert opinion data only at the sub-index development stage in order to determine the most significant constructs in each sub-index. The BAI calculation is, however wholly based on hard data.

With reference to Table 5, the BAI's ordinal ranking of the selected countries in the Sub-Saharan Africa is similar to those of both IDI and NRI, adding an independent validation of the BAI framework. However, in view of the above discussions, and the observed relatively higher individual country scores in the BAI compared to both the IDI and the NRI (in original scores) suggest that the BAI framework scores (in cardinal terms) are closer to the "true" state of broadband across the entire broadband eco-system in developing countries than with either the IDI or NRI framework scores. The researcher contends that the consistently low scores for developing countries in the IDI and NRI rankings are due to the over-emphasis on "fixed broadband", and "broadband access at home" constructs by the two frameworks, and the failure to put more emphasis on mobile broadband access, digital literacy, age, income, and the individual as the unit of investigation. The BAI framework incorporates measures to correct for the above shortcomings of the IDI and the NRI frameworks.

The BAI framework presents a solution to the critical need for a composite broadband metric in the domains of readiness, intensity and adoption in developing countries for informed decision making by the stakeholders in the broadband eco-system including Policy makers, Regulators, Broadband service providers, Researchers and the General public. The framework presents a useful composite metric for the assessment of the state of broadband, and for informed decision making in targeting and evaluating public policies affecting broadband .This is critical for developing countries especially as they embark on the development of their national broadband policies and strategies.

There are several advantages of the proposed BAI framework. For instance, using the framework, a given country could quickly identify which targets need to be improved compared to others, and the ordering of these targets . To date, most policy decisions have been based only on the "Push or supply role", i.e provision of national ICT infrastructure. The BAI framework brings out key demand side factors such as digital literacy which are of equal importance. For example, based on Table 3, a policy maker in the Gambia would conclude that the development of a national broadband policy or strategy is vital for the country, while a policy maker or operator in Ghana would infer the need to improve broadband adoption. Further, a policy maker or operator in Kenya would infer the need to improve public awareness on broadband, while a Zimbabwean policy maker would emphasise improvement in digital literacy, in addition to the traditional push role of infrastructure provision. On-Overall, all the Sub-Saharan Africa countries evaluated in the BAI framework need to put more resources in the improvement of broadband readiness, intensity and adoption in order to improve their standings in international broadband benchmarks.

The BAI computation algorithm is programmable and the process of calculating the composite broadband assessment index can be easily automated. Also, the weights assigned to each construct/measure in the BAI framework can be varied to reflect the priorities of a particular decision modeler to suit a given country's special requirements. Finally, although designed with special focus on developing country characteristics, the BAI can be used in international state of broadband benchmarks with results that will relatively score developing countries higher than with current benchmarking frameworks such as the IDI which, as already pointed out, unduly underscore developing countries.

## 6. LIMITATIONS AND FUTURE WORK

Several limitations in this study are presented. The initial studies to determine the most significant constructs for developing the sub-indices of the BAI, namely Broadband Readiness (BR), Intensity (BI), and Adoption (BA) were conducted within Kenya as a representative of developing countries. The findings may not be directly applicable in other geographical areas or across other cultural environments in other developing countries. However, since broadband deployment and adoption is still in its embryonic stage in most developing countries, and given Kenya's recent rankings in international benchmarks such as the IDI and NRI, Kenya presents a viable sample space for the assessment of the state of broadband in developing countries.

In the initial studies, the sampling methodology was limited to snowballing technique because of the inability to have adequate advance information on broadband users, especially due to increasing access through mobile and nomadic devices. Hence the homogeneity of target respondents may not necessarily be suitable to provide a complete picture to generalise for the developing countries as a whole. Future research, subject to the improved availability of data on the state of broadband in developing countries, could emphasise more on conducting cross-country surveys in the individual countries. This will also correct for possible inaccuracies in the current ITU and other international institutions' hard data, which is collected from designated reporting agencies from individual countries. These agencies in turn rely on self reported data from sector stake holders.

Furthermore, the additive functions and averaging used in the BAI framework may not reflect the composite effect of the factors especially given the effects of cross sub-index or construct correlation. Therefore, it is recommended that future research moderate sub-indices and constructs in order to examine cross-relationships among them. Finally, the determination of the sub-index and construct weights in the BAI is subjective. Future research may explore statistically advanced methods in the development of the sub-indices and construct weights.

## 7. CONCLUSION

This paper presented a framework and a composite broadband metric, the Broadband Assessment Index (BAI) that scores the state of broadband of a developing country based on three sub -indices namely, broadband readiness (BR), broadband intensity (BI), and broadband adoption (BA) respectively, across 13 constructs. This is the first broadband assessment instrument across the three domains of the broadband eco-system, namely readiness, intensity and adoption specifically designed for use in developing countries. Compared to the ITU's IDI, and the World Economic Forum's NRI frameworks, the BAI framework introduces additional constructs such as Age, Income, Digital literacy, and Access to mobile broadband that are crucial for assessing the state of broadband in developing countries. The BAI framework recommends that in addition to gaining advantage in global ICT rankings, It is appropriate for developing countries to identify BAI factors that would best align with their individual short term and long term development strategies. An example is the recommendation, based on the BAI framework, that Sub-Saharan Africa countries prioritise the development of their national broadband policies or strategies.

Using real-world hard data from re-known international organisations including the International Telecommunication Union (ITU), the World Bank, the United Nations, and the World Economic Forum (WEF), the top ranked Sub-Saharan Africa countries in the 2011 ITU's IDI, and the World Economic Forum's NRI were evaluated using the BAI framework. The results appropriately validated the BAI framework, and showed distinct advantages of the BAI framework over the IDI and NRI frameworks when applied to developing countries.

Despite its simplicity and limitations, the researcher is convinced that the BAI framework out performs international ICT benchmarking tools such as the IDI and NRI, when applied to developing countries. Furthermore, although designed with special focus on developing country characteristics, the BAI can be used in international state of broadband benchmarks with results that will relatively score developing countries higher than with the current benchmarking frameworks such as the IDI.

Stakeholders in the broadband eco-system including International institutions, Policy makers, Regulators, Broadband service providers, Researchers and the general public are called upon to further evaluate the BAI framework in the assessment of the state of broadband across broadband readiness, intensity, and adoption domains.

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