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Developing Economies Green Computing Adoption Framework for Universities: Case Study of Burundi

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Abstract:

Despite the benefits of green computing use in education, its uptake by universities in Burundi to deliver its services has been low. The study sorts to assess green computing adoption parameters and develop a green computing adoption Framework for universities in Burundi. The study undertook a survey of public and private universities in Burundi targeting the ICT departments. Based on the findings from the field, the study established to be personnel capacity, green computing status, power consumption management, and ICT governance as the key components of concern towards the adoption of green computing by universities in Burundi. The study further developed a green computing adoption framework for use by universities in Burundi towards adopting green computing.

Keywords: *Developing economies, Green computing adoption framework, ICT governance, ICT personnel capacity, and power consumption management*

1. Introduction

Businesses are increasingly relying on Information Communication and Technology (ICT) to facilitate business, gain a competitive advantage, provide better services, and achieve the organization's business goals. An exponential rise accompanying the ICT uptake has resulted in increased power consumption and the emission of greenhouse gases. This raises greenhouse gas emissions, which in turn has led to increasing the significant threat to energy scarcity and generation ICT e-waste [1]. Scholars have indicated that, because of ICT's high energy consumption, it is responsible for 2% of CO₂ emissions [2]. Green computing has been proposed as a means of mitigation in the use of ICT and keeping a healthy climate. Green computing is therefore seen as an industry's solution to climate change and many other problems within an organization in the current world [3]. Green computing has been defined differently by different authors [4]. The lack of a clearly defined meaning makes it difficult to easily identify how green computing is embraced by an organization as well as how efficient it is. Green computing has been broadly defined as 'the study and practice of designing, manufacturing, using, and disposing of computers, servers, and related subsystems, such as monitors, printers, storage devices, and networking and communication systems, with no impact on the environment' [5][6][7][8]. However, this leaves a gap in the way green computing is applied therefore limiting the potential of green computing. Furthermore, it tends to ignore the contribution to ICT footprint through the manufacture, use, and disposal of ICT devices. The focus of green computing adoption in institutions of higher learning has so far been more on green computing practices, benefits, and related issues [4]. It has been assumed that personnel and students just need to be prepared and encouraged to use ICT devices in a way that reduces computing device power consumption. This, it is assumed, would automatically raise personnel awareness, but, to the contrary, institutions of higher learning are among the largest producers of ICT e-waste and are heavy users of cutting-edge technologies in educational processes [5]. Going green preserves the environment and ultimately saves money. It would also benefit institutions of higher learning by lowering overall energy costs, mitigating the negative environmental effects of ICT, rising stakeholder satisfaction, and improving reputation [6][7][9].

2. Statement of the Problem

In Burundi, universities have recognized the need for promoting knowledge development via the use of Information and Communication Technology (ICT) to benefit the community in terms of teaching and learning. Despite the numerous benefits ICT provides to the community, its use is associated with concerns such as power consumption and greenhouse gas emissions associated with ICT production and use. The use of ICT in education has many benefits and a lot of potential, as witnessed during the COVID-19 period yet universities in Burundi are yet to embrace it in the provision of

services. This is most likely due to the presumed power bills that are assumed to arise as a result of excessive power usage, or a lack of green computing human capacity or ICT governance. The paper discusses the development of a framework that will assist universities in Burundi in adopting green computing.

3. Research Methodology

This study used a survey research design, which was deemed to be an appropriate strategy due to its versatility and ability to be applied to a wide range of studies (Streefkerk, 2021). The goal of employing this survey design was to assess green computing adoption parameters and develop a green computing adoption Framework for universities in Burundi. The study involved public and private universities in Burundi focusing on the ICT departments. Based on the findings obtained factor analysis was employed to filter the variables contributing to green computing and the framework development. KMO and Bartlett's test of sphere city was doneto ascertain the suitability of the obtained data for factor analysis giving a value of 0.846 thatindicatedthe suitability use of factor analysis. Principal Component Analysis and factor rotation was used to extract 7 components that contributed to framework development.

4. Findings and Discussion

After performing factor analysis to completion, including rotation, 26 variables were loaded into the 7 main components that were extracted. These were subject to further processing to develop the green computing adoption framework.

4.1. Green computingStatus

From the study findings after the final stage of factor analysis, the variables that final loaded on component 1 were as presented in Table 1.

Factors	1
Green computing budget	0.858
Green computing Projects	0.616

Table 1: Green Computing Status Component 1 Factor Loadings

The variables that loaded into component 1 that was later named green computing status sub-construct were summarized from the items 'My University had a green computing budget (GCS1)' with a factor loading of (0.858) and 'My University has implemented green computing projects (GCS2)' with a factor loading of (0.616) as can be observed in table 1. The two variables were combined since they reflected green computing status sub-construct, whose contribution was considered as being the average of the factor loadings of the two variables ($\frac{0.858+0.616}{2}$) yielding (0.737), with reference to status in universities. However, the contribution of each variable to the green computing status sub-framework was obtained as a ratio of what each contributed by taking the factor loading of each variable and dividing it by the total loadings of the two variables: green computing budget ($\frac{0.858}{1.474}$), yielding (0.582) and green computing Project ($\frac{0.616}{1.474}$), yielding (0.418). This is represented graphically as given in Figure 1.

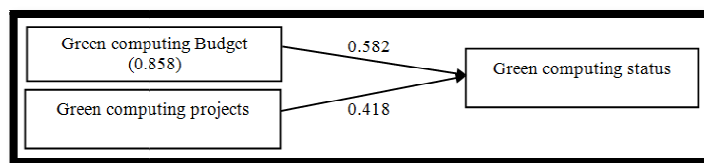


Figure 1: Green Computing Status Sub-construct

4.2. ICT Personnel Capacity

From the study findings after the final stage of factor analysis, the variables that finally loaded onto components 1, 4, 6, and 7 tended to build into a similar construct and were as presented in Table 2.

Factors	Loading			
	1	4	6	7
PC power enforcement management	0.734			
Expertise in green computing	0.676			
Practical experience in green computing	0.852			
Working years		0.826		
Age		0.819		
Experience in ICT		0.852		
Education level			0.876	
Job position			0.828	
Gender				0.782

Table 2: ICT Personnel Capacity Components 1, 4, 6 and 7 Factor Loadings

Based on the findings presented on Table 2, The item 'I do enforce PC power management (PC1)' had a factor loading of (0.734) summarized as pc power enforcement, 'I am an expert in Green computing (PC2)' had a factor loading of (0.676) summarized as Expertise in green computing, 'Personnel have practical experience of implementing green computing (PC5)' had a factor loading of (0.852) summarized as Practical experience in green computing. This component loaded on component 1. This component 1 was renamed ICT skills who weighting was taken as the average of the three items factor loading ($\frac{0.734+0.676+0.852}{3}$) yielding 0.754. the contribution of PC power enforcement management towards ICT skills is given is given by ($\frac{0.734}{0.734+0.676+0.852} = 0.324$), Expertise in green computing is given by ($\frac{0.676}{0.734+0.676+0.852} = 0.299$) while Practical experience in green computing is given by ($\frac{0.852}{0.734+0.676+0.852} = 0.377$). The item 'working years working in the university setup' had a factor loading of (.826) summarized as working experience, 'age' has a factor loading of (.819) summarized as age and 'years working in ICT department' with a factor loading of (.852) summarized as experience in ICT loaded on component 4. The component 4 was renamed experience whose weighting was taken as the average of the three items factor loading ($\frac{0.826+0.819+0.852}{3}$) yielding 0.832. The contribution of working years, age and experience in ICT towards experience were respectively given by ($\frac{0.826}{0.826+0.819+0.852} = 0.331$), ($\frac{0.819}{0.826+0.819+0.852} = 0.328$) and ($\frac{0.852}{0.826+0.819+0.852} = 0.341$). The item 'Level of education' had a factor loading of (0.876) summarized as education level and 'job position being held' with a factor loading of (0.828) summarized as job position loaded on component 6. The component 6 was renamed Job working status whose weighting was taken as the average of the two items factor loading ($\frac{0.876+0.828}{2}$) yielding 0.852. The contribution of education level and job position status towards working status were respectively given by ($\frac{0.876}{0.876+0.828} = 0.514$) and ($\frac{0.828}{0.876+0.828} = 0.486$). The item 'Gender' had a factor loading of (0.782) and loaded on component 7 which was renamed gender. The variables ICT skills, work experience, job working status and gender were founded to contribute towards Green human ICT capacity. They were combined to form ICT personnel capacity sub-construct.

To establish how much each of these variables contributed to the overall ICT personnel sub-construct, a ratio of the loading of each was determined in relation to their sum total loading (0.754+0.832+0.852+0.782 = 3.22). The ratio of what each contributed to the personnel capacity sub-construct was therefore calculated by dividing the sum of the average of the loadings of the sub-construct fall under personnel capacity whereby: ICT Skills ($\frac{0.705}{3.22}$) yields (0.234), Experience ($\frac{0.832}{3.22}$) yields (0.258), Working status ($\frac{0.852}{3.22}$) yields (0.265) and Gender ($\frac{0.782}{3.22}$) yields (0.243). The discussion under section 4.2 is graphically summarized as given in the Figure 2.

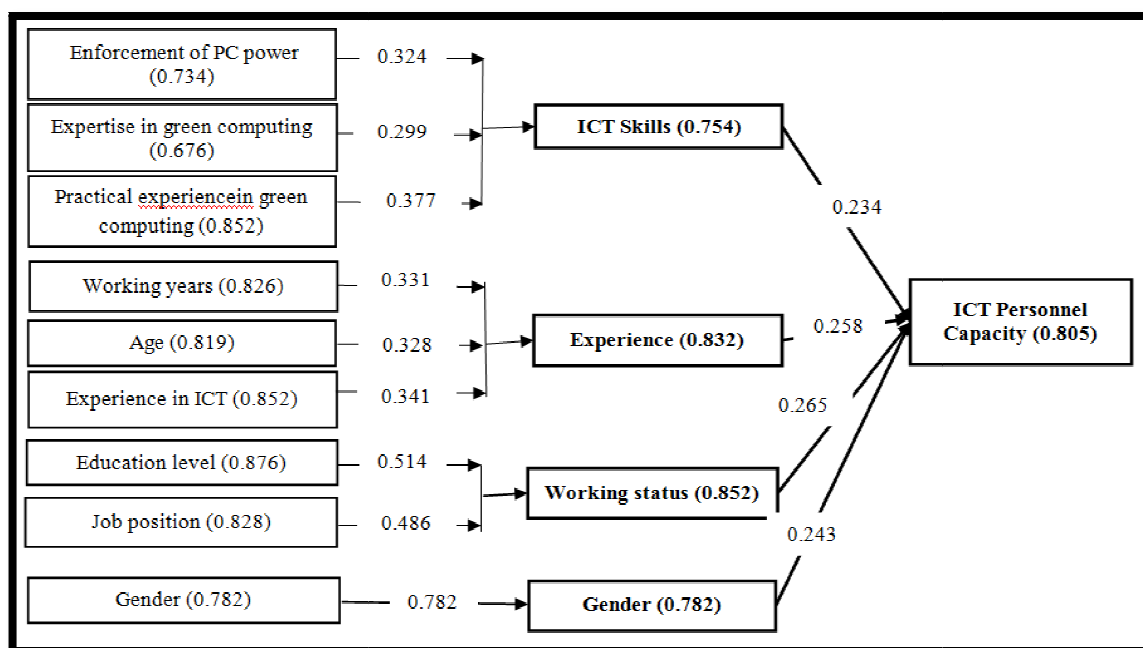


Figure 2: ICT Personnel Capacity

4.3. Power Consumption Management

Based on the final stage of factor analysis, there were variables that loaded on components 2 and 5 as given in Table 3.

Loading Factors	2	5
University Power Management Practices		
I am aware of the status of the power management features of the ICT systems that I regularly use	0.829	
The university enforces PC power consumption management	0.923	
My university has investigated ways to reduce ICT’s power consumption in the last one year	0.921	
My university has an ICT power consumption efficiency measurement system	0.915	
Personnel Power Management Practices		
I prefer PC power management for reduction of power bills		0.956
I turn off my computer when I am not using it		0.958

Table 3: Power Consumption Management Factor Loadings

The item ‘I am aware of the status of the power management features of the ICT systems that I regularly use’ that was summarized as ICT systems features had a factor loading of (0.829), ‘The university enforces PC power consumption management’ that was summarized as PC power enforcement had has a factor loading of (0.923), ‘My university has investigated ways to reduce ICT’s power consumption in the last one year’ that was summarized as ways to reduce PC bills had a factor loading of (0.921), ‘My university has an ICT power consumption efficiency measurement system’ that was summarized as measurement system had a factor loading of (0.915) load on component 2 that was found to be more university enforced habits. The component 3 was named university power management practices. The item ‘I prefer PC power management for reduction of power bills’ that was summarized as power bills reduction had a factor loading of (0.956), ‘I turn off my computer when I am not using it’ that was summarized as computer turning off had a factor loading of (0.958) load on component 5 that was found to be more of personnel enforced habits. The component 5 was named Personnel powermanagement practices. The component 2 and component 5 were combined since they had in common something related to power consumption management are renamed as power consumption management.

The contribution of ICT systems features, PC power enforcement, ways to reduce PC bills and measurement system towards university power management practices was obtained as ratios of the loading of each item to the sum total respectively as $(\frac{0.829}{0.829+0.923+0.921+0.915}) = 0.231, (\frac{0.923}{0.829+0.923+0.921+0.915}) = 0.257, (\frac{0.921}{0.829+0.923+0.921+0.915}) = 0.257,$ and $(\frac{0.915}{0.829+0.923+0.921+0.915}) = 0.255$. On the other hand the contribution of power bills reduction and computer turning off towards Personnel power management practices was obtained as ratios of the loading of each item to the sum total respectively as $(\frac{0.956}{0.956+0.958}) = 0.499$ and $(\frac{0.958}{0.956+0.958}) = 0.501$.

The university power management practices weight was obtained by $(\frac{0.829+0.923+0.921+0.915}{4}) = 0.897$ while that of Personnel power management practices was given by $(\frac{0.956+0.958}{2}) = 0.957$. The contribution of university power management practices and personnel power management practices towards power consumption management was respectively equally obtained as $(\frac{0.897}{0.897+0.957}) = 0.484$ and $(\frac{0.957}{0.897+0.957}) = 0.516$. The findings therefore of 4.3 are represented graphically as given in Figure 3.

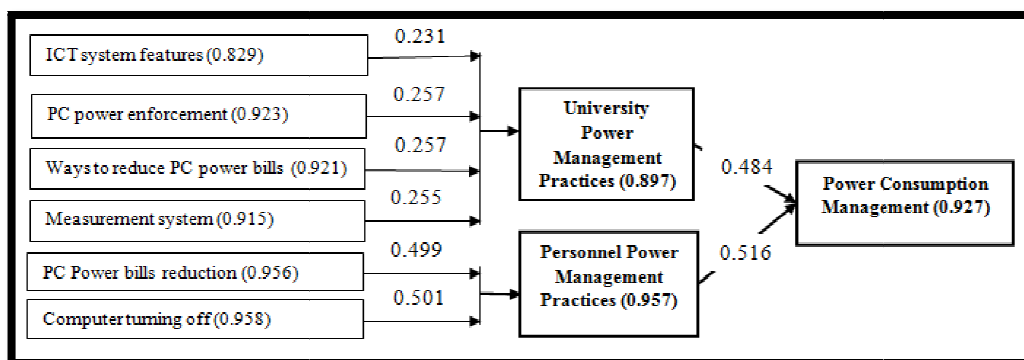


Figure 3: Power Consumption Management Sub-construct

4.4. ICT Governance

Factor analysis to completion added up other items loaded on components 3 and 7 as presented in Table 4 that were later found to be closely related to matters of ICT governance in terms of policies.

Factors	3	7
ICT Policies		
Advocacy of supplier green computing adoption	0.778	
ICT energy efficiency policy	0.676	
PC turn off policy	0.680	
Supplier Green track record		0.685

Table 4: ICT Governance Factor Loadings

Based on Table 4 findings, it's noted that the items 'My university advocates the adoption of green computing by potential ICT suppliers' that was summarized as Advocacy of supplier green computing adoption had a factor loading of 0.778, 'There is a policy on employees use of ICT in an energy-efficient manner' summarized in table 4 as ICT energy efficiency policy had a factor loading of 0.676, and 'My university has a policy that states staff should turn off computers when not in use' summarized as PC turn off policy had a factor loading of 0.680 upon component 3. Component 3 was named ICT policies with its weight obtained as $(\frac{0.778+0.676+0.680}{3}) = 0.711$. The item 'Preference of ICT suppliers that have a green track record' summarized as supplier green track record had a factor loading of (0.685) load on component 7 that was named supplier green track record. The components 3 and 7 were combined based on their policy aspects with the resultant combination being ICT governance.

The ration of Advocacy of supplier green computing adoption, ICT energy efficiency policy and PC turn off policy contribution towards ICT policies was respectively obtained as $(\frac{0.778}{0.778+0.676+.680}) = 0.365$, $(\frac{0.676}{0.778+0.676+.680}) = 0.317$ and $(\frac{0.680}{0.778+0.676+.680}) = 0.319$. At the same time ratios of ICT Policies and supplier green track record contribute to the ICT governance as $(\frac{0.711}{0.711+0.685}) = 0.510$ and $(\frac{0.685}{0.711+0.685}) = 0.490$ respectively. The summary of the findings under the ICT governance are presented graphically in Figure 4.

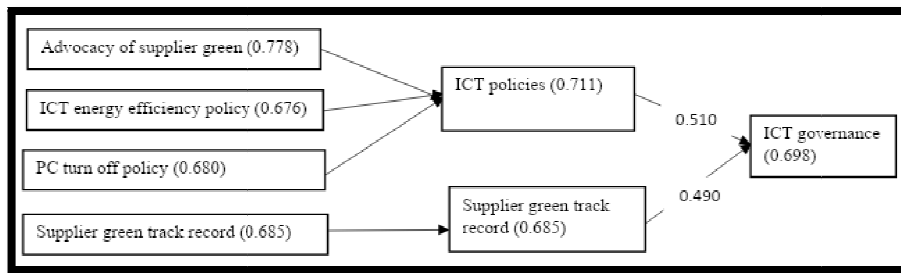


Figure 4: ICT Governance

5. Green computing Adoption Framework (GCAF)

Using the results discussed 4.0 a green computing adoption framework was development for use by universities in Burundi and validation was undertaken.

5.1. Framework Development

The findings of section 4.0 clearly indicated the final constructs that were loaded overall for the framework development were green computing status with a weight of 0.737, personnel capacity with a weight of 0.805, power consumption management with a weight of 0.927 and ICT governance with a weight of 0.698 as illustrate graphically in Figures 1, 2, 3 and 4. The ratio of contribution of each of this constructs towards the GCAF therefore are obtained for green computing status as $(\frac{0.737}{0.737+0.805+0.927+0.698}) = 0.233$, personnel capacity as $(\frac{0.805}{0.737+0.805+0.927+0.698}) = 0.254$, power consumption management as $(\frac{0.927}{0.737+0.805+0.927+0.698}) = 0.293$ and ICT governance as $(\frac{0.698}{0.737+0.805+0.927+0.698}) = 0.220$. Based on these findings therefore the GCAF graphically is represented as given in Figure 5.

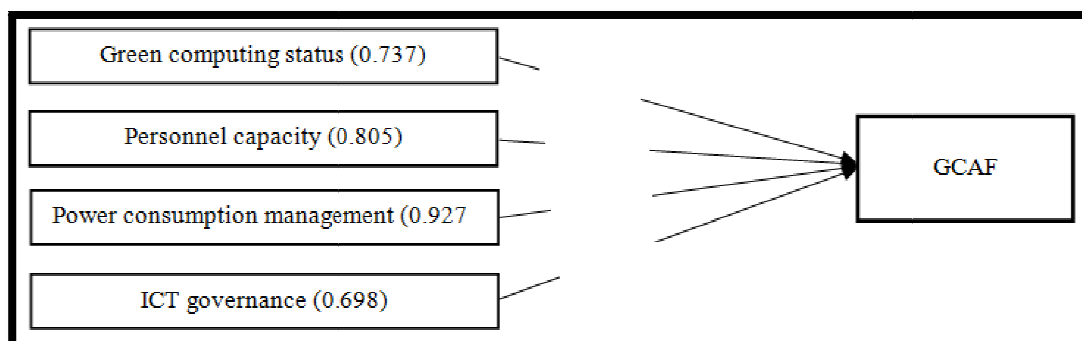


Figure5: GCAF

From Figure 5, it is noted that the universities in Burundi working towards adopting green computing will need to available investment resources according to the developed green computing adoption framework on green computing status at 23.3%,on personnel capacity at 25.4% power consumption management at 29.3% and ICT governance at 22.0%. Under each of the construct in the framework, there are a number of items that will be contributing to each construct respectively. This can be summarized with all details as represented in figure 6.

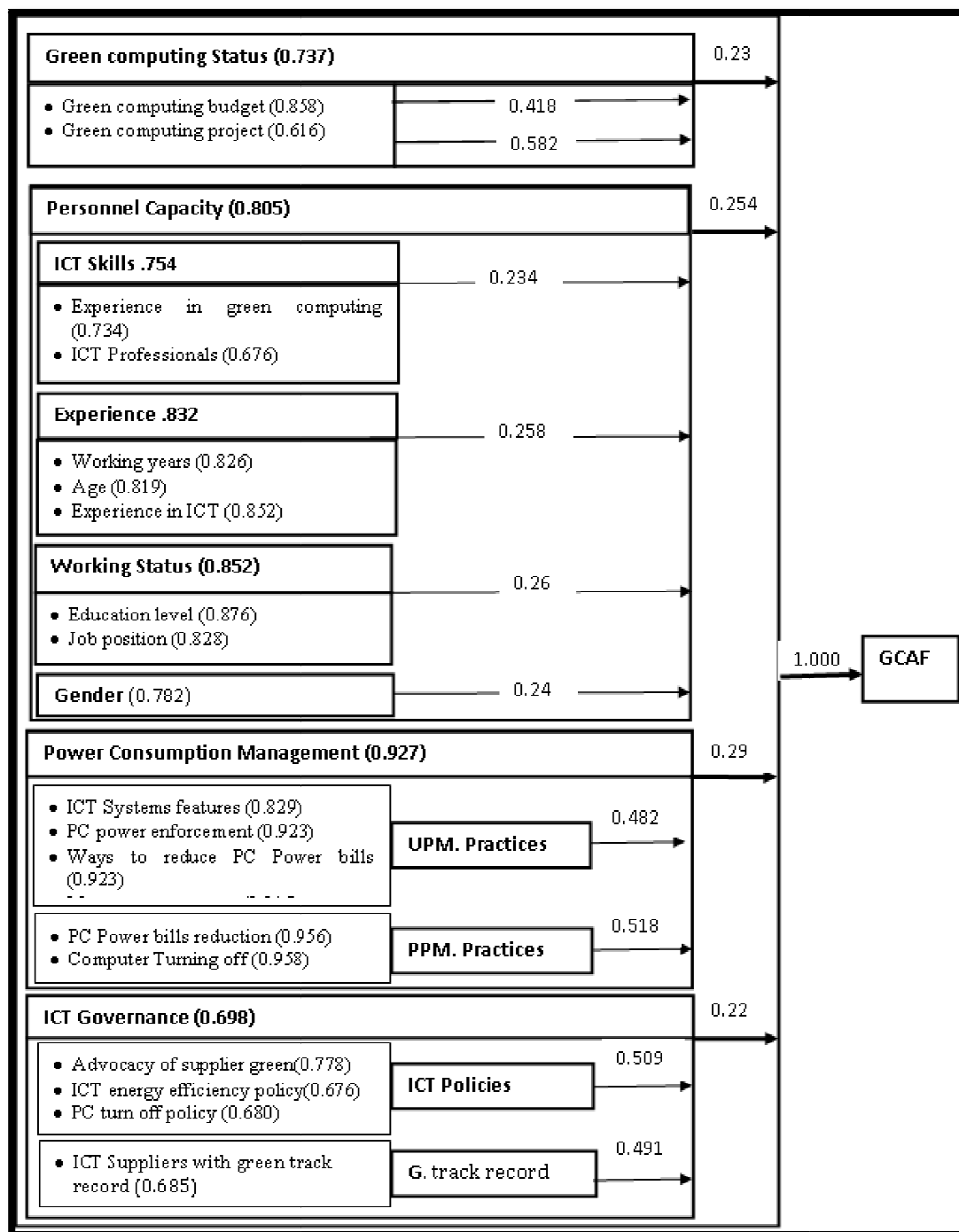


Figure 6: Expanded GCAF

5.2. Framework Validation

Eight green computing experts were used to validate the GCAF through focus group discussion in an organized seminar. This was done through discussing and soliciting feedback on the framework's acceptability and usability. The findings of the validation process are presented in Tables 5.

Following the seminar presentation, the researcher employed questioning protocol technique to elicit concerns and feedback from the experts about the framework and its concepts. The responses were ranked on a Likert scale of 1 to 3, with Agree = 3, Undecided = 2, and Disagree = 1. Table 5 gives a summary of the findings.

	Mean	N
Is the framework a true represent real-situation of green computing concepts with reference to universities in Burundi	2.38	8
Is the framework accurate representation of the supporting theories' study	2.50	8
Is framework easy to use or apply in the universities in Burundi	2.25	8
would the framework be useful therefore easily acceptable to universities in Burundi	2.63	8

Table 5: Framework Validation Response Summary

From Table 5, the average mean of the four items used gives it as 2.44 with all items having values above 2. This converted to a percentage gives 80%. Therefore, the experts were on the overall agreed to 80% that the GCAF was acceptable and usable with reference to green computing adoption by the universities in Burundi.

6. Conclusions from the Study

The paper discussed the development of the GCAF for use by universities in Burundi towards green computing based on the study findings. The framework's key components were established to be green computing status, personnel capacity, power consumption management and ICT governance as illustrated in Figure 5. Each of the components had other subcomponents that contributed to each of them as provided under section 4.0 and illustrated in Figure 6.

6.1. Acknowledgement

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