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Full Length Research Article

CONCEPTUAL DESIGN OF E-GOVERNMENT DEPENDENCY MATURITY ASSESSMENT MODEL

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ABSTRACT
E-government solutions globally are removing the barriers of time and location while reducing the cost of governance. Nevertheless, they are laden with vulnerabilities that are potentially exploitable by cyber threat actors. Cyberattacks on e-government platforms have the potential for monumental consequences due to the criticality of government digital assets and the possibility of cascaded effects. However, current research mainly assesses the availability of online services to stakeholders. It does not evaluate how much government enterprises depend on these e-services. Additionally, it overlooks the link between this dependency and the potential impact on government digital assets during cyberattacks. Consequently, this article presents a conceptual design of an E-Government Dependency Maturity Assessment Model to address this gap. The model has the potential to calculate the E-Government Dependency Maturity Index (EDMI). This index is a composite metric that reflects the extent to which an organization relies on e-government services. Consequently, it also indicates the organization's level of cybersecurity risk exposure.

Keywords: e-government, dependency, maturity, model, degree of dependency.

INTRODUCTION

In recent decades, there has been a growth trajectory in the Information and Communication Technology (ICT) sector such that every industry and human endeavour is adopting ICT at an increasing scale and sophistication. This is to support production and services delivery without the barriers of time and location while cutting down dramatically the cost of doing so. Governments across the world are driving the process of ICT implementation in the private sector through regulations to bolster their economies. To be able to connect with the private sector and citizens, governments are also adopting cyber technology in their business processes at an increasing rate and sophistication.

The COVID-19 pandemic has further increased the rate of technology usage in government sectors as it has become the safest means by which government business can be carried out without spiking the rate of infection. According to Domínguez and Charles (2010), e-government is an innovative application of information and communication technologies, implemented predominantly through web-based Internet applications to deliver services. In Lim, Masrom, and Din (2013), it is argued that the goal of e-government is to provide citizens and businesses with more convenient access to government information and services, to improve the quality of the services, and to provide greater opportunities to participate in democratic institutions and processes. Thus, increasing access to government services with greater ease and convenience.

E-government implementation supports the government to re-engineer government processes and culture in a manner that citizens are aware, and develop an interest in participating in the governance process(Al-hakim, 2007). E-government services or relationships known as e-government models can be between government and citizens (G2C), government and employee (G2E), government and the private sector or businesses is (G2B), and between government and government (G2G) (Zarei, 2018). However, it has been argued that the relationship between the service provider (government) and service consumers or prosumers (citizens, employees, businesses and other government entities cannot be unidirectional (Fakeeh, 2016; Lim et al., 2013). Thus, the relationship may be viewed as government to citizen to government (G2C2G, G2E2G, G2B2G and G2G2G). These models provide the basis for the adoption of e-government solutions across national and sub-national governments.

The gains of e-government implementation are tremendous as it is with every area of adoption of technology. However, there is equally high risks associated with cyber technology as will be inherited into the governance ecosystem as a result of the accompanying vulnerabilities in the ICT infrastructure (Mwathi & Okelo-odongo, 2017). Notwithstanding the inherent risk, global indices show that countries are increasingly adopting ICT to drive governance as reflected in the various global indices, namely: E-Government development index (United Nations, 2020); The network readiness index (NRI) (Dutta & Lanvin, 2019, 2020); the ICT development index (IDI) (United Nations, 2005). In essence, governments across the world are high technology consumers and these consumptions permeate the entire governance ecosystem. Thus, given the risk associated with technology, it has become important that governments have the capability and tools to gauge quantitatively the levels of dependency on e-government solutions so that the ICT related risks can be assessed and proactively tackled. This is consequent upon the assertion that there is a strong nexus between the cyber risk of organizations and their degree of dependency on ICT infrastructure (Luiijf, Nieuwenhuijs, Klaver, Van Eeten, & Cruz, 2010; Mbanaso & Kulugh, 2021). However, there is no known model that gauges the dependency of government institutions on e-government platforms. Thus, this paper presents a model that determines the degree of dependency of government institutions on e-government solutions for driving policy and rendering services to citizens, employees, businesses and other government entities. The key objectives of the paper are:

i. To identify the building blocks for an e-government dependency model;
ii. Build a relationship between these building blocks that supports the quantitative assessment of the level of dependency of governments on ICT
iii. Develop a computational model for the measurement of the e-government dependency maturity index (EDMI)

The concepts of government and governance have been used as synonyms in literature, denoting the exercise of authority in an organization, institution or state; in (Carino, 2001), it is argued that government is the name given to the entity exercising that authority while governance is the art of exercising the authority. Government is a territorially based body that makes authoritative decisions for which it has constitutional or legislative authority that are binding on citizens and businesses and other levels of government within its geographic boundaries. Governance on the other hand is the formulation and execution of collective action at the local level which encompasses the direct and indirect roles of formal institutions of local government and government hierarchies, as well as the roles of informal norms, networks, community organizations, and neighborhood associations in pursuing collective action (Weissbourd & Kosarko, 2011).

In this conception, government (the public sector) is nearly always involved and usually plays a vital role in every aspect of the society. According to the definitions above, one can deduce that while

government is an entity, governance is the activities that the entity carries out for the purpose of achieving set objectives. However, while governance is used in not-for profit, privately owned organisations, government is used only in the public sector parlance. (Carino, 2001), further argues, that to understand the working of government, we will understand firstly the activities, actors, processes and capacities needed to be developed to achieve set goals. In an age where all human endeavours are driven by technology, understanding the above parameters will require that we look at them through the lens of technology, this brings us to the concepts of e-government and e-governance.

E-Government and E-Governance

E-governance is the adoption of information and communication technology (ICT), especially the internet or web-based networks to provide services to the citizens, employees of government, businesses or other levels of government (Republic of South Africa, 2010). With the use of the internet, the communication and interaction among citizens and the government can be conducted on a single counter or at home on the computer 24 hours a day, 7 days a week without being physically present at the government's offices to get forms, legislation, news and other information from respective departments of the government. Nevertheless, this is only possible by the government's willingness to decentralize the responsibilities and processes by using electronic means of the internet (Lim et al., 2013). One key objective of e-government is to improve service delivery to citizens and in so doing improve the efficiency of the government's processes. E-government entails moving citizen services online, but in its broadest sense it refers to the technology-enabled transformation of government such that cost is reduced, while promoting economic development, transparency, service delivery, public administration and facilitating the advancement of an information society (Yildiz et al., 2013). E-governance aims at promoting an inclusive societies where everyone can benefit from basic services and participate actively in the political, economic and cultural life (Lim, Masrom, & Din, 2020). This is in line with the principle of 'leaving no one behind' of the United Nations (United Nations, 2015). Various entry points can be identified, namely: Access to information; Service provision that facilitates greater transparency and effectiveness; Public sector reforms, local governance and decentralization; Dialogue between government and non-governmental stakeholders; - Sharing knowledge and training.

E-Governance Business Models

According Ntulo & Otike (2013); Alshehri, Mohammed; Drew (2010) the following e-governance models can be adopted for government business, namely; Government to Citizen (G2C) - deals with the relationship between government and citizens. G2C allows citizens to access government information and services instantly, conveniently, from everywhere, anytime by use of multiple channels. Citizens may also respond to service or perform their obligation to government; this extend the G2C model into a new model, namely government to citizens and to government (G2C2G) (Fakeeh, 2016). Government to Business (G2B) consists of e-interactions between government and the private sector. The opportunity to conduct online transactions with government reduces red tape and simplifies regulatory processes, therefore helping businesses to become more competitive. Government to Government (G2G): Governments depend on other levels of government within the state to effectively deliver services and allocate responsibilities. G2G facilitates the sharing of databases, resources and capabilities between and among government institutions and hierarchies; thus, enhancing the efficiency and effectiveness of processes. The government to employee (G2E) model on the other hands addresses the relationship between government and her employees, this model is foundational for the other models to thrive.

Benefits of E-Governance

The primary aim of governance is to regulate and protect the state and its citizens. It also has the mandate of managing the affairs of the state on behalf of the citizens. The use of electronic medium in governance, that is E-governance, is to facilitate the easy flow of interactions between the government and the citizens or its clients. Thus, E-governance enhances the efficiency and flexibility of providing public goods and service (Backus, 2001; Chowdhury & Satter, 2013). Computers and the associated networks inherently have the ability to improve processes by enhancing speed, quality of service and blocking avenues for leakages. According to (Lim et al., 2013) an e-government project will therefore; reduce costs both on the sides of government, businesses and citizens. Consequently, putting services online substantially decreases the processing costs of many activities compared with the manual way of handling operations. Efficiency is also attained by streamlining internal processes and by enabling faster and more informed decision making. Promoting Economic development: In order to grow and prosper, all private enterprises, but especially SMEs, need a suitable legal and regulatory environment, a reliable infrastructure as well as different financial and business services. To support the above (Belgian Development Corporation, 2017) said that the use of ICT in government and in its interaction with the business community and citizens can create new businesses, attract investments and generate employment. Thus, enhancing transparency and accountability; e-governance helps to increase the transparency of decision-making processes by making information accessible – publishing government debates and minutes, budgets and expenditure statements, outcomes and rationales for key decisions, and in some cases, allowing the online tracking of applications on the web by the public and press. Improving Service Delivery: Government service delivery, in the traditional process, is time consuming, lacks transparency, and leads to citizen and business dissatisfaction. By putting government services online, e-governance reduces bureaucracy and enhances the quality of services in terms of time, content and accessibility. For example, the online international passport processing, tax administration, land registration. Improving Public Administration: E-government administrative components, such as a computerized treasury, integrated financial management information systems, and human resource management systems, lead to greater efficiency in public administration. Features include the integration of expenditure and receipt data, control of expenditure, human resources management, intelligent audit through data analysis and the publishing of financial data. Example: E-procurement has proven itself to be one of the more effective and efficient tools for bringing good governance to the procurement process. In order to improve public sector governance and move beyond traditional, paper-based procurement, many countries in Africa are adopting e-procurement systems. Facilitating an e-society: One of the main benefits of an e-government initiative consists of the promotion of ICT use in other sectors. The technological and management capacities required for e-government administration encourage, in turn, the development of new training courses and modules in schools and universities trying to supply the required skills and capabilities to the market. This has the potentials to develop citizens who will compete in part of the world with their e-skills.

Disadvantages of E-Governance Systems

In spite of the many advantages outlined earlier, there are drawbacks in the implementation of e-government platforms, (Alshehri, Mohammed; Drew, 2010) observed that there are several challenges and barriers that can delay progress of e-government implementation. The variety and complexity of e-government initiatives implies the existence of a wide range of challenges and barriers to its implementation and management. chief among them is the inherent vulnerabilities and threat actors waiting in the wing to exploit the vulnerabilities for their malicious intentions, (Babalola, 2014). Lack of skilled capabilities to develop and run the technology required to effectively manage e-government platforms, especially in developing economies is a serious impediment. Yildiz et al., (2013) further summarised the challenges to comprise technical, organisational, social and financial. Carino, (2001) elaborated those technical problems like lack of shared standards and compatible infrastructure among departments and agencies. Also, privacy and

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security of personal data of citizens are critical barriers in implementation of e-government is citizens' concern. The guarantee by the government will not suffice unless accompanied by technical solutions, transparency of procedures and possibly independent auditing. The implementation of e-government transcends technical barriers into organizational enterprise, organizational challenges include; top management support, resistance to change to electronic ways, collaboration, lack of qualified personnel and budgetary constraints. Overcoming these avalanches of issues will require total buy-in of top management.

Comparison of E-Government Measurements

There have been efforts to measure the utilization of ICT by governments across the world. However, these measurements do not delve into the understanding the implementation of e-government based on the e-government business models (e.g. G2C, G2B, etc.) and the extent to which national governments and sub-national governments depend on e-government from a cyber-risk-based prism. For example, the e-government development index (EGDI) is an aggregation of the quality of services constructed on the key pillars of: Online Service Index (OSI); Telecommunication Infrastructure Index (TII); The Human Capital Index (HCI). The EGDI does not measure the level of dependency or sophistication of e-government vis-à-vis the risk that it brings. Besides it measures these indices at national government levels only (United Nations, 2020). The network readiness index (NRI) (Bibao-Osorio, Dutta, & Lanvin, 2014; Dutta & Lanvin, 2019, 2020) measures the readiness of nations or societies to tap into the technology networked society to improve livelihood. It is built on the pillars and indicators of technology (access, content and future technologies); People (individuals, businesses, government); Government (trust, regulation, inclusion) and Impact (economy, quality of life, SDG contribution). It has no bearing on e-government dependency measurement. The manual for measuring e-government (United Nations Economic Commision for Africa, 2014) measures e-government on the basis of: use of ICT by persons employed in government organizations, availability of ICT to government organizations, Use of ICT by government organizations and Supply of e-government services to citizens. This does not provide measures of dependency of government on ICT, rather, they measure how much ICT is implemented in government from the perspective of the indicators provided. In (Mbanaso, Kulugh, Musa, Aimufua, & Dandaura, 2021) the authors researched on the dependency of critical infrastructure on cyber infrastructure. They define three metrics of dependency with graduation from the least to the most sophisticated, namely: adoption, integration and automation. They argued that cyber risk to depending critical infrastructure is directly proportional to the level of sophistication of its dependence on ICT. This work however, did not cater for e-government and the metrics did not address the issues in e-government implementation. This article models government reliance on ICT based on metrics driven from e-government models. This follows a chronological implementation from the least to the most sophisticated models. The e-government implementation models in context are: G2E, G2C, G2B and G2G in the order, with G2E being the least and G2G as the most sophisticated.

MATERIALS AND METHODS

This article adopts the design science research (DSR) strategy to enable it fashion the e-government dependency maturity artefacts (the framework and model) that will support the measurement of the degree of dependency of governance on e-government solutions. Fig. 1 provides a detailed illustration of the process showing the six phases of the DSR process, namely: problem identification and motivation, solution objectives, design and development, demonstration, evaluation and communication (Hevner & Chatterjee, 2010; Oates, 2006) and how other elements of the methodology are tied to the relevant phases of the DSR strategy to achieve the objectives of this article. Details are explained in the following sub-sections of the methodology.

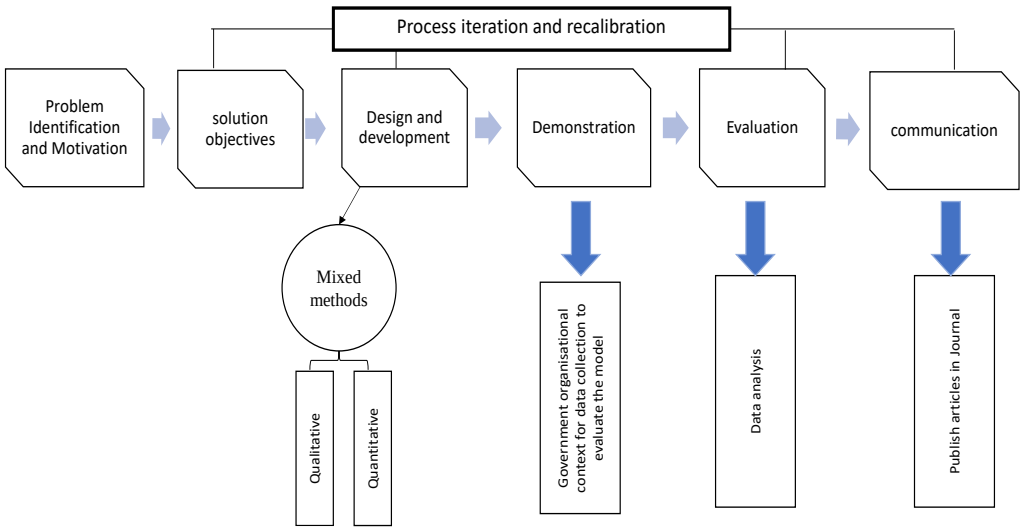

Figure 1: Research Methodology Framework

Problem Identification and Solution Objectives

These two phases as illustrated in Fig. 1 depict the elements that begin this article in the introduction section. Thus, the problem identification and solution objectives have been addressed in the introduction section of this article.

Design and Development

The design and development phase followed a mixed methods approach that combines the qualitative and quantitative paradigms. The qualitative paradigm drew from the existing body of knowledge to describe the characterisations of e-government models that help generate the building metrics and measures (variables) for assessing ICT or e-government dependency of government entities. This led to description of a conceptual relationship between the building metrics. The quantitative paradigm on the other hand leveraged the conceptual framework developed in the qualitative process and its building metrics define measurement scales and mathematical equations that forms the computational engine of the model for the calculation of the e-government dependency maturity index (EDMI).

Demonstration

To demonstrate the working of this model, the organisational context will be used. The research context describes the environment of the research that will form the unit of data collection and analysis (Sekaram

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& Bougie, 2016). The framework will be demonstrated within the context of government institutions based on identified business models of e-government, namely; G2E, G2C, G2B and G2G. These variables will be further broken down to arrive at the lowest unit of measure which will be defined by a five-points scale of equal intervals referred to as e-government dependency measure scale in Table 2. However, this phase is beyond the scope of this article and will be addressed in future work.

Evaluation and Communication

The evaluation will be done when data collected at the demonstration phase from the public sector organisations is analysed to show how the model is able to achieve its objectives, the results will be communicated through publications. However, when the objectives are not met, the process iteration component (in Fig. 1) of this methodology allows a review of the process. While this phase evaluates the framework, it provides empirical data and computations of the degree of dependency of government enterprises on ICT. However, demonstration and evaluation are not within the scope of this article and will be covered in future work.

E-GOVERNMENT DEPENDENCY MATURITY MEASUREMENT FRAMEWORK (EDMMF) CORE

Fig. 2 represents EDMMF which is conceptualised on basis of the building blocks realised in literature, referred to as e-government business models. The framework core has three main components, namely; e-government dependency maturity function (E-GDMF), e-government dependency maturity mathematical model (EDMMM) and the e-government dependency maturity comparative quadrant (EDMCQ).

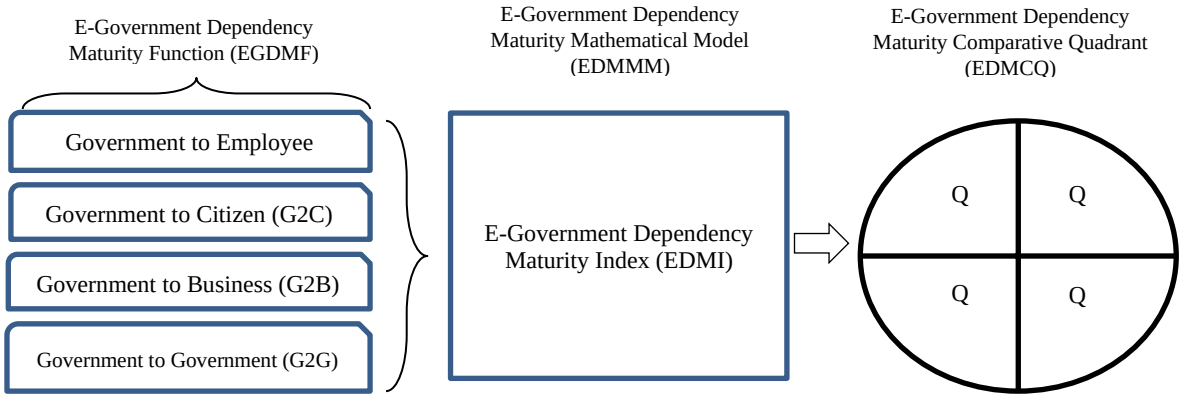

Figure 1: E-Government Dependency Maturity Measurement Framework (EDMMF) Core

i. **E-Government Dependency Maturity Function (EGDMF)**

The e-government dependency maturity function (EGDMF) also referred to as the key pillars of the framework provide the high-level metrics for the measurement of the degree of dependency of government entities on e-government solutions. The EGDMF are arranged on the basis of their sophistication from top to bottom (the least sophisticated at the top and the most sophisticated at the bottom). The contemplation is that, as government entities transit from one e-government model to higher or more complex models, the degree of dependency or maturity and the cyber risk proportionately increase. Thus, the authors considered the least sophisticated solution to be the government to employee (G2E) model where internal processes relating to employees are automated, government to citizen (G2C), government to businesses (G2B) and government to government (G2G) in that order. Each of these models is further analysed such that their sub-elements are broken down to granularity for the purpose of attaining quantitative measurement of the degree of dependency as shown in Fig. 3.

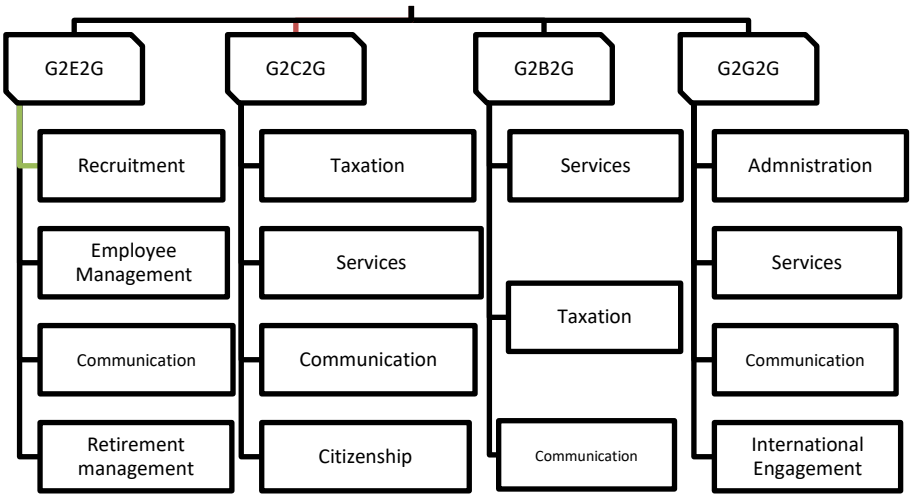

Figure 2: E-Government Dependency Maturity Function (EGDMF)

The EGDMF as shown in Fig. 3 reflects the layers of measurements in the framework core. It is immediately followed by a sub layer referred to as the e-government dependency maturity category (EDMC). For instance, the G2E2G function has four EDMCs which measure the implementation of e-government solutions that supports employee related activities in a government enterprise, namely; recruitment,

employee management (salary administration, transfers, appraisal, promotions and disciplinary issues), communication, retirement management, etc. The G2C2G's EDMC deals with the measurement of the availability of e-government applications that handles government and citizens relationship, thus, its measures availability and usage of e-government platforms for taxation, services, communications and citizenship (national identity, voters' registration and voting, international passports, etc.). The G2B2G solutions on the other hand measure the capability of government institutions to provide services to private business entities through e-government platforms; the EDMC in the G2B2G function are: services such as taxation, business registration, regulations and communications. In the G2G2G realm, the frameworks measure the capability of the various agencies of government to interoperate through information and data sharing platforms, this may span inter-agency interaction within a country and even inter-governmental engagements at an international scale.

ii. E-Government Dependency Maturity Mathematical Model (EDMMM)

The EDMMM provides the mathematical equations or the computational engine that calculates the E-Government Dependency Maturity Index (EDMI). The EDMI is a composite value that expresses the degree of dependency or the maturity of a government institution on e-government solutions. It is computed through the aggregation of the values of the four EGDMF (i.e. G2E, G2C, G2B and G2G) based on their contributing effects on the EDMI, the contributing effects of each EGDMF is described in Table 1. The following section describes the processes that lead to the derivation of the EDMMM.

Weighting of the EGDMF Metrics Contributions

Four high-level metrics (G2E, G2C, G2B and G2G) have been defined for the computation of the EDMI. However, these high-level metrics do not have equal effects or contribute equally to degree of dependency or maturity of e-government solutions and risk associated with this dependency. Therefore, the degree of dependency on e-government solutions cannot be distributed equally across these metrics, similarly, the cyber risk exposure arising from the degree dependency cannot be equal across the metrics (Mbanaso & Kulugh, 2021). Thus, the Weightings reflect the quantitative contributions of the individual high-level metrics. Similarly, from a cyber risk perspective, the weighting reflects the proportionate cyber risk relative to the sophistication of the EGDMFs. This shows that the risk and benefits will be distributed according to the level of contributions by individual elements. Consequently, the weights in Table 1 are allocated to each EGDMF in line with the progressive level of sophistication of e-government solution. It is considered that the sophistication and value of the four e-government models increase as one moves downwards on the framework in Fig. 2. Table 1 provides the weights of the EGDMF Metrics Contributions to the EDMI.

Table 1: Weights of E-Government Dependency Maturity Functions (adopted from (Mbanaso, Kulugh, Musa, & Aimufua, 2019b)

#	Metric	Acronym	Weight	Weight factor (w_f)
1	Government to Employee	G2E	10	0.10
2	Government to Citizen	G2C	20	0.20
3	Government to Business	G2B	30	0.30
4	Government to Government	G2G	40	0.40
	Total		**100**	**1.00**

As shown Table 1, G2E has 10% weight as it is considered the e-government implementation with least sophistication and thus least risk relative to the others. In that order, G2C (20%), G2B (30%) and G2G (40%) respectively, these corresponds to weight factors (w_f) of 0.1, 0.20, 0.30 and 0.40 respectively.

Definition of Variables

To build the computation engine (EDMMM), variables are defined based on the EDMMF core represented in Fig. 2 and its extension in Fig. 3. Consequently, the following variables are defined and used in the derivation of the EDMMM for the computation of the EDMI.

1. *The e-Government Dependency Maturity Index* (*EDMI*) is an aggregation of the e-government dependency maturity function indexes (EGDMFI), (i.e., G2E, G2C, G2B and G2G). The value of EDMI lies between 0.00 – 1.00
2. *E-government dependency maturity functions index (EGDMFI)* is an aggregation of the e-government dependency maturity category indexes (EMDCI) under each of the E-GDMFs.
3. *E-government dependency maturity category index (EDMCI)* is an aggregation of e-government dependency maturity measures (EGDMM), i.e. the summation of the granular measurement of e-government solutions adopted by organisations under each e-government dependency maturity category (EDMC).
4. *E-government dependency maturity measure (EGDMM)* is the quantitative evaluation of the degree of dependency or implementation of a particular *EDMC*. It is defined on a quantitative scale of equal intervals (0 – 4) as shown in Table 2.

Table 2: E-government Dependency Maturity Measure Scale (EDMMS)

Qualitative	Quantitative	Description
None	0	Poor or complete absence of the attribute of the e-government solution been measured
Low	1	Few elements of the measured e-government solution in place but incoherently applied
Moderate	2	Some elements e-government solution is in place but not consistently and unstructurally organised many and/or important elements are missing
High	3	Measured e-government solution is structurally implemented but not consistent; only a few and/or minor elements missing
Very High	4	The highest level of the e-government solution in place and comprehensively implemented

Derivation of the e-government dependency maturity mathematical Model (EGDMMM)

E-government dependency maturity category index (EDMCI): The EDMCI is the summation of the *E-government dependency maturity measure (EDMMs)* of a particular e-government dependency category (EDMC) and is expressed mathematically thus:

$$EDMCI = \sum_{i=1}^{n} EDMM_i \quad \text{..... Equation (1)}$$

where i run from 1 to n, and n is the number of EDMMs been measured

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per EDMC

E-government dependency maturity function index (EGDMFI): E-GDMFI is a summation of the e-government dependency maturity category index (EDMCI) under each of the *EGDMF* and is represented in the equation below:

$$EGDMFI = \sum_{i=1}^{n} EDMCI_i \quad \text{..... Equation (2)}$$

where i run from 1 to n, and n is the number of EDMCI*s been measured per EGDMFI*

The E-Government Dependency Maturity Index (EDMI) is an aggregation of the indexes of the main functional pillars referred to as the e-government dependency maturity function index (*EGDMFI*), i.e., (G2E, G2C, G2B and G2G). The value of *EDMI* lies between 0.00 – 1.00. This is represented in the equation below:

$$EDMI = w_i \sum_{i=1}^{n} EGDMFI_i \quad \text{..... Equation (3)}$$

Where i = 1 to n and n is the number of E-GDMFs, in this case n = 4 i.e., G2E, G2C, G2B and G2G. w_i *is the weight factor of each metrics as indicated in Table 1. Therefore, equation (3) becomes:*

$$EDMI = [(E\text{-}GDMF_{G2E})(w_{G2E})] + [(E\text{-}GDMF_{G2C})(w_{G2C})] + [(E\text{-}GDMF_{G2B})(w_{G2B})] + [(E\text{-}GDMF_{G2G})(w_{G2G})] \text{.....Equation (4)}$$

the weight factors (w_i) as assigned in Table 1 when substituted in equation (4), it becomes:

$$EDMI = 0.1(E\text{-}GDMF_{G2E}) + 0.20(E\text{-}GDMF_{G2C}) + 0.30(E\text{-}GDMF_{G2B}) + 0.40(E\text{-}GDMF_{G2G}) \text{.....Equation (5)}$$

Thus, equation (5) is the EGDMMM that computes the EDMI of government organisations.

iii. E-Government Dependency Maturity Comparative Quadrant (EDMCQ)

The EDMCQ is a grouping of the computed values of the EDMI into four bands of equal intervals to provide a single comparative view of the degree of dependency of various organisations on e-government solutions. It also provides for the comparison of the scores of the various metrics within and organisation. For instance, the value of G2E may be compared against that of G2C or G2B to know the areas of higher implementation of technology solutions in governance. This comparison has the potentials to unravel trends that will reflect the process of implementation of e-government platforms within organisations. The quadrants also depict the level of risk to degree of dependency. The four quadrants are respectively labeled as Q1, Q2, Q3 and Q4 as presented in Table 3.

Table 3: E-Government Dependency Maturity Comparative Quadrant (adopted from (Mbanaso et al., 2019)

Quadrant	Composite Values	Note
Q1	0.00 – 0.25	The agency is considering the use of e-government solutions but efforts are at a very limited level. This connotes lower dependency and lower risk.
Q2	0.26 – 0.50	Some e-government solutions are in place, but not consistently and structurally organised; considerably, important elements of ICT are missing. This represents implies high risk with low dependency.
Q3	0.51 – 0.75	e-government solutions are structurally implemented and integrated into the core organisation's operations but with fewer elements missing. This quad means high dependency and high risk.
Q4	0.76 – 1.00	Critical operations, services and functions are ICT-enabled and automated with all e-government models. This quadrant implies high dependency and very high risk.

CONCLUSION AND FUTURE WORK

This article presented the e-government dependency maturity measurement model (EGDMMM) with potentials to compute the degree or dependency or level of maturity of the application e-government solutions, referred to as the e-government dependency maturity index (EDMI). The model essentially incorporates three key components, namely: the E-Government Dependency Maturity Function (EGDMF), E-Government Dependency Maturity Mathematical Model (EDMMM) and the E-Government Dependency Maturity Comparative Quadrant (EDMCQ). All these components are interlinked to design the EGDMMM. For instance, the EGDMF derived its metrics from the e-government business models of G2E, G2C, G2B and G2G respectively. Its sub-categories provide the metrics that forms the basis of measurement to a level of granularity. The EDMMM uses the metrics provided by the EGDMF as variables for the derivation of the mathematical equations that support the computation of the EDMI. The EDMCQ on the other hand is a grouping of the values of the EDMI for the purpose of comparisons; either between organisations or among metrics and sub-metrics. The difference between this model and other existing works that measures the performance or application of e-government is that its model as a basis for developing an e-government dependency measurement tool (EGDMT). A software that will provide a data collection interface, a computation engine and a reporting interface that organisations, national or sub-national governments can use to assess their level of dependency on e-government solutions. The data generated from this process have potentials for application in many areas of governance. For instance, the degree of maturity of the dependency depicts proportionate of cyber risk. This data can also be used to measure the extent of the return on ICT investment, that is the value e-governance brings to the governance ecosystem vis-à-vis the level of dependency as may be computed.

metrics are driven from the e-government models, thus, having the capacity to measure the incremental application of e-government solutions in governance. The computation of the dependency maturity also provides insights into the level of cyber risk exposure that the organisations may face based on its degree of dependency on e-government. The detailed implementation and evaluation of the framework

Based on the methodology framework in Fig. 1, this paper did not cover the demonstration and evaluation phases of the DSR strategy. Consequently, future work will address these phases through the development of a survey instrument for collection of data that support an empirical assessment of the degree of e-government dependency maturity, using government institutions in Nigeria as the research context. While this process evaluates the model, it will provide government entities with empirical data on their level of dependency and by extension their proportionate cybersecurity risk exposure. This will help government entities manage their cyber risk based on empirical data. Additionally, future work will also use this

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Table 4: Comparative Analysis EGDI, NRI and EGDMI

Criteria	E-Government Development Index (EGDI)	Network Readiness Index (NRI)	E-Government Dependency Maturity Index (EGDMI))
Purpose	Measures the development of e-government services and infrastructure	Assesses a country's overall readiness to exploit opportunities offered by ICT	Assessment of the degree of dependency of government on ICT
Focus Area	Public sector service delivery and e-participation	Broader digital readiness, including individuals, businesses, and governments	Digital relationship between government, employees, citizens, businesses and inter-government
ICT Dependency Scope	Focuses on government reliance on ICT for service provision	Measures societal, economic, and institutional dependency on ICT	Focuses on government reliance on ICT for service delivery and how this could present cybersecurity risk.
Components Related to ICT	1. Online Services Index (OSI) 2. Telecommunication Infrastructure Index (TII) 3. Human Capital Index (HCI)	1. Technology (e.g., access, content) 2. People (e.g., usage) 3. Governance 4. Impact	e-government Models (G2E, G2C, G2B and G2G)
Dependency Measurement Approach	Indirect – dependency inferred through e-government service availability and infrastructure readiness	More direct – evaluates how ICT is used, governed, and contributes to development	Direct assessment of how government depends on ICT and the security risk this dependency presents
Targeted Institutions	Government institutions	Government, private sector, and civil society	Government institutions
Granularity of ICT Dependency	Primarily qualitative and infrastructure-based	Combines quantitative indicators with broader digital ecosystem assessments	Quantitative with indicators measuring the extent of dependency
Cybersecurity Relevance	Limited – cybersecurity is not a primary indicator	Moderate – governance and trust indicators may reflect cybersecurity posture	Key indicator as the dependency is to help understand the cybersecurity risk exposure.
Output Format	Composite index (0–1 scale)	Score (0–100 scale) and global rank	Composite index (0-1 scale)
Use in Policy-Making	Guides digital public service development	Supports national digital strategies and investment decisions across sectors	Supports governments at levels to understand their degree of dependency and how this poses cybersecurity risk to their existence.

Table 4 presents a comparative analysis of existing e-government assessment models, namely: the e-government development index (EGDI), the network readiness index (NRI) and the model presented in this article i.e. the E-Government Dependency Maturity Index (EGDMI). Table 4 highlights the differences in: purpose of models, focus area, cybersecurity relevance, ICT related components, targeted institutions and ICT dependency scope

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