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Investigating Design Science Research Framework for Studying Decision Making Criteria

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Abstract

According to studies, there is a need to continue advancing the Design Science Research (DSR) framework so that researchers can study complex phenomena and design appropriate computer technology solutions. Evidence from a Decision-Making Criterion (DMC) in Uganda's government service delivery at district and local council levels was selected. DSR was applied to analyze the complexity of this DMC, showing what DSR covers and what it does not cover. Other theories were then explored to address the identified inadequacies of DSR, and a newer DSR framework was proposed for studying DMCs and guiding computer science research. The main research question which guided the study was: "how can inadequacies in DSR be addressed using DMC complexity phenomenon"? This paper adopted a qualitative approach to evaluate DSR for inadequacies and arrived at a newer version for complex phenomena. NVivo software was used to analyse qualitative data, findings were generated, a DSR model was designed, a conclusion was reached, recommendations and future learning aspects for improved DSR model were highlighted.

Contribution to Sustainable Development Goals (SDGs)

This research develops a Design Science Research (DSR) framework for decision-making criteria in institutions, promoting sustainable, evidence-based innovation in industry and infrastructure planning (SDG 9). It enhances transparency, accountability, and institutional trust through structured evaluation (SDG 16). The framework fosters collaboration among academia, industry, and policymakers, strengthening partnerships and knowledge-sharing (SDG 17).

1. Introduction

Studies have highlighted an open call for continuous advancement of Design Science Research (DSR) framework for studying complex and computer related phenomena. It is reported that the DSR framework is inadequate in guiding researchers to capture the nuances in complex real-

world phenomena, yet computer solutions associated to complex realities are in demand both for solving complex societal problems and computer science research [1-3, 7-10]. DSR is a lens for analyzing real-world phenomena for computing solutions (Figure 1).

The DSR framework is a problem-solving paradigm focused on creating innovative artifacts (solutions, processes, or models) to address real-world problems. It is an artifact-centric approach that not only provides a practical solution but also contributes to new design knowledge. DSR typically involves a cycle of problem identification, design and development of the artifact, and rigorous evaluation to demonstrate its utility. DSR has been defined as the scientific study of and creation of artefacts to solve real-world problems that are of common interest [1].

DSR seeks to enhance technology and science knowledge bases via the creation of innovative artifacts that solve problems and improve the environment in which they are instantiated. The results of DSR include both the newly designed artifacts and design knowledge (DK) that provides a fuller understanding via design theories of why the artifacts enhance (or, disrupt) the relevant application contexts [2]. The outcomes of a study using DSR should solve an identified problem and improve existing processes and environment. The artefact development can also make improvements to existing solutions, and design science can identify new uses for artefacts that already exists [1, 7, 29].

Accordingly, the DK in the Information Systems (IS) discipline includes knowledge of how to structure and construct a database system, how to model business processes, how to align IS with organizational strategy, how to deliver data analytics for effective decision making as well as how to use information technology to support sustainable practices [3, 15]. DSR must produce a viable artifact in the form of a construct, a model, a method, or an instantiation [3, 25].

DMC are the standards, principles, factors, or guidelines used to evaluate and compare alternatives when making a choice. These criteria act as a "filter" to help select the best option by providing a framework for a more rational, structured, and fair decision-making process [4, 15].

Decision-making criteria are real-world service delivery applications, nuanced with complexities of decision systems composed of frameworks, iterative processes, structures, entities, data and people, historically conditioned to work together in making decisions and policies on a continuous basis [15, 33-34, 37-39]. The flow of operations within DMC is faced with complexity arising from their internal and external environments (Figure 1).

In Uganda, the service delivery decision and policy making criterion at district and local council levels, is nuanced with complexity and lack of efficiency in decision making. It is difficult to coordinate too many decision-making components (frameworks, structures, processes, entities, data, people) and not all stakeholders and entities are involved in providing information and knowledge to aid appropriate decision making (e.g., 17 out of 26 respondents in RQ allude to this fact). Studying this complexity for its simplification using computer technology requires a framework to guide capturing the nuanced reality herein.

Nonetheless, decision makers have continuously struggled to keep pace with complex decision systems leading to sub-optimal decisions. Evidence obtained from previous studies [15, 32, 35, 47] and empirical data collected in this study (17 out of 26 responses in RQ a) confirmed that there is a need to address complexity aspects in DMC to enable better operations and optimal decisions [4].

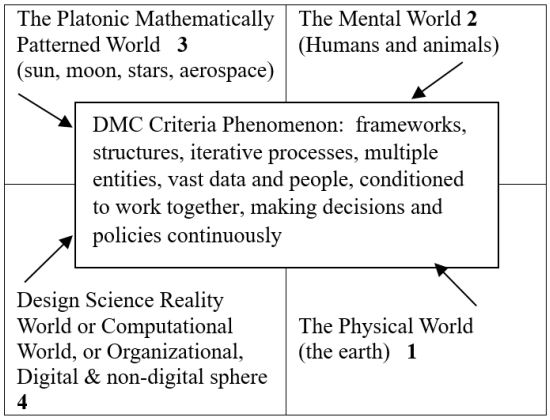


Figure 1. Contextual background of DMC vs DSR in this study (internal and external environments).

Figure 1 depicts DMC environment for analysis using DSR, sub-sectioned into lens 1, 2, 3 and 4. The external environment (1, 2, 3) includes the following: physical world (lens 1) where multiple DMC entities and DMC physical digital spheres are located; mental world (lens 2), constituted with the human and animals' consciousness playing a pivotal role in decision and policy making on a continuous basis; aerospace/platonic world (lens 3), where digital spheres of DMC tap the aerospace for long distance connectivity of entities in different locations; direct DSR-DMC relationship world (lens 4), subdivided into i. DSR world, ii. organizational world, iii. computational or digital world–where DSR enables researchers to analyse internal or organizational environment of DMC, comprising of the following: people from multiple entities; structures to allow work in various domains; following iterative processes guided by multiple frameworks; use of vast data to make decisions; and policies with uncertain outcomes. This complexity makes it difficult for decision makers to analyse situations, weigh options and choose optimal options on a continuous basis.

The era of computer technology to solve societal problems, coupled with recommendations from scholars, both offer a big promise for a solution to complex aspects. The nuances of reality in DMC cannot be inferred using the basic DSR framework alone. Its focus stops at *Lens 4 subdivision ii*. The DSR is limited in guiding analysis in lens 1, 2, 3 and 4-subdivision iii. It is not able to guide studies in analyzing associated nuances therein. The DSR focuses on technology artifacts as may be captured through lens 4 or DMC's internal environment. Even this approach alone, according to scholars, has remained a challenging aspect [6, 16, 38].

Therefore, it is inevitable to advance the DSR framework to enable studying complexity in DMC by co-opting further guidance from contextual theories in computing [11-13, 48] and decision-making [15-16] disciplines. Multiple theories provide different lenses and variables for consideration and a variety of paradigms (paradigm pluralism) to the study. The computer science theories were sought to uncover DMC from the natural lens (higher level – lens 1, 2, 3 in Figure 1) and the computational lens (lower level – lens 4 subdivision iii, computational world in Figure 1). While the frameworks in decision making (DPF and CDPF) were sought to organize realities in DMC so that they fit within the industry best practice, the computational theories were sought for studying what could be computable, how efficiently, serving as the basis for algorithms, data structures, programming languages and compilers [5]. It offers a systematic approach (all-round/360 degrees) to solving complex problems, proves correctness, analyses performance, and enables communication and innovation across different fields to solve real-world problems. The computer science theories were needed and applied at different levels to guide determination of how much computation the DMC algorithm may require (and defining the "amount of computation" is already a nontrivial task), and whether the algorithm would work correctly in all instances to solve the intended problem.

Thus, the main research question which guided the study was: "how can inadequacies in DSR be addressed using a DMC complex phenomenon"? The specific research questions which guided literature search and data collection included:

a) What features and characteristics explain complexities in decision making criteria?
b) What computer science theory can complement DSR framework at a higher level?
c) What computer science theory can complement DSR framework at a lower level?
d) How can DSR framework guide exploration of complexities in decision making criteria?

This study adopted a qualitative approach, applied the basic DSR framework to guide collecting DMC data. In the process, it highlighted DSR strengths, limitations, and identified theories to niche DSR limitations (Figure 5). The findings were the basis for the researcher to arrive at the new DSR model, recommendations, and conclusions.

2. Critical Review of Relevant Literature

2.1 Theoretical background

Computer science research involves addressing phenomena from its own discipline and other disciplines. This implies that its research theoretical usage cuts across as many disciplines as the contexts of phenomena may hold. It is reported that the DSR theory dominates in guiding computer science studies, and a consensus from researchers holds that DSR remains a foundational theory and a lens for explaining its advancements [8, 26-29]. In this study, DSR theory was considered the foundation and starting point for explaining how two other computer science theories (NPCS and CSCT) and decision making frameworks (DPF and CDPF) were co-opted to constitute a theory which guided this study (Figure 8). These theories were adopted to provide this study different lenses, variables, a variety of paradigms (paradigm pluralism) for consideration and to enable stronger inferences of complexity in the DMC phenomenon.

The five theories adopted included: Computer Science Computational Theory, Design Science Research Theory, Natural Philosophy of Computer Science Theory, Co-Design Policy Framework and a standard Decision and Policy Framework as indicated in the theoretical framework in Figure 5. These theories were selected because they are grounded theories that are mostly used to explain qualitative and quantitative empirical studies that apply DSR to explore computer decision-making applications.

a) The Design Science Research (DSR) Framework

According to Van der Merwe Alta et al. [6] and Figure 2, the DSR framework shows and defines systems to the computer science researchers as 'a hierarchy of levels of abstraction (LoAs), arranging hardware levels at the bottom of such a hierarchy and extending upwards to elements of the design and outwards to include the users. The DSR theory directs that use-case details (which include make plans, designer, developer, use plans) be captured and designed into different LoAs, and implemented to sit over appropriate computer software and hardware. The framework also cautions that use case context details are never complete, which means that they do not stop at make plan and use plan but rather remain changing and demanding their continuous revision in a cycle. According to scholars and practitioners such as Hans et al.[7], Dresch et al. [8], Venable, [9] and Carlsson [10], DSR is a dominant theory adopted to guide design of computer artifact(s)/solutions. Literature further emphasizes that attempts to advance DSR framework start from the basic DSR framework for easy understanding of any newer versions. Dresch et al. [8] share that computing researchers should be utilizing what has been made easy in the computer science research and getting the best out

of it while suggesting new ways for developing better artifacts. The DSR theory helps placement of this study to the computer science research fraternity. It lays out the lens for placing contributions obtained herein to the computing fraternity. In agreement with other researchers, this study uses basic DSR framework in explaining its findings.

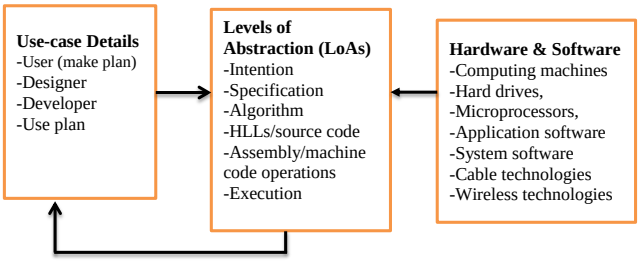


Figure 2. Summary of design science research (DSR) framework/lens/theory.

b) Natural Philosophy of Computer Science (NPCS) Theory/Framework

The frameworks by Gavilanes et al. and Penrose [11, 12] state that three Worlds and three Deep Mysteries (The Physical world, The Mental world and the Platonic Mathematical patterned world) exist naturally (Figure 3). They are the 'Platonic trinity of reality' and are the foundation of natural philosophy of computer science and other disciplines. Gavilanes et al. and Penrose [11, 12], explain the 'Platonic trinity of reality' to the computer science researchers. The three Worlds are the natural system where all computational systems point towards and draw their existence. A computer is an element of the universe and it has been made to be a mere object which extends human consciousness – making computers also essential to being participators in the study of reality. According to Angius et al. [13], Gavilanes et al. [11], and Cranfield School of Management [14], natural reality encapsulates entire society and, therefore, all societal study problems irrespective of their discipline are cited out for research from these lenses. Every computer problem in society exists under and within the umbrella of natural reality – the physical earth, sun, moon, stars, aerospace, people and animals.

Following NPCS and DSR frameworks, the researcher realized the need to follow both frameworks. The DSR and NPCS are combined as shown in Figure 4. The researcher deduced that the ontology and epistemology of DSR exists inside (is inscribed in) NPCS (the overall natural system of three worlds). The NPCS and DSR ontology and epistemological lenses are visible for adoption in this study. This study considered DSR and NPCS ontological and epistemological lenses for viewing the higher level aspects of decision-making criteria.

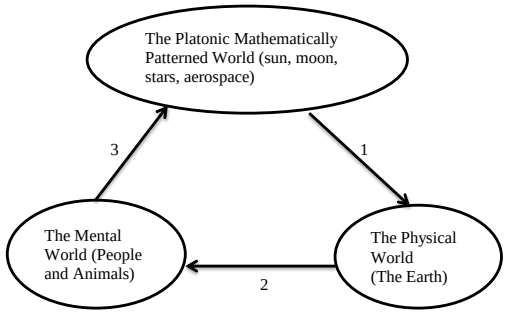


Figure 3. Three 'worlds': the platonic mathematically patterned world, the physical world and the mental world (Rogers-Penrose et al. (2021) and Xavier et al. (2022)).

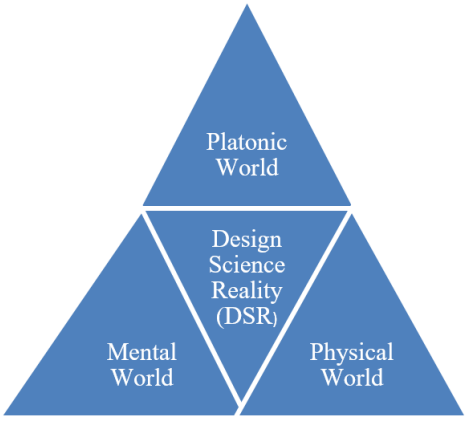


Figure 4. Design science reality lens inscribed within super natural reality.

c) Computer Science Computational Theory (CSCT) by Michael Sipser [5]

The CSTC is a one umbrella term theory of four sub-theories: Language Theory-which refers to how computations are expressed, Automata Theory – which refers to how computations are carried out, Computability Theory–which refers to fundamental limits of computation and, Complexity Theory–which refers to what resources are required to perform a certain computation. Computability sub-theory guides figuring out which functions are and are not computable and guides identification of decision making aspects. Complexity sub-theory is concerned with "How much time and memory are needed to solve a given aspect?", and guides gauging related hardware and software capabilities to support identified aspects of decision making criteria. In this study, the context for applying these sub-theories was realities in decision making criteria as depicted by the empirical findings section. The theories guide determination and/or description of appropriate computer science technologies to underly decision making criteria (Algorithm Design Language, decision trees, machine or deep learning, neural networks, or quantum), and to highlight inadequacies of existing software and hardware for future sharing with software and hardware fraternity i.e., expression of computational aspects of DMCs - how they will be carried out-in binary digits, decisions true/false, artificial intelligence (AI) or quantum, determination of fundamental limits of the DMC aspects of computation, and recommendations of resources required to perform certain DMC computational aspects. The theories also guide description of computer-based ontological and epistemological aspects of decision-making criteria and, finally, they guide advancement of the 'state-of-the-art' in computer science philosophical and theoretical discourse. The focus of CSCT umbrella theory is the computational environment of computing systems.

d) Decision and Policy Framework (DPF)

This is a standard prescribed framework for decision and policy development. It is envisaged to keep decision making criteria fit within decision making industry prescribed standards [15]. Its adoption in this study played a role in highlighting specific aspects for consideration to arrive at better decision making criteria. DPF guided focus, reliability and acceptability aspects factored in the layout and arrangement of study findings. The components of the DPF adopted to guide design of decision making criteria included: Scoping/idea, Process design, Explore policy options, Design & test, Implementation & Evaluation.

e) Co-Design Policy Framework (CDPF) [16]

This framework is adopted from Land Use Policy 134 (2023) 106901 Co-design framework by Julie Urquhart (2023) [27]. The policy is designed within the standard conceptual decision and policy lifecycle with iterative processes operating over six stages. It focuses on the development of understanding and trust, participation and inclusion for all stakeholders in decision and policy making without which co-participation remains confusing. The CDPF framework is trending in public policy development and international best practice. The study picked the 'Stakeholder' variable from this framework to spell out stakeholder relationship roles and to translate outcomes into clear messages for DMC stakeholders. The framework is reported in the literature [16].

Following the theoretical framework in Figure 5, two computer technology theories complement and/or extend basic DSR framework. One at higher level and the other at lower level; and two decision making theories from decision making discipline guided alignment of the study decision making criterion with decision making industry standards. This theoretical framework and research questions guided design of conceptual framework depicted in Figure 6.

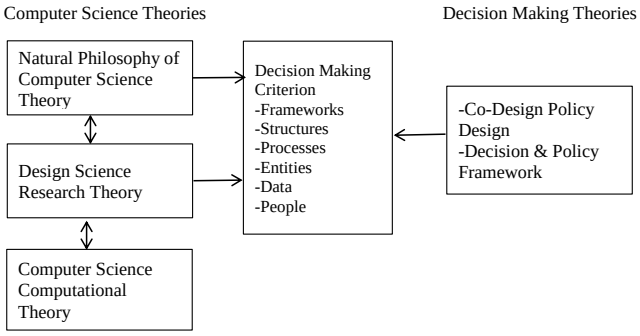


Figure 5. The DSR-Decision-Making Theoretical Framework.

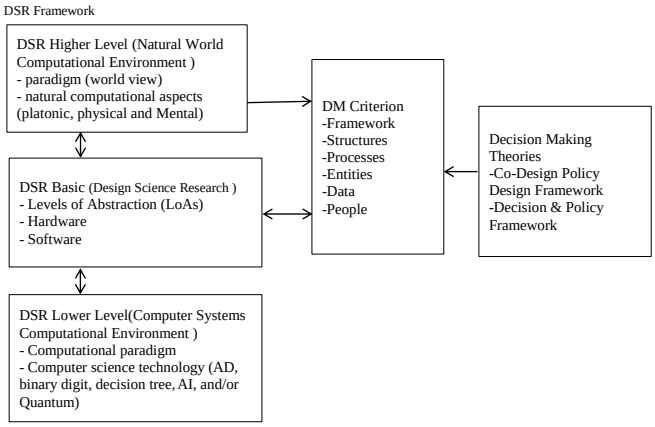


Figure 6. Conceptual framework.

f) Decision and Policy Making (DPM) Criteria

Decision and Policy Making (DPM) criteria are complex decision systems involving stakeholders, decision structural levels, processes, technologies, putting related data together, coupling data, their intuition and judgement, acting in decisions and policy making [16, 38, 45]. Decision making is constrained with such complexity and attempts to address complexity and its associated challenges are called for on a continuous basis [16, 34, 38]. In this technology era, it is inevitable to opt for computer technologies. However, to make results far better beyond computer solutions, embracing decision making industry standards promises better results. However, this approach sets-in multidisciplinary aspects in the context of the study, thereby raising a need for multiple theories to guide the study. Assessing the phenomenon for contextual disciplines from which to identify respective theories to guide the study was paramount. In the same context, capturing nuances of complexity call in a mixed methods approach. However, in this study, theories from computer science and theories from decision making disciplines, which contextualize this study, were identified and a qualitative method approach was adopted.

The DSR framework variable is composed of DSR higher level, DSR basic, and DSR lower level. DSR higher level picked its latent constructs from the Natural Philosophy of Computer Science theory. DSR Basic picked its latent constructs from the existing DSR framework/theory. DSR lower level picked its latent constructs from the Computer Science Computational theory. The combination of theories in 'DSR framework' variable and theories in the 'Decision making' variable led to the suggestion of 'Newer DSR model' for studying 'Decision Making Criteria' and any other future related studies. The variables shown in the conceptual framework were used for searching appropriate theories to guide this study.

Thus, from the review of the literature linked to the above theories in line with the specific objectives of the study and research questions, the following hypotheses were proposed in this study.

H1: Features and characteristics explain complexities in decision making criteria.
H2: Computer technology theory (NPCS) can complement DSR framework at higher level.
H3: Computer technology theory (CSCT) can complement DSR framework at lower level.
H4: DSR framework guides exploration of complexities (the internal environment) in decision making criteria.

3. Method

The first part involved a literature review searching for other scholars' views on DSR, strengths and inadequacies. DSR inadequacies pointed at inability to expound complex aspects of reality. DMC evolved a real-world aspect of

complexity. Decision and policy makers are challenged with complex decision structures, several stakeholders and guidelines. A case of a decision-making criterion (DMC) in Uganda's government service delivery at district and local council levels was selected. A qualitative approach was adopted and the basic DSR framework was used for analyzing complexity in the identified DMC. What DSR was able to cover and what it could not, were highlighted. Other theories were sought to address the identified inadequacy of the basic DSR framework, and a newer DSR framework was proposed for studying DMCs and guiding computer science research. The main research question which guided the study was: "how can inadequacies in DSR be addressed using the identified DMC complexity phenomenon"? NVivo software was used to analyze the qualitative data, findings were generated, a DSR model was designed, a conclusion was reached, recommendations and future learning aspects for improved DSR model were highlighted.

3.1 Research design

This study adopted exploratory research design to identify the range of key attributes relevant to evaluate the inadequacies in DSR framework using evidence in DMC - a case of complex phenomena. Exploratory research design was adopted because it helped the researcher to have a better and in-depth understanding of the phenomenon under study. A semi-structured interview was used to collect the data in this study because it allowed exploration of a range of pre-defined themes and freedom to cover additional related topics.

3.2 Participants and sample selection

The qualitative nature in the research questions was a basis for adoption of purposive sampling strategy to enable understanding complexity in the decision making criterion, description of DSR inadequacy and collection of purposeful data from which, the suggested newer DSR model was derived. Contextual disciplines of this study phenomenon were used to enable identification of relevant theories. In-depth semi-structured interview and focused group discussion were used to collect responses from 26 participants, interviewed individually and 55 people interviewed through focused group discussion. The interviews were conducted to get information against each specific research question. The main participants were stakeholders at district and local council levels in Uganda. The interviews and focused group discussion were conducted in six districts in Uganda as indicated in Table 1.

Table 1. Showing qualitative sample interviewed.

District	**Numbers Interviewed Direct**	**Numbers in Focus Groups**
Moroto	4	1 group of 9 persons
Kumi	8	1 focus group of 21 persons
Kitgum	6	1 group of 14 persons
Nakasongola/Luwero	3	No focus group
Mbarara	3	No focus group
Wakiso/Kampala	1	1 focus of 11 persons
Total number interviewed	26	55

3.3 Data collection

The data for this study were collected using a semi-structured interview guide. A semi-structured interview involved questions guided by identified themes in a consistent and systematic manner interposed with probes to elicit more elaborate responses as guided by Qu and Dumay, [17, 42]. This helped to generate descriptions grounded in the study phenomenon as shared in Miles & Huberman [18, 43]. The participants were informed about the aim of the study and they were asked to sign a consent form. Prior to data collection, confidentiality was assured and interviews were recorded and fully transcribed. The interviews focused on the realities in DMC, what DSR's guide can capture and what it cannot capture. The interviews lasted between 45 to 50 minutes for each

participant. The total number of participants was reached when the point of saturation was achieved, whereby, analysis of additional interviews led only to repetition of aspects that had already been mentioned in previous conversations with participants and did not result in new findings [19, 44].

3.4 Data analysis and management

The data collected from the interviews were analyzed through content analysis technique based on guidelines stipulated by Creswell [19, 44]. Nvivo 16 software was used to analyze and index the data into relevant themes. Besides, three qualitative data analysis strategies identified by Creswell, Phillip, Elo and David [19-22] which included preparing and organizing the data, coding, and presenting the data in the form of text, Tables, and Figures were also adopted in this study. The research questions were used as a guide for conducting the analysis and each question was turned into a major coding category that was broken down into sub-categories/themes.

The qualitative data analysis that involved transforming raw data by searching, evaluating, recognizing, coding, mapping, exploring and describing patterns, trends, themes, and categories in the raw data were carried out to interpret and extract their underlying meanings through thematic data analysis process [20, 22]. According to Phillip Adu [20, 49], Elo et al. [21, 40], and Byrne [22, 50], qualitative researchers can adopt two types of qualitative analysis, i.e., thematic analysis and Content analysis. Thematic analysis was used to generate themes and codes while content analysis was used to generate codes and themes before coding the data. The themes were identified based on the conceptual framework and research questions. The answers from each respondent were coded and pegged against the respective themes derived from the research questions. Content and thematic qualitative analyses were carried out on qualitative data collected to answer research questions – generating themes based on the raw data collected and arriving at framework or theory, contributions, recommendations and conclusions arrived at in the study findings.

The unit of analysis was the paragraph in each transcript that dealt with the separate DMC components. The initial coding was deductive and the scheme representing DMC was generated. The definitions of the different components were considered to help facilitate the coding process. The predetermined categories were then coded into tree nodes. Further analysis was performed, where all transcripts were carefully reviewed and text sentences were categorized into emergent themes. The emergent themes formed the sub-category codes within each of the major categories. This helped in managing the data because it eliminated irrelevant data. The components of each sub-category were specified using selective coding. This involved grouping quotations from the transcripts that represented each sub-category. This enabled us to use the participants' own words as much as possible to maximize representation of their own views as opposed to those of the researchers.

Finally, after the comprehensive coding process, cross case analysis was performed, and for each of the codes, the different components of DMC were compared. The careful analysis of the coded record helped to ensure that the domains derived accurately reflected participants' perspectives and not the researchers' own bias. This was important because it helped the researcher to avoid bias in situations of investigating reality. Further analysis was performed on the data to identify relationships using the search option. This enabled an in-depth understanding of the meaning of each coded statement and relationships among the different components of DMC. The qualitative inquiry influenced descriptions and explanations in the data collection, reliability/validity, analysis, ethical considerations and reporting of findings in this paper.

4. Results

The findings were based on the specific research questions and respective hypotheses generated under this study. The qualitative findings were used to suggest an improved DSR model (Figure 8) that can be used to study complexity in DMC and any other related future studies.

H1: Features and characteristics explain complexities in decision making criteria

According to the findings in Figure 7, the features and characteristics explaining complexity in DMC include: frameworks of structures, entities, processes, people and data. This is also supported by David [15, 17], Figure 1 and empirical evidence from 26 interviewees, 55 focused group discussion participants against specific research question (a). The government of Uganda service delivery structure in six representative districts provided DMC raw data to the study together with Government of Uganda Policy Guidelines and decision making industry standards. Mother Nature (external environment/lens 1, 2, 3 in Figure 1) impacts functionality of DMC, thereby, contributing complexity to DMC. Therefore, hypothesis (*H1*) was supported.

H2: Computer technology theory (NPCS) can complement DSR framework at higher level.

It was found that The Natural Philosophy of Computer Science (NPCS) theory by Xavier et al. [11] and Roger-Penrose [12] complements the DSR framework at higher level or outwardly. The higher level (also referred as natural reality level, and/or external environment) of the basic DSR framework is susceptible to natural realities of phenomena which are complex and unexplorable by one theory. The use case or context details of phenomena are never complete; they do not stop at make plan and use plan as guided by basic DSR framework but rather remain changing and demanding their continuous revision in a cycle [13, 23, 32]. The NPCS theory extends its guidance to uncover the gap-inabilities of basic DSR towards capturing natural related aspects. Therefore, hypothesis *H2* was supported.

H3: Computer technology theory (CSCT) can complement DSR framework at lower level.

It was found that the CSCT theory by Sipser [5] and Aquil et al. [24] extends the DSR framework at lower level. The lower level (also referred as hardware/software level, or computational level, or internal computing environment) of DSR is threatened with constant change as technology advances and changes as newer lower level computational technologies evolve. There are sustainability challenges to solutions obtained through the guide of DSR theory alone. The CSCT theory guides understanding underlying computer science aspects in all computer solutions of today and tomorrow. Therefore, hypothesis (*H3*) was supported.

H4: DSR framework guides exploration of complexities (the internal environment) in decision making criteria.

It was found that findings in *H2* and *H3* enable understanding of DMC aspects at higher and lower levels respectively. A newer version of the DSR framework was suggested for uncovering decision making criteria and any other future related studies as indicated in Figure 4. However, as the basic DSR enables exploration of organizational or internal environment of DMC, it limits exploration of computational theory aspects - the computational lens 4 in Figure 1, a lens for studying what could be computable, how efficiently, serving as the basis for algorithms, data structures, programming languages, and compilers [5]. Therefore, *H4* was not supported.

Core/Basic Design Science Research (DSR) Framework

According to Primiero Giussepe, Vom Brocke and Cloutier, the DSR framework is designed as a

research method which has guided and is still guiding design of computer solutions [23, 25, 26]. Its usage is well known for a very long time in computer design and research. The DSR framework concentrates in organisational aspects (Figure 1, Lens 4) and IT artifacts and ignores lens 1, 2 and 3 in Figure 1. DSR framework is, therefore, attributed to inability to uncover complex studies seeking computer technology for solutions. There is a call for continuous advancement of DSR framework as supported in computing literature [7-10, 23, 26, 31]



Figure 7. Cloud summary of findings.

According to findings in NVivo software word cloud, features and characteristics explaining complexity in DMC include: frameworks of structures, entities, processes, people and data. This is also supported by David Benett [15] and that DMCs are part and parcel of mother nature, according to Figure 1 and evidence arising from 26 out of 26 informants during field data collection. Mother nature impacts functionality of DMC, thereby adding complexity to DMC. The government of Uganda service delivery structure in six representative districts provided DMC raw data to the study; together with Government of Uganda Policy Guidelines and decision making industry standards.

According to the main findings under hypothesis (*H1*), the explanation of features and characteristics of complexities in DMC was obtained from information gathered through field data collected and the literature reviewed. Furthermore, from the findings based on hypothesis (*H2*) and hypothesis (*H3*), two main areas/disciplines evident in the phenomenon of this study i.e., computer science on one hand and decision making on the other hand, enabled identification of five theories (Figure 5) through reviewing literature in computer science and decision-making disciplines. Finally, the findings under hypothesis (*H2*) and hypothesis (*H3*) inform hypothesis (*H4*), a newer version of DSR framework emerged as indicated in Figure 8.

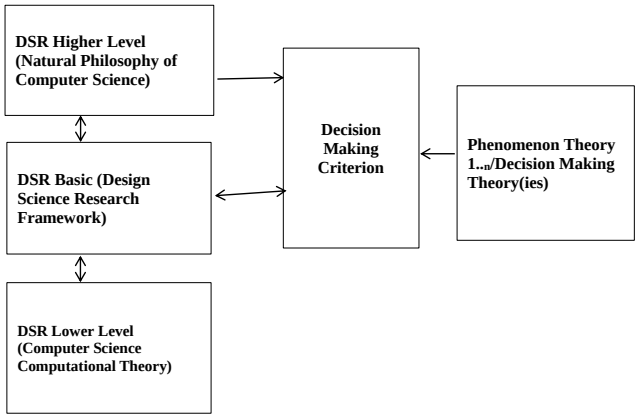


Figure 8. Suggested DSR model for studying DMC.

5. Discussions of Findings

Following the analysis of the collected data and the literature review, the study identified theories from the disciplines of computer technology and decision-making. The paper describes these theories and explains how they complement and extend one another in uncovering the criteria underlying decision-making. In addition, the paper summarizes the relationships among the theories, demonstrates their complementarity in grounding the phenomenon under study, and identifies the theoretical gap that the study seeks to address by updating or advancing the basic DSR framework.

The paper found that the DSR framework can be adopted together complementarily with the NPCS) theory and the CSCT theory. The model in Figure 9 summarizes a typical framework showing how the findings of this study have suggested a newer version of the DSR framework by

integrating the NPCS and CSCT theories with basic DSR. This implies that NPCS and CSCT can be used alongside the basic DSR framework to uncover decision making criteria. Therefore, whenever DSR framework is sought to study a complex societal phenomenon, the NPCS theory complements DSR outwardly to cover higher level and natural environmental aspects of phenomena. Similarly, the CSCT theory extends DSR inwardly to cover lower level and deep computational environmental aspects of phenomena.

H1: Features and characteristics explain complexities in decision making criteria

The DMC are organizational decision systems (Figure 1, lens 4), which are guided by decision making best practice standards while backed by computer technologies and organized by well-spelt-out frameworks, structures and entities with their iterative processes, vast data and people coordinated to work together to support decisions making. On the other hand, DMC operate in Mother Nature environment (Figure 1, lens 1, 2 and 3) and it is inevitable to understand nature's related impact to functions of DMC besides organizational aspects. The implication is that the DMC complexities cannot be explored in one theory, hence, the need to co-opt other theories from the context of DMC.

H2: Computer technology theory can complement DSR framework at higher level

The DSR framework at higher level/outwardly is natural reality explained in Figure 1 (lens 1, 2, and 3). The implication is that the NPCS theory at this level would guide exploration of the natural world aerospace (Figure 1, lens 3) of DMC and phenomena in general for: (i) computational opportunities within the aerospace (wireless technologies such as waves, satellites, Bluetooth, infrared and the natural sun energy) which may be opted as connectivity technologies in computer systems; (ii) for enabling scholars to describe ontological aspects and identify epistemic aspects of phenomena since these are always not an option in any research according to Hans [7]; (iii) considering physical locational (Figure 1, lens 1) aspects of computer systems which support the functions of the DMC; (iv) considering the mental (people and animals) aspects (Figure 1, lens 2) which interact with computing systems to attain required goals; and (v) capturing environmental aspects of phenomena in general.

Core/Basic Design Science Research (DSR) Framework

The inadequacies of the DSR framework are the focus of this study and foundation for explanation of the findings. The DSR framework lays the basis and lens for any further advances to it by scholars. The DSR framework guides identification of DMC organisational details (Framework, Structures, Processes, Entities, Data, and People) for clarification and alignment purposes, overall plans, design, developer, and usage plans for computer technology support aspects, appropriate computer software and hardware. *Implication*: the DSR framework limits its guidance to uncover organizational or core functional areas (Figure 1, lens 4). It is inadequate in guiding studies to uncover lens 1, 2 and 3 in Figure 1. This study addresses inadequacies of the DSR framework, thereby fitting its findings in the computer science research.

H3: Computer technology theory can complement DSR framework at lower level

The CSCT helps the study to describe appropriate computer sciences to underlie each DMC criterion's computational aspects for sustainability i.e., whether binary digit codes, binary or artificial intelligence (AI) decision trees, machine learning, neural networks, deep learning or quantum computing or a combination of any. *Implication:* it can enable studies to highlight inadequacies of existing software and hardware for future sharing with software and hardware fraternity or to make recommendations for

resources required to perform certain DMC computational aspects. The theories also guide description and understanding of computer-based ontological and epistemological aspects of studies, thus, enriching computer science philosophical discourses.

H4: DSR framework guides exploration of complexities in decision-making criteria

Complexities in DMC are diverse and dynamic by nature as summarized in Figure 1 and findings in hypothesis (*H1*). While complexities are institutional-based, DMC are part and parcel of Mother Nature which cannot be ignored when scholars understand the dynamics which affect functions of decision and policy makings. *Implication:* Providing studies with wider lenses enables understanding of complexities inevitably. The DSR basic framework is extendable outwardly and inwardly as explained in the findings in hypotheses (*H2*) and (*H3*) to form hypothesis (*H4*), thereby enabling evolution of a model (Figure 8) for studying other future phenomena.

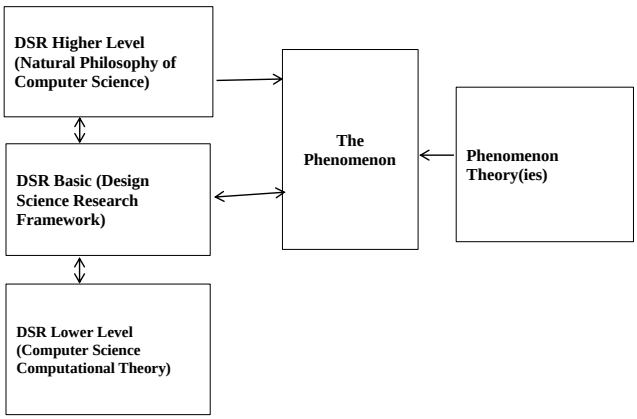


Figure 9. Proposed DSR model for studying other future phenomena.

6. Conclusion

Following results and discussions in the previous section, this study was able to find answers to its research questions and hypotheses derived under the study. The paper concludes with a suggested newer version of DSR framework (Figure 8) for studying decision making criteria, and Figure 9 for any other future related studies. The findings of this study contribute to computer science and computer solutions research, particularly in advancing the basic DSR framework.

The study also concludes that contextual areas/disciplines of phenomena are the sources of theories which can be considered for studying complex phenomena. Thus, in this study, disciplines evident in the phenomenon were the contexts explored in identifying respective theories to complement the DSR model (Figure 8). Besides, Figure 8 provides guidance in exploring and addressing doubts about AIs and their relevance in solving complex society problems - because Figure 8 facilitates exploration of natural reality where all phenomena belong. A further study could be carried out exploring suggestions of advancing DSR by other scholars and comparing Figure 8 against such suggestions to identify strengths and weaknesses.

Lastly, further studies may investigate a step-by-step use of the proposed DSR framework in other contexts than local governments.

7. Implications and Future Research Outlook

The findings from this study benefit the computer science research fraternity (advancing the basic DSR framework) in a format illustrated in Figure 9. The proposed DSR is more exploratory and captures real-world scenarios. However, further research in computational environment (hardware and software) to support complexities which Figure 9 may bring out for computation could be useful.

The findings of this study may enable practitioners using existing computer environments, especially governments in developing countries like Uganda, to share understanding and explanations regarding adequacy or inadequacy of their computing

resources to support real-world needs of their works. This can guide development of appropriate policies towards computing resources.

The findings from this study can drive advocacy towards improved DSR model that can be used by stakeholders such as governments and non-government institutions in developing countries. The institutions can engage with developers and inventors of computer programs to develop models that can supplement human knowledge in decision making and provide solutions to problems faced by society, such as improved access to health services, education services, water and sanitation, and housing.

The findings of this study can also help computer science researchers to contextualize applicability of DSR. Inadequacies in DSR can be context based. Developers and inventors of computer models can design context-based DSR models and provide solutions to diverse problems in different contexts other than generalizing its applicability.

The basic DSR has enabled development and successful usage of some AIs. However, it is limited in providing appropriate guidance in developing other AIs (especially where AIs are envisaged to solve complex aspects of life). Exploratory nature of the newer DSR has a ripple effect in providing guidance towards tuning AIs to business requirements (Users) and AI technology developers, designers and manufacturers.

8. Strengths and Limitations of the Basic DSR Framework

8.1 Strengths

Basic DSR framework enables researchers to study aspects such as internal or organizational environments of phenomena and enables researchers to arrive at technological artifacts [6]. The DSR framework also guides researchers, though to a lesser extent, to specify some portion of computational or lower level aspects of phenomena. For instance, in this study, the DSR framework guides a researcher to identify appropriate computer language for expressing DMC user requirements (algorithm design language such as UML). It also further guides researchers in determining appropriate programming languages for implementing technological artifacts. This is supported by different DSR scholars, such as Van der Merwe Alta et al. [6].

The DSR framework has been in the computing industry for a very long time. It has been adopted by scholars, practitioners and applauded as the foundational framework' from which to explain any suggestions to its advancement [2-3, 6-10, 25-29].

8.2 Limitations

The basic DSR is limited in enabling researchers to study external or natural environments of phenomena and/or the natural aspects of phenomena. For instance, in this study DSR is limited for studying DMC natural environment aspects explained in (lens 1, 2, 3) as indicated in Figure 1, or the DSR higher levels as indicated in Figure 6, 8 and 9. *The* NPCS theory facilitates researchers in studying external or natural environments of phenomena. This is supported in Gavilanes et al., Penrose Rogers, et al., and Giuseppe Primiero [11-12, 23].

The basic DSR framework does not enable researchers to investigate deeper computational or lower-level aspects of complex phenomena. For instance, in this study, basic DSR is limited in guiding the researcher to study DMC lower-level aspects indicated in (lens 4, subdivision iii). It emphasizes the importance of a researcher to identify automata technology related aspects to underly decision-making criteria - whether binary digit, binary decision trees, machine or deep learning, neural networks, or quantum should be the engineering technology to run the DMC artifact, as may be obtained from DSR. The Automata sub

theory of the CSCT theory guides researchers in these aspects. This is supported by Sipser, Michael [5] and Aquil et al. [24].

The basic DSR framework does not sufficiently guide researchers in distinguishing between computable and non-computable functions within phenomenal artifacts. The computability sub theory of the CSCT theory guides researchers in these aspects. This is also supported by Sipser, Michael [5] and Aquil et al. [24]. The DSR framework is also limited in guiding researchers to describe and communicate ontological and epistemological aspects of phenomena artifacts. The higher-level variable of the new DSR (natural lens) in this study is envisaged to guide researchers. This is also supported in Gavilanes et al., Penrose Rogers, et al., and Giuseppe Primiero [11-12, 23].

Finally, the computing environment of DSR artifacts is threatened with constant change in technology advances. Newer lower-level computational technologies evolve continuously. There are sustainability challenges to solutions obtained through the guide of DSR theory alone. The CSCT theory *component embedded in the new DSR in this study* guides understanding underlying computer science aspects in all computer solutions of today and tomorrow.

How the proposed DSR framework addresses Limitations

The study sought other theories to cover the limitations in DSR in studying DMC's complexity. The study identified theories in both computing and decision-making disciplines showed complementarity in theories (Figure 5) with DSR to uncover DMC's complexity. The newer DSR borrows from two theories, namely NPCS and CSCT, for exploring external environments/higher levels of phenomena (lens 1, 2, 3) in Figure 1, and internal environments of phenomena (lens 4, subdivision iii) in Figure 1. The study sought frameworks (DPF and CDPF) in decision making for organizing/aligning realities in DMC according to industry frameworks and best practice.

The CDPF focuses on development of understanding and trust, participation and inclusion for all stakeholders in decision and policy making without which co-participation remains confusing. The CDPF framework is trending in public policy development and international best practice. 'Stakeholder' variable from this framework to enable spelling out stakeholder relationship roles and to translate outcomes into clear messages for DMC stakeholders. The CDPF framework is reported in the literature as adaptable to any range of decision and policy making development scenarios [16]. Different components as explained above were put together to arrive at the new DSR framework, which offers a systematic approach (all-round/360 degrees) to solving complex problems. The study therefore concludes with an updated DSR framework (Figure 8) which enables researchers to study DMC's complexity and any other future complex phenomenon. The newer DSR puts together NPCS at higher level, basic DSR, CSCT at lower level, and decision making frameworks on the other hand (Figure 8).

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CONTRIBUTIONS OF CO-AUTHORS

Among Judith	[ORCID: 0009-0009-9416-5255]	Conceived the idea and wrote the paper
Makafui Nyamadi	[ORCID: 0000-0001-8858-4888]	Conducted experiments and analyzed results
Nyeko Sonny		Provided technical info on methods and materials

REFERENCES

[1] P. Johannesson and E. Perjons, "An Introduction to Design Science Research," in *Systems Development and the Method Framework for Design Science Research*, Cham: Springer, 2014, doi: 10.1007/978-3-319-10632-8_11.

[2] J. vom Brocke, A. Hevner, and A. Maedche, "Introduction to Design Science Research," in *Design Science Research. Cases*, Cham: Springer Nature Switzerland AG, 2020, ch. 1, doi: 10.1007/978-3-030-46781-4_1.

[3] A. R. Hevner, S. T. March, J. Park, and S. Ram, "Design Science in Information Systems Research," *MIS Q.*, 2004.

[4] B. Simone, "Public Policy Decision-Making: How Decisions Should Be Made Versus How They Are Made in Practice," Lead Univ., San José, Costa Rica, 2019. [Online]. Available: https://ulead.ac.cr/es/publicaciones/blog/public-policy-decision-making-how-decis

[5] M. Sipser, *Introduction to the Theory of Computation*. Boston, MA: Course Technology Cengage Learning, 2012.

[6] A. Van der Merwe, A. Gerber, and H. Smuts, "Guidelines for Conducting Design Science Research in Information Systems," Univ. of Pretoria, 2021.

[7] H. Weigand, P. Johannesson, and B. Andersson, "An Artifact Ontology for Design Science Research," *Data Knowl. Eng.*, vol. **133**, p. 101878, 2021.

[8] A. Dresch, D. P. Lacerda, and J. A. V. Antunes Jr., *Design Science Research: A Method for Science and Technology Advancement*. 2015.

[9] J. Venable, "A Framework for Design Science Research Activities," in *Emerging Trends and Challenges in Information Technology Management*, 2006.

[10] S. A. Carlsson, "Towards an Information System Design Research Framework: A Critical Realist Perspective," Claremont, CA, 2006, pp. 192–212.

[11] X. A. T. Gavilanes, "Solipsism, Schmolipsism, Multiprocessing and Alternative Architecture, The Natural Philosophy of Computer Science," 2022.

[12] R. Penrose, "Computational Natural Philosophy: A Thread from Presocratics Through Turing to ChatGPT," in *Model-Based Reasoning, Abductive Cognition, Creativity*, E. Ippoliti, L. Magnani, and S. Arfini, Eds., vol. **70**, Cham: Springer, 2024. *(Author attribution inferred — original entry garbled.)*

[13] N. Angius, R. Turner, and G. Tamburrini, "The Philosophy of Computer Science," *Stanford Encyclopedia of Philosophy*, substantive revision, 2021.

[14] Chandaria School of Management, "Research Philosophies – Importance and Relevance," 2009.

[15] A. Bennet and D. Bennet, "The Decision Making Process Under Complex Situations," in *Complex Environments*, ch. 1, 2020.

[16] J. Urquhart *et al.*, "A Co-Design Framework for Natural Resource Policy Making: Insights from Tree Health and Fisheries in the United Kingdom," 2023.

[17] S. Q. Qu and J. Dumay, "The Qualitative Research Interview," *Qual. Res. Account. Manag.*, vol. **8**, no. 3, pp. 238–264, Aug. 2011.

[18] M. B. Miles and A. M. Huberman, *Qualitative Data Analysis: An Expanded Sourcebook*. Thousand Oaks, CA: Sage Publications, 1994.

[19] J. W. Creswell, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. London: Sage Publications, 2006.

[20] A. Phillip, "Guides in Conducting Qualitative Data Analysis Using Nvivo," 2019. [Online]. Available: https://www.youtube.com/watch?v=fI-kSSHjWxM

[21] S. Elo, M. Kääriäinen, O. Kanste, T. Pölkki, K. Utriainen, and H. Kyngäs, "Qualitative Content Analysis: A Focus on Trustworthiness," 2014.

[22] D. Byrne, "A Worked Example of Braun and Clarke's Approach to Reflexive Thematic Analysis," Technological Univ. Dublin – Blanchardstown Campus, Dublin, Ireland, 2021. *(First name inferred from context.)*

[23] G. Primiero, "Information in the Philosophy of Computer Science," in *The Routledge Handbook of Philosophy of Information*. USA: Routledge, 2016.

[24] S. M. Aquil and M. N. Burney, "A Brief History of Mathematical Logic and Applications of Logic in CS/IT," Karachi Univ., *J. Sci.*, vol. **34**, no. 1, pp. 61–75, 2006.

[25] J. vom Brocke, A. Hevner, and A. Maedche, "Introduction to Design Science Research. Cases," Cham, 2020, doi: 10.1007/978-3-030-46781-4_1. *(Duplicate of [2].)*

[26] M. Cloutier and R. L. [surname unclear], "Design Science Research: Issues, Debates and Contributions," 2018.

[27] G. A. Luis, "A Design Science Research Methodology for Information Systems Research," academia.edu, 2020.

[28] V. Dolgopolovas, V. Dagienė, and E. T. Jasutė, "Design Science Research for Computational Thinking in Constructionist Education: A Pragmatist Perspective," *Problemos*, vol. **95**, Vilnius Univ. Press, 2019.

[29] J. Venable, J. Pries-Heje, and R. Baskerville, "FEDS: A Framework for Evaluation in Design Science Research," *Eur. J. Inf. Syst.*, vol. 25, no. 1, pp. 77–89, 2016.

[30] S. Gregor and A. R. Hevner, "Positioning and Presenting Design Science Research for Maximum Impact," *MIS Q.*, pp. 337–355, 2013.

[31] W. Kuechler and V. Vaishnavi, "A Framework for Theory Development in Design Science Research: Multiple Perspectives," vol. **13**, no. 6, p. 3, 2012.

[32] S. Marc, "Automated Machine Learning: AI-Driven Decision Making in Business Analytics," vol. **18**, p. 200188, 2023.

[33] E. Brynjolfsson and K. McElheran, "Data in Action: Data-Driven Decision Making and Predictive Analytics in US Manufacturing," Rotman School of Management Working Paper No. 3422397, 2019.

[34] The Republic of Uganda, "A Guide to Policy Development & Management in Uganda," Kampala, Uganda, 2013. [Online]. Available: www.regulatoryreform.com

[35] P. A. Busch, "Tacit Knowledge Acquisition and Processing Within Computing Domain: An Exploratory Study," ch. 11, IRM Press, Idea Group Inc., 2002.

[36] P. Raj, "Common Policy Problems and What Researchers Can Do About Them," London School of Economics and Political Science, LSE Book Review, 2020.

[37] T. Birkland, *An Introduction to the Policy Process: Theories, Concepts, and Models of Public Policy Making*, 5th ed. Routledge, 2019, doi: 10.4324/9781351023948.

[38] B. Marko, "Decision Making: A Computer Science and Information Technology Viewpoint," *Interdiscip. Descr. Complex Syst.*, vol. **7**, no. 2, pp. 22–37, 2009.

[39] The Republic of Uganda, "A Guide to Policy Development & Management in Uganda," 2013. *(Duplicate of [34].)*

[40] L. Floridi, "Philosophy and Computing, an Introduction," 2001.

[41] M. J. Hatch and A. L. Cunliffe, *Organization Theory*, 2nd ed. Oxford: Oxford Univ. Press, 2006.

[42] A. R. Hevner, "A Three Cycle View of Design Science Research," *Scand. J. Inf. Syst.*, vol. **19**, no. 2, pp. 87–92, 2007.

[43] J. Venable, J. Pries-Heje, and R. Baskerville, "FEDS: A Framework for Evaluation in Design Science Research," *Eur. J. Inf. Syst.*, vol. 25, pp. 77–89, 2016. *(Duplicate of [29].)*

[44] S. Seidel, J. Recker, and J. vom Brocke, "Sensemaking and Sustainable Practicing: Functional Affordances of Information Systems in Green Transformations," *MIS Q.*, vol. **37**, no. 4, pp. 1275–1299, 2013.

[45] B. Beatrice, "A Process for Defining Decision Making Criteria," Int. Inst. for Facilitation and Change, 2018.

[46] A. Bennet and D. Bennet, "The Decision Making Process Under Complex Situations," in *Complex Environments*, ch. 1, 2020. *(Duplicate of [15].)*

[47] F. Banha, A. Flores, and L. S. Coelho, "A New Conceptual Framework and Approach to Decision Making in Public Policy," *Knowledge*, vol. **2**, no. 4, pp. 539–556, 2022, doi: 10.3390/knowledge2040032.

[48] G. Primiero, "Information in the Philosophy of Computer Science," in *The Routledge Handbook of Philosophy of Information*, Univ. of Milan: Routledge, 2016. *(Duplicate of [23].)*

[49] B. Simone, "Public Policy Decision-Making: How Decisions Should Be Made Versus How They Are Made in Practice," Lead Univ., San José, Costa Rica, 2019. *(Duplicate of [4].)*

[50] M. N. K. Saunders, P. Lewis, and A. Thornhill, *Research Methods for Business Students*, 8th ed. UK: Pearson Education Limited, 2019.

[51] E. G. Guba and Y. S. Lincoln, "Competing Paradigms in Qualitative Research," in *Handbook of Qualitative Research*, 1994.

[52] C. Hakim, *Research Design: Strategies and Choices in the Design of Social Research*, Contemporary Social Research Series 13. London: Allen and Unwin, 1987.

[53] K. Mwita, "Thematic Analysis of Qualitative Research Data: A Seven-Step Guide," SSRN 5200939, Mar. 2025.

[54] J. W. Creswell, *Qualitative Inquiry and Research Design: Choosing Among Five Traditions*, 2nd ed. California, USA: SAGE Publications, 2007.

[55] M. Q. Patton, *How to Use Qualitative Methods in Evaluation*. USA: SAGE Publications, 1987.

[56] V. Braun and V. Clarke, "Using Thematic Analysis in Psychology," *Qual. Res. Psychol.*, vol. **3**, no. 2, pp. 77–101, 2006, doi: 10.1191/1478088706qp063oa.

[57] K. Hartl and O. Jacob, "The Role of Data Quality in Business Intelligence – An Empirical Study in German Medium-Sized and Large Companies," 2016. *(Author order inferred from garbled entry.)*