

Full paper

STUDYING COMPUTER SCIENCE AND OTHER TOOLS CAPABILITIES TO SIMPLIFY AND ENHANCE DECISION AND POLICY MAKING CRITERIA

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Abstract

The phenomenon ‘studying computer science and other tools capabilities to simplify and enhance decision and policy making (DPM) criteria’ is multidisciplinary and complex. While the study promises a better model of DPM criteria, approaches to studying complex and computer science technology related studies are reported to be dominated by single research methods, i.e., quantitative or qualitative. Minimal studies have adopted mixed methods research. This methodological gap led this paper study to a main research question ‘...How can mixed methods research (MMR) uncover studying computer science and other tools capabilities to enhance DPM criteria? This study reviewed literature, investigating for MMR model to answer this main research question, guided by specific research questions and an existing MMR theory. The findings reveal a suggested mixed methods research (MMR) model for adoption to study the said phenomenon and any other future related studies.

Keywords: mixed methods research; computer science and other tools; decision and policy making criteria.

Introduction

Decision and policy making (DPM) criteria are complex decision systems comprised of frameworks, iterative processes, structures, entities, data and people, historically conditioned to work together making decisions and policies (Benett & Benett, 2020; Primiero, et al, 2021; Schmitt, 2023; Busch, et al 2002), and others. Actual workings of DPM criteria are unclear and increasing need for scientific evidence to guide development of better DPM criteria is reported in other studies (Patel, 2020; Birkland, T.A., 2019).

The phenomenon ‘studying computer science and other tools capabilities to simplify and enhance decision and policy making (DPM) criteria’ is multidisciplinary besides being complex. While a study which combines computer science technologies, other tools and techniques promises to simplify and enhance DPM criteria, approaches to complex and computer science technology related studies are reported to be dominated by a single research method, i.e., quantitative or qualitative; and minimal examples have adopted mixed methods research (Samuelsson, 2023, Primiero, 2016, Floridi, 2001, Musa, 2018, Alexander, Gavilanes, 2022, and Penrose, 2021, Urquhart, 2023, Benett & Benett, 2020, Musk, 2023, Amarasinghe, et al, 2023), and others. Quantitative or qualitative research approach alone cannot be adequate to uncover complexity in DPM criteria. In this study, mixed methods research approach is investigated for a model to uncover complexity and inadequacy of single method’s gap. According to (Plano-Clark, 2018; Creswell, 2014), and others, mixed methods have been used successfully to address complex phenomena. The main research question arising from inadequacy of a single method’s approach and gap for this study is ‘...How mixed methods research (MMR) can uncover studying computer science and other tools capabilities to enhancing DPM criteria’. This study investigated literature for a MMR model to answer this main and specific research questions.

Following the topic complexity and cross-disciplinary nature, this paper specifically used a convergent mixed method sequential and explanatory design (MMSED) which involves conducting the qual and quan components of the study sequentially (Viswanath, et al, 2023, Venkatesh et al., 2016, Creswell & Plano-Clark, 2018). Quantitative phase (RQi and RQii) followed by qualitative phase (RQiii), data collection and analysis occurring sequentially, and the results of the QUAN phases were integrated to guide development of QUAL phase as summarised in *Figure 6*, with qualitative data results taking the higher weight. Findings were used to propose a mixed methods research model (*Table 4*) as an approach for adoption in studying DPM criteria and any other future related study.

The main research question which captured attention in this paper is: ‘...How can mixed methods research (MMR) approach uncover the phenomenon of studying computer science and other tools to enhance DPM criteria? The specific research questions, therefore, which guided literature search and review process include:-

- (i) What theories can guide studying computer science technology embedded with other tools to simplify and enhance decision and policy making criterion?
- (ii) What elements constitute a standard mixed methods research?
- (iii) How can mixed methods research (MMR) uncover computer science and other tools capabilities to enhance DPM criterion using findings of research question (i) and (ii) above? .

Literature Review

Critical Review of Relevant Literature

Mixed Methods Research (MMR) Approach

Mixed method is a research design with philosophical assumptions as well as methods of inquiry. It is both methodology and method. As a methodology, it involves philosophical assumptions guiding the direction of collection, analysis and mixing of qualitative and quantitative data in many phases of the research project, and; as a method, it involves collecting, analysing and mixing quantitative and qualitative data in a single study. Its main premise is to understand the research aspect better than either approach alone. Consensus among mixed methods researchers points out that centrality of mixing the quantitative and qualitative approaches is a distinguishing feature of MMR and that it is both a methodology and method (Creswell, Plano, 2018, Creswell & Plano 2007, p.5, Johnson, Onwuegbuzie, Turner, 2007) and others. The MMR has been commonly associated with multiple views of the world or critical realist studies, and a research method for complex phenomena addressing weaknesses of single research approaches (Quan or Qual). (Creswell & Creswell, 2018) (Venkatesh et al., 2016) and others. In this study, centrality of mixing MMR, MMR as a methodology and MMR as a method are explained in the ‘Method’ section. Besides, ‘computer science and other tools capabilities to simplify DPM criterion’ is complex phenomenon of objects, entities and structures historically conditioned to co-exist in decision and policy making. The MMR approach, therefore, is adopted for the study.

Mixed Method Research Design (MMRD)

Scholars in mixed method research argue for purpose/appropriateness of using mixed methods in given studies and have portrayed a significant agreement towards what elements constitute a good mixed methods research design (Greene, 2007, et al). According to scholars, there are existing MMR frameworks from past studies, all of which, portray basic common elements of MMR. These frameworks guide MMR. The MMR approach to phenomena, therefore, have

existing MMR frameworks from past studies which guide MMR. This study adopted existing MMR framework (*Table 5-1*) which summarises general properties or elements of a good research method design *adapted from (Viswanath, et al, 2023), pg 78.*) to include:- design investigation strategies, strands of the study, time orientation, priority of methodological approach, and mixing strategies (Viswanath, et al, 2023), (Creswell & Creswell, 2018) and others.

In this study all the general properties of MMR are adopted and specific subcategories are pointed out to portray the methodology herein to address this study main research question. *Table 5-1* guided this study as the main theory and the basis for deriving *Table 4*, which summarises MMR model as this paper study outcome.

Computer Science (CS)

Computer science comprises many sub fields or specialized areas such as artificial intelligence (machine learning (ML), deep learning, natural language processing, computer vision), algorithm design (AD) to make up software or express specifications, theory of computing, computer hardware architecture, programming languages and software engineering, security and cryptography, systems and networking, human computer interaction, cloud computing, edge computing, quantum computing, extended reality, bioinformatics and robotics (Massachusetts Institute of Technology EECS, 2024, Chiradeep BasuMallick, 2024, Michigan Tech, 2024) and others. The different computing technologies solve societal problems contextualised in their respective sub fields/areas. Computer science cuts across multiple disciplines, drives interdisciplinary collaboration in helping users address critical societal problems of the era (Hosman, Fife, Arme, 2008, Amnon H. Eden 2007) and others.

This study picked computer science machine learning (ML) and computer science algorithm design (AD) technologies because (i) extraction of data from one point to the other characterizes decision and policy making criteria and ML technology addresses this challenge. Machine Learning (ML) is a computer science tool commonly applied in tasks which require information extraction from large datasets (Sara Brown, 2021), Shreya Kulkarni, et al (2023), (Tsedal Neeley, 2023), and; (ii) empirical data which will be collected from the study will require to be simplified from its natural appearances and this calls for AD technique. According to Tsedal Neeley, 2023, Amnon H Eden, 2007), Algorithm Design (AD) is a computer science area which concerns modelling existing society problem - making it ready for computation, and; prior to ML application, complexity in data generated requires to be broken down systematically into an algorithm or its representation, and; AD is central to ML and is a prerequisite to ML. .

However, any other computer science technology will also be co-opted based on how the study data which will be collected may find it fit.

Other Tools

These are tools which can be combined to work hand in hand with identified computer science technologies to simplify and enhance decision and policy making (DPM) criteria.

In this study, these tools are two decision and policy making industry frameworks adopted with the aim to keep the findings of the study within established and already understood and practiced standards. Adopting the frameworks will also enable acceptability, reliability and consistency aspects of the study findings in the decision and policy making industry, studies and body of knowledge. The two tools are:- (i) the Co-Design Policy Framework (CDPF) by Julie Urquhart, 2023 adapted from Land Use Policy (134, 2023) 106901 - which is currently trending framework

in public policy development and international best practice standard in spelling out all stakeholder roles in decision and policy making. The framework is reported to be adaptable to any range of DPM development scenarios (Julie-Urquhart, 2023), and; (ii) the Decision and Policy Framework by Alex Benett and David Benett, 2020 - which is also a standard prescribed approach for adoption in any area/activity requiring policy development. It also guides focus, and alignment of overall findings of the study to a final decision and policy making criterion.

Decision and Policy Making (DPM) Criteria

Decision and policy making (DPM) criteria are complex decision systems which are comprised of frameworks, iterative processes, structures, entities, data and people involved and conditioned to work together making decisions and policies. Their actual workings are unclear and there is increasing need of scientific evidence to guide development of better DPM criteria (Benett & Benett, 2020, et al, 2021, Bohanec, 2009, Peter et al, 2002, Dinur, 2011), and others. Combining computer science technologies, other tools and techniques to address decision and policy making criteria aspects promises better DPM criteria but sets-in multidisciplinary to the context of the study. The study cannot be well explored using only one research method (quantitative or qualitative alone) but rather a mixed methods approach. Multidisciplinary also brings in a need for multiple theories other than one theory to guide the study. Assessment of phenomena for contextual disciplines from which to identify respective theories to guide the study is paramount. In this study, theories from computer science and theories from decision and policy making disciplines - the disciplines which contextualise this study were identified.

Conceptual Framework

Theoretical Background

Computer science research addresses phenomena from its own discipline and other disciplines. Its research theoretical usage, therefore, cuts across as many disciplines as the contexts of phenomena dictate. This calls for assessment of given research phenomena for contextual discipline(s), respective theories, and connection-ness to computer science for solutions. This complexity cannot be well explored using guidance from only one theory. There is a need to co-opt guidance from contextual theories of phenomena.

However, studies report that design science research (DSR) theory dominates guiding computer science solution studies and it is a foundational theory from which to further any new theories and updates to it by researchers (Nicola, et al, 2021; Michael, 2012; Luciano-Florida, 2001) and others. In this study, DSR theory is considered the foundation and starting point for explaining co-option of other discipline theories into guiding exploration of this study phenomenon.

Multiple theories provide different lenses and variables for consideration and a variety of paradigms (*paradigm pluralism*) to the study (Viswanath, 2023; Venkatesh, et al, 2016). This is also the philosophy underlying the use of mixed methods research in this study. Researchers are encouraged to embrace pluralism within mixed methods in order to realise stronger inferences and richer insights of phenomena (Viswanath, 2023).

Theories

This study identified and blended components of one main theory and five other theories to guide exploration of the mixed methods research (MMR) gap of this study. The theories include:- MMR framework (main theory), 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). *Table 2, Figure 1, Figure 2 and Figure 3* respectively, are explanations of each theory and how it is expected to guide this study, a diagrammatic summary of DSR theory, a diagrammatic summary of NPCS theory, and a diagrammatic illustration of relationships in theories to uncover computer science and DPM aspects of the study.

Table 2, Figure 1, Figure 2, Figure 3
Visual summary of Theories/Frameworks (MMR, DPF, CDPF, NPCS, DSR and CSCT)

Theory/Framework and References	Explanation	How it guides study
Mixed Methods Research (MMR) Framework by <i>(Viswanath, Venkatesh, Susan-Brown, Yulia-Sullivan, 2023), pg 78 and others Table 5-1</i>	This is a framework which states standard general properties mixed methods researchers adopt to uncover complex research phenomena.	This study uses the MMR framework <i>table 5-1</i> to derive and, to specify general properties of MMR for this paper study. *It is the main theory guiding this study.
Co-Design Policy Framework (CDPF), by <i>(Julie-Urquhart, 2023) adopted from (Land Use Policy 134, 2023) 106901</i>	CDPF is a trending framework in public policy development and international best practice standard designed within the standard conceptual policy lifecycle with iterative process operating over six stages. It is a guide to simplification and enhancement of DPM within the familiar concept of policy cycle from initiation to evaluation. It guides development of understanding and trust, participation and inclusion for all stakeholders within the policy development process, without which stakeholder roles are confusing and not possible.	The study picks the ‘Stakeholder’ variable from this framework to spell out stakeholder relationship roles and to translate outcomes into clear messages for DPM improvement. The framework is reported in the literature as adaptable to any range of DPM development scenarios <i>(Julie-Urquhart, 2023)</i> .
Decision and Policy Making (DPM) Criterion: <i>(Benett and Benett, 2020, Giuseppe , et al, 2021, Bohanec, 2009, Busch, et al,2002, Dinur, 2011), and others</i>	A framework of a complete decision system involving all stakeholders in decision structural levels, processes, putting related data together, coupling data and their intuition and judgement, taking action and make decisions.	This is an overall expected end result of this study, i.e. a simplified and enhanced DPM - A complete decision system, both computer science technology based and other tools based, spelt out framework, its iterative processes, structures, entities, data and people, coordinated to work together, making decisions and policies.

<p>Decision and Policy Framework (<i>Alex Benett and David Benett, 2020</i>).</p>	<p>-Decision and Policy Framework is a standard prescribed approach to be taken to an area/activity requiring policy development (<i>Alex Benett and David Benett, 2020</i>).</p>	<p>DPF is a standard policy framework envisaged to keep this study policy process consistent and fitting it within existing policy standards (<i>Alex Benett and David Benett (2020)</i>). Its adoption in this study plays a role in highlighting specific aspects for consideration to arrive at the study decision and policy criterion. It guides focus, reliability and acceptability of the study outcome.</p>
<p>The Design Science Research (DSR) Theory by (<i>Primiero, 2016</i>)</p>	<p>The DSR theory is design as a research method and states that use-case details (make plans, designer, developer, use plans) be captured and designed into different levels of abstraction (LoAs), and implemented to sit over appropriate computer software and hardware; and cautions that, use case context details are never complete, they do not stop at make plan and use plan but rather remain changing and demanding their continuous revision in a cycle. <i>See Figure 1 below.</i></p>	<p>The DSR points out ontological and epistemological views of computing systems from their internal computing environment. Its guide helps placement of this study to the computer science research fraternity. It lays the basis and a lens for placing any contribution obtained herein to the computing fraternity. DSR guides identification of DPM details (Framework, Structures, Processes, Entities, Data, People - for clarification and alignment purposes; overall plans, design, developer, & usage plans for computer technology support aspects, appropriate computer software and hardware;</p>
<p>Natural Philosophy of Computer Science (NPCS) Theory By (<i>Xavier, Alexander, Tintin, Gavilanes, 2022</i>) and (<i>Roger-Penrose, 2021</i>)</p>	<p>Explains the ‘Platonic trinity of reality’ to the computer science research fraternity. It deduces that the ontology of digital computational systems exists in the overall natural system of three worlds (Physical, Mathematical patterned world and Mental world). <i>See Figure 2.</i></p>	<p>The theory guides the study to derive investigation directions for exploring the natural aspects of the phenomenon. The theory extends ontological and epistemological views of computing systems from their internal computing environment to the ‘natural reality’ environment and/or platonic reality (from the DSR direction</p>

	<p>NPCS states that three Worlds are the natural system where all computational systems point towards and draw part of their existence. A computer is an element in the nature 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.</p>	<p>to natural reality).</p>
<p>Computer Science Theory of Computation (CSTC) by (Sipser, Michael, 2012),</p>	<p>The CSTC is a one umbrella term theory of four sub theories:- Language Theory (how computations are expressed), Automata Theory (how computations are carried out - binary digits, decisions yes/no, true/false, quantum, etc), Computability Theory (fundamental limits of the computation) and Complexity Theory (what resources are required to perform a certain computation). CSTC points out the deeper computer system lens beyond DSR does. Computer science is seen as the computational environment of computing systems.</p>	<p>The CSTC helps the study to describe appropriate computer technologies to be embedded in DPM criteria (AD, ML, or other) and/or to highlight inadequacies of existing software and hardware for future sharing with software and hardware fraternity (expression of computational aspects of DPMs, how computational aspects of DPMs will be carried out - binary digits, decisions yes/no, true/false, quantum, etc), fundamental limits of the DPM aspects of computation, and recommendations of resources required to perform certain DPM computational aspects). The theories also guide the computer-based ontological and epistemological directions of the study; and, guide advancement of the computer science state of the art – such as making a contribution in computer science philosophical discourse.</p>

Table 2: Theories/Frameworks, Explanations and How they Guide the study

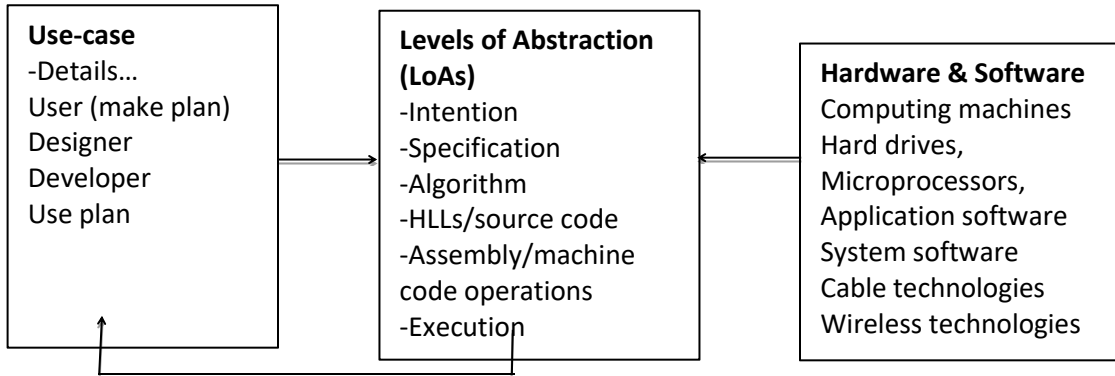


Figure 1: Summary of Design Science Research (DSR) Framework/Lens/Theory

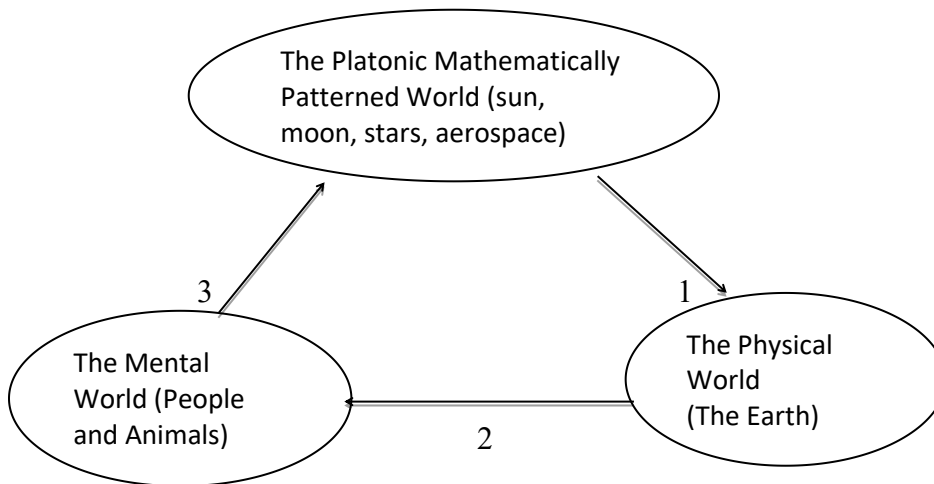


Figure 2: Three 'Worlds' (Natural Reality) - The Platonic Mathematical Patterned World, The Physical World and The Mental World. This diagram summarises the framework of the NPCS and provides the researcher a natural lens of viewing the phenomenon.

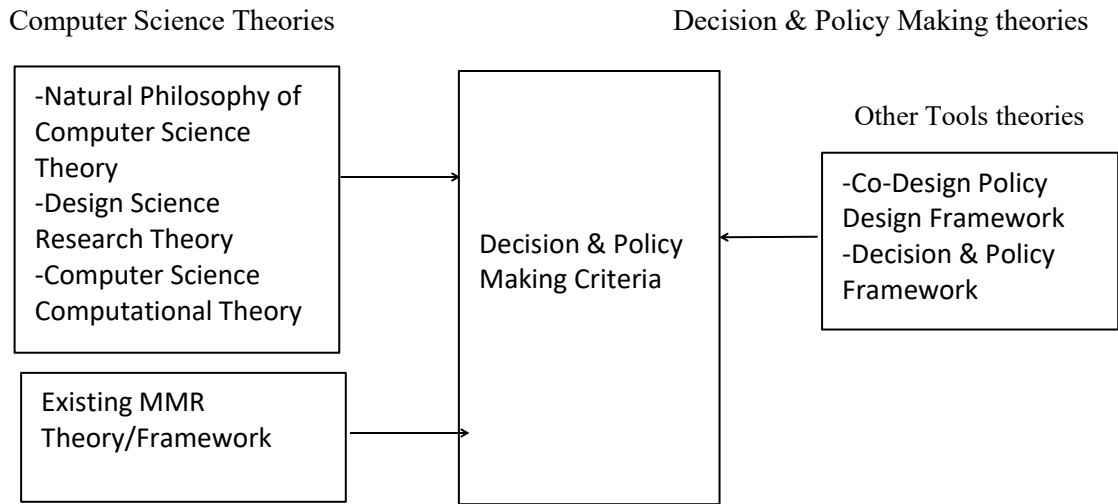


Figure 3: Computer Science Theories, DPM theories and Existing MMR Framework will together guide studying DPM Criteria.

Following theoretical framework in *Figure 3*, 3 computer science discipline theories, an existing mixed methods research theory/framework and 2 theories from decision & policy making discipline, will guide studying computer science and other tools capabilities to simplify and enhance decision and policy making criterion. This theoretical framework guided design of conceptual framework depicted in *Figure 4* below.

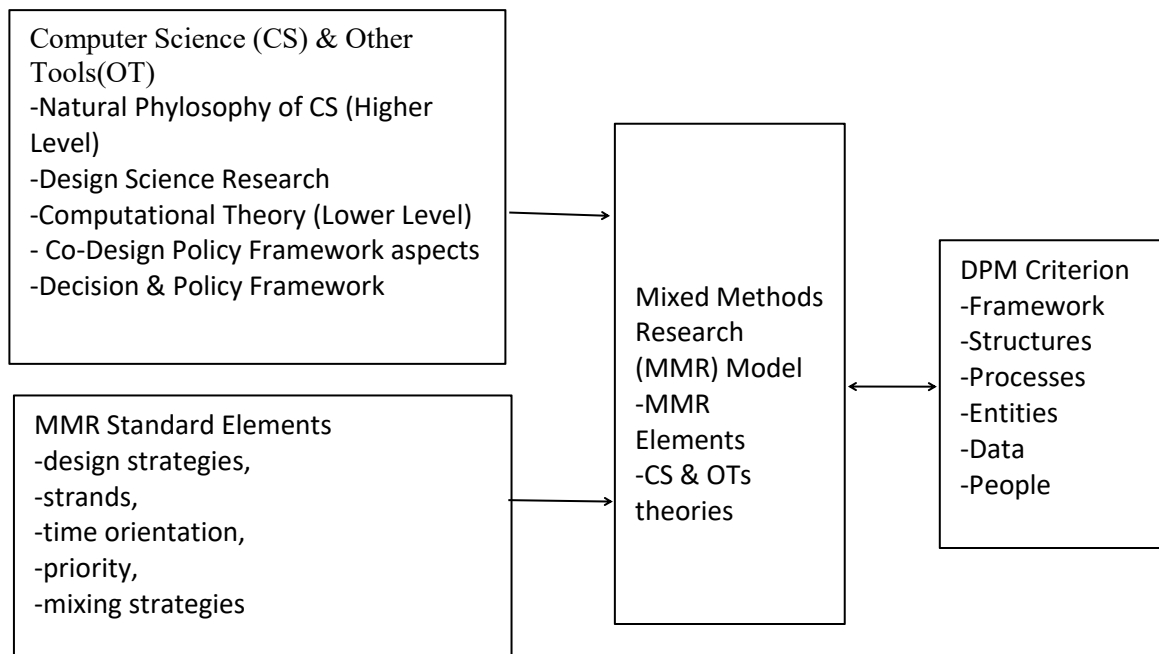


Figure 4: Conceptual Framework designed from four variables in the theoretical framework

Theories in computer science discipline and theories in decision and policy making discipline will guide studying computer science and other tools variable. Existing mixed methods research framework (*Table 5-1*) provides standard elements which any mixed methods research framework should have and it is from which, the 'MMR Standard Elements' variable was obtained. The combination of theories in 'computer science & other tools' variable and elements in the 'MMR Standard Elements' variable lead to 'MMR model' for studying 'DPM Criterion'. Elements in existing mixed methods research framework are unanimously accepted by many mixed methods research scholars (Viswanath, Venkatesh, Susan-Brown, Yulia-Sullivan, 2023), pg 78) and others. The two together lead to the suggestion of a mixed methods research model for studying a simplified and enhanced decision and policy making criterion.

Method

Study Design

While literature review was the main method and data collection adopted, Mixed Methods Sequential Explanatory Design (MMSED) guided which data was collected first and which one subsequently. In MMSED, Quantitative phase is followed by Qualitative phase, data collection and analysis occur sequentially, and the results of the QUAN phase guide development of QUAL phase (Creswell & Plano Clark, 2011: 69, Ivankova, Creswell, Stick, 2006). Figure 6 summarises the MMSED of this study. The MMSED time orientation property involves conducting the qual and quan components of the study sequentially (Viswanath, et al, 2023, Venkatesh et al., 2016). Research Qn ii after Research Qn i and RQn iii after RQn i and ii sequentially. The results were analyzed separately and converged, compared against required themes, concepts and research questions, discussion is made, MMR model is suggested and conclusion is made.

Data Collection Approaches

This started with a systematic literature review.

a. Article Search and Selection Criteria. Database search – The review process identified database(s) that cover the discipline of computer science solutions research work; and journals or articles and reports or working documents that have recorded research work on related studies in the discipline of decision and policy making.

Databases searched include:- Elsevier; Journal of Behavioral and Applied Management, International Journal of Science & Research (IJSR); International Research Journal of Engineering and Technology; Taylor & Francis e-Library, Emerald, Google Scholar, Sage online journals, Oxford university press.

Scholarly works obtained from:- MIT Sloan School of Management; Harvard Business Review, Computer Science Faculty, National Polytechnic School; Bergen, Long Island University, Cranfield School of Management, Cambridge University Press; The Change Leadership Conference.

Textbooks: Textbooks and book chapters partly reviewed include:- Introduction to Computing, Explorations in Language, Logic and Machines, 2019 Edition; Organization Theory; Tacit Knowledge Acquisition and Processing Within Computing Domain: An Exploratory Study, Chapter 11;

b. Search terms: These included:- mixed methods research, computer science theories and theorists, philosophy of computer science, design science research, natural philosophy of computer science, computer science frameworks/models, decision making structures and

frameworks.

c. Inclusion Criteria. In screening for inclusion, articles of computer science solution studies, decision and policy making, tools and techniques for decision and policy making definitions, models/theories or related concepts were included.

d. Articles Selected from Inclusion Criteria. Distribution of articles by year of publication: Articles from the period 2019 - 2023 were looked at focusing on the debate on computer science philosophy, natural philosophy of computer science, computer science theories, decision and policy making, decision policy frameworks. Articles and research works from the period back in 1960s, 70s and early 2000s regarded other disciplines and research works from which this research shares and borrows its ideas and concepts. Computer science is an interdisciplinary field seeking to solve different problems in society irrespective of fields where need arises.

Distribution of articles by regions: Articles and textbooks reviewed are from different parts of the world, i.e., USA, Korea, Mexico, Slovenia, Australia, Europe, University of Arkansas, University of Arizona, State University of New York, Binghamton, Uppsala University, Uppsala, Sweden, University of Toronto Research Ethics Board. Computer Science Faculty, National Polytechnic School; Bergen, Long Island University, Cranfield School of Management, Cambridge University Press.

Article classification is based on research method (qualitative papers, quantitative, mixed, case studies, content analysis): Papers of qualitative method were picked than those which adopted quantitative method; and only 2 papers from mixed method research. See *Figure 5*.

Sequential data collection followed the systematic literature review. According to Creswell & Creswell, 2018, Creswell, et al, 2003, in Sequential data collection, QUAN or QUAL data is collected first, and the results inform the second QUAN or QUAL form of data collection. The forms of data are related or connected or independent. In this study, a qualitative approach was used to collect both Qual and Quan data from literature reviewed, where relevant theories (RQn i) and key elements of a standard mixed methods research (RQn ii) were identified and explained. Data collected was also compiled in Excel sheet and synthesised into qualitative and quantitative content. Some of the findings are summarised in *Figure 5*.

Sampling (Random and Purposive) techniques. The QUAN-QUAL mix nature in the research questions is a basis for adoption of mixed methods sampling strategies. Probabilistic/random sampling strategy is adopted in the QUAN strands (RQn i and RQn ii) analysis of literature for relevant theories, elements of MMR and evidence to this study gap. In the QUAL strand(RQn iii), purposive sampling is adopted to pick literature which is purposeful to the realisation of the suggested MMR model or end result of this study.

Data analysis involved pooling some data into an Excel sheet and analysed simultaneously for qual and quan data strands and research qns of this study. Other data was constantly compared and analysed for required aspects as it was collected from the readings. On one hand, findings of analysis were picked and included in this paper write up straight away and on the other hand, the findings were recorded in an Excel sheet. Analysis of the literature reviewed enabled generation, explanation and summarising of different models, frameworks, drawings, & figures in this paper.

The mixed methods mixing points (MMMPs) in this paper occurred right away from the philosophical phase (a critical realist view of a decision and policy making framework, its iterative processes, structures, entities, data and people, coordinated and conditioned to work together over time, making decisions and policies' as the study philosophical direction, to the

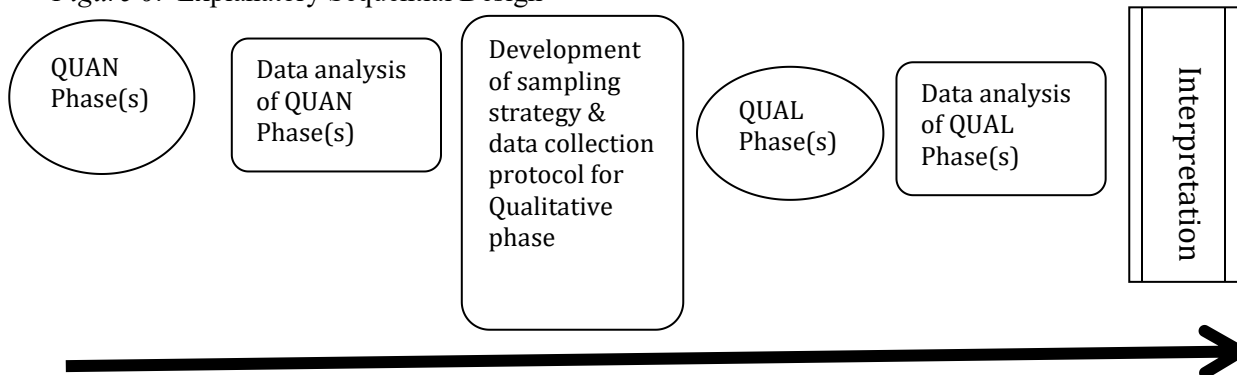
research questions (QUAN and QUAL) the literature review itself (identification and description of theories), to the data collection and data analysis levels. The mixing of the mixed methods mixing points of this study, therefore, is fully mixed.

Table 5-1. General Properties of Mixed-Methods Research

Mixed-Methods Property	Key References	Key Design Questions	Possible Dimensions
Design investigation strategies	Tashakkori and Teddlie (1998)	What is the goal of the mixed-methods study? Does the study attempt to develop a theory or test a theory?	<ul style="list-style-type: none"> • Exploratory • Confirmatory • Both
Strands/phases of research	Teddlie and Tashakkori (2006)	How many phases/strands of research does the study need to answer the research questions?	<ul style="list-style-type: none"> • Single phase (or single study) or monostrand • Multiple phases (or research program) or multistrand
Time orientation	Creswell (1995); Creswell et al. (2003); Tashakkori and Teddlie (1998)	What is the order of the qualitative and quantitative components of the study?	<ul style="list-style-type: none"> • Sequential • Concurrent
Priority of methodological approach	Johnson et al. (2007); Tashakkori and Teddlie (1998)	Are the qualitative and quantitative components of the study equally important?	<ul style="list-style-type: none"> • Equivalent/equal status • Dominant-less dominant (i.e., qualitative dominant or quantitative dominant)
Mixing strategies	Teddlie and Tashakkori (2009)	When does the mixing take place?	<ul style="list-style-type: none"> • Fully mixed • Partially mixed

Adapted from Venkatesh et al. (2016). Obtained in: (Viswanath Venkatesh Susan Brown Yulia Sullivan, 2023), pg 78

Figure 6: Explanatory Sequential Design



Creswell & Plano Clark (2011: 69)

The Mixed Methods Research (MMR)

The MMR Framework in *table 5-1* is an existing and main theory which has been adopted to guide the process of realizing MMR model/approach and output of this study which is summarised in *table 4*.

In concluding the methodology, both the MMR framework (Adapted from Venkatesh, et al., 2016)., obtained in: (Viswanath et al, 2023, pg 78) and the relevant theories identified from the literature review process have guided realization of a proposed mixed methodological approach to computer science and other tools capability to simplify and enhance DPM criteria of this study and any other future related study.

Results/Discussion/Implication

Main Findings:

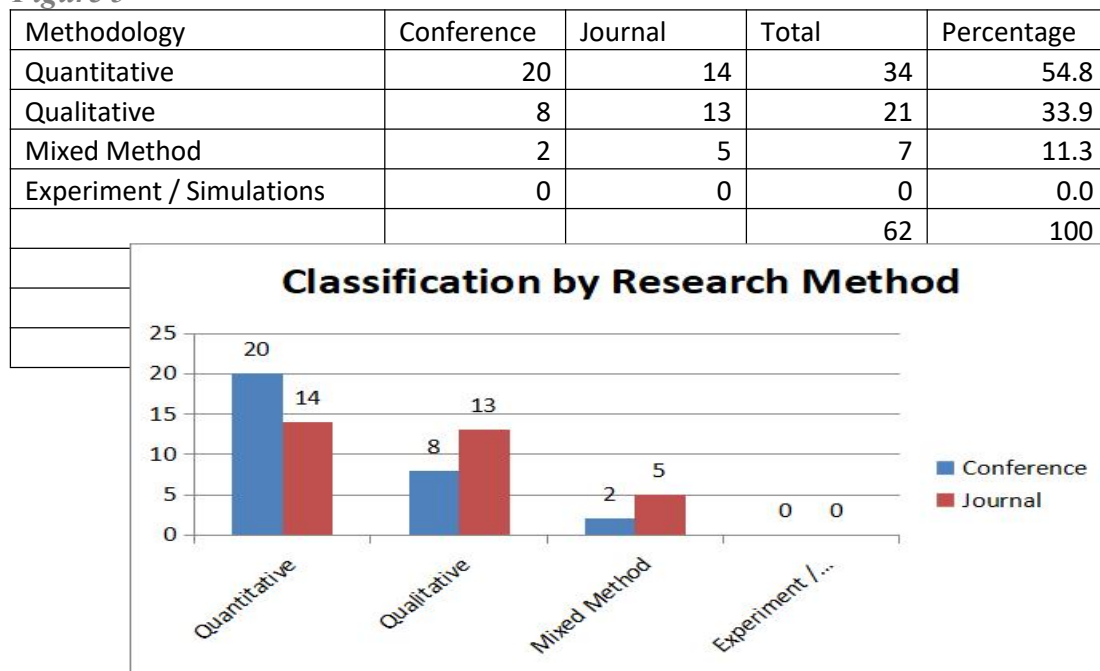
i.In RQi, two main areas/disciplines are evident in the phenomenon of this study, i.e., computer science on one hand and; decision and policy making on the other hand. Five theories were identified from the two areas. See details in the Theories section of this write up - *Table 2, Figure 1, Figure 2, Figure 3*.

ii.In RQ ii, elements which constitute a standard mixed methods research include:- design investigation strategies, strands of the study, time orientation, priority of methodological approach, and mixing strategies (picked from an existing MMR table 5-1, adapted from Venkatesh et al. (2016). Obtained in: (Viswanath Venkatesh Susan Brown Yulia Sullivan, 2023), pg 78.

iii.In RQ iii, based on the findings in RQ (i) and RQ ii, mixed methods research (MMR) for studying the phenomenon at hand is a summary of the five theories obtained in (RQ i) and the mixed methods research elements presented in table 5-1 framework. See *table 4*.

iv.In regard to this study gap, single research methods (quan or qual) dominated studies reviewed. Only two of the studies reviewed used mixed methods research (*Figure 5*).

Figure 5



Discussion/Implication

Following integration of qual-quant analyses of literature review data, the study was able to identify:- the main theory guiding this study (MMR framework in *Table 5-1*), two sub disciplines in the study phenomenon (computer science & decision and policy making), three theories in computer science, and two theories in decision & policy making. The paper has described each theory, explained how it is expected to uncover specific aspects of the study and the study gap itself, summarised relationships between the theories to show the complementarity each plays in grounding the study phenomenon.

In regard to the gap in adopting mixed methods research (MMR) approach in computer science solution studies, the study used MMR approach as the main guide and shows that:- The MMR approach to phenomena has existing MMR frameworks from past studies which guide MMR. This study adopted existing MMR framework (*Table 5-1*) and generated MMR framework (*Table 4*) customised to answer this study specific and main research questions.

Table 4: This Study Suggested Mixed Methods Research Model

Mixed Methods Property	Key references	Key design answers	Possible dimensions
Design investigation strategies	Tashakkori and Teddlie (1998)	The goal of the mixed methods study is complementarity. Specifically the study intends to develop mixed methods research (MMR) model to guide studying this study phenomenon and any other related future studies.	Exploratory (through literature review)
Strands/phases of research	Teddlie and Tashakkori (2006)	Two strands/phases of research, i.e., qualitative and quantitative	multistrand
Time orientation	Creswell (1995); Creswell et al. (2003); Tashakkori and Teddlie (1998); (Viswanath Venkatesh Susan Brown Yulia Sullivan, 2023)	The order of the qualitative and quantitative components	Sequential
Priority of methodological approach	Johnson et al. (2007); Tashakkori and Teddlie (1998)	Qualitative and quantitative components of the study are equally important	Qualitative dominant and quantitative less dominant
Mixing Strategies	Teddlie and Tashakkori (2009); (Viswanath Venkatesh Susan Brown Yulia Sullivan, 2023)	The level of mixing takes place at \longrightarrow	Fully mixed, i.e., mixing takes place at the paradigm, data collection and interpretation stages.
Relevant Theories			
Phenomenon sub disciplines	-Computer science -Decision & policy making		
Sub discipline 1 theory(ies) (Computer Science)	Natural Philosophy of Computer Science (NPCST) Theory; Design Science Research (DSR) theory Computer Science Computational Theories (CSCT)		
Sub discipline 2....n theory(ies) (Decision & policy making)	Decision and Policy Framework (DPF) Co-Design Policy Framework (CDPF)		

Note: Inclusive in the table above, are relevant theories identified from disciplines evident in this study phenomenon. See detailed explanation of relevant theories in the literature review section, *Table 2, Figure 1, Figure 2, Figure 3.*

It should, however, be noted that *table 4* has ‘Relevant Theories’ subsection at the bottom as this study update and contribution towards MMR approach to uncover the study on computer

science and other tools capabilities to simplify and enhance DPM criterion. Table 4 is this study mixed method research (MMR) model and study outcome.

Conclusion

This study was able to find answers to its specific and main research questions, and the paper concludes with a suggested mixed methods research (MMR) model approach/framework (*Table 4*) for studying ‘computer science and other tools capability to simplify and enhance decision & policy making criteria’ and; the model can be adopted to guide any other future related studies. The study also concludes that contexts of phenomena may contain sub disciplines and these require to be identified for their respective theories to be considered as part of study frameworks - thus disciplines in phenomena contexts, their respective theories 1....n , should be part of the MMR model as exemplified in *table 4*.

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