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Linked Decisions: A Data Standard for Distributed Decision Support Systems

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Linked Decisions: A Data Standard for Distributed Decision Support Systems

by

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree

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ACCEPTANCE

This dissertation was prepared under the direction of the *JAROSLAV KLC* Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Business Administration in the J. Mack Robinson College of Business of Georgia State University.

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ABSTRACT

Linked Decisions: A Data Standard for Distributed Decision Support Systems

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This dissertation addresses a critical challenge in the domain of decision support systems: synthesizing real-world decision information in a way that's coherent, accessible, and actionable—particularly when decision-making occurs across multiple people, systems, and locations, known as "distributed decision-making contexts." The crux of this challenge lies in designing an effective "information architecture" that connects and organizes data to enable efficient decision-making in these complex, interconnected settings.

By employing distributed cognition as a theoretical framework, this research explores the pivotal role that a well-structured information architecture plays in enhancing collective decision-making. Distributed cognition, which perceives cognitive processes as extending beyond individuals to encompass artifacts and systems, provides a robust basis for examining decision-making in distributed environments.

To tackle this challenge, the study adopts the Design Science Research Methodology (DSRM), which emphasizes the creation and evaluation of artifacts aimed at addressing practical problems. This research leads to the development of a global multi-dimensional decision matrix model, designed to standardize, integrate, and streamline the exchange of decision information across diverse stakeholders and platforms. This innovative model incorporates cellular decision modeling and semantic web technologies to improve the efficiency of distributed decision-making.

The contributions of this dissertation are significant for both literature and practice. Practically, it introduces a new data standard that fosters improved collaboration, transparency, and efficiency in decision-making processes. Theoretically, it enriches the discourse on information architecture in distributed cognition by translating its principles into a tangible artifact, providing a concrete example of theoretical concepts applied in real-world scenarios.

In essence, this study offers a solution to a pressing problem in decision support systems, while simultaneously advancing academic discourse by bridging the gap between theoretical frameworks and practical design science research. The resulting artifact underscores the potential of rigorous, informed research to contribute meaningfully to both academic scholarship and practical applications in the realm of decision support.

INDEX WORDS: decision support, distributed decision-making, decision data standard, global decision matrix, cellular decision modeling

I INTRODUCTION

I.1 Research Problem

The central problem this dissertation addresses is the absence of standardized data protocols for managing and sharing decision-making information across the digital and interconnected landscape of the global internet. When referring to "global scale" in this study, it specifically denotes the all-encompassing reach of the internet, aiming to create a data standard that supports decision-making processes across various digital platforms, transcending organizational, cultural, and geographic barriers in a manner akin to the internet's own global nature. Despite the wealth of research into decision-making theories and decision support systems, a conspicuous research gap remains: the need for a framework that ensures decision-making data can be seamlessly exchanged and utilized across the internet's vast, borderless network. Individuals and companies are not fully benefiting from global sharing of decision information as the current decision support technologies, implementing existing data exchange standards, are limited in terms of creating and consuming structured decision information content.

The global sharing of decision information offers numerous benefits across various domains. In the healthcare sector, it enables the design of more robust risk-sharing arrangements, aligning the interests of manufacturers and decision makers (Eckermann & Willan, 2013). In communication networks, it can enhance an agent's utility, provided that trust is established (Tang et al., 2014). In collaborative decision-making environments, it leads to improved performance and profit ((Yoon et al., 2009). In global supply chains, it can benefit both buyers and suppliers, enhancing partnership performance (Myers & Cheung, 2008). In government, it can improve efficiency, service quality, and transparency (Gil-Garcia et al., 2009; Karla Mendes et al., 2012; Waters et al., 2009a). However, challenges such as limited capacity and mistrust need to be addressed, particularly in the Global South (Serwadda et al., 2018).

The suboptimal level of capabilities to create and use distributed decision information can be linked to some limitations of the current decision support systems identified in the extant literature. A synthesis of scholarly critiques highlights critical areas requiring advancement.

- **Group Decision-Making**: The complexities of dispersed group decision-making processes are emphasized by Carneiro et al. (2021), who critiques the inadequacy of current web-based group DSS. Effective facilitation of collaborative decision-making, especially in distributed settings, remains a significant hurdle for existing systems (Carneiro et al., 2021).

- **Universality and Flexibility**: Kadenko et al. (2020) identifies a gap in the universality and flexibility of DSS, particularly in strategic planning contexts. This limitation suggests a need for DSS that are adaptable across various domains and capable of accommodating changing decision environments and criteria (Kadenko et al., 2020).

- **Knowledge Integration**: Cuza highlights the crucial distinction between mere data and actionable knowledge within DSS frameworks. There is a pressing need for the evolution of DSS into knowledge-based systems that can effectively translate vast data sets into insightful, actionable knowledge for users (Cuza, 2013).

The existing literature recognizes the need for decision data standardization on the technical and ontological levels; however, no viable general standard suitable for global adoption has been proposed. In web-based information systems, data standardization and modeling are implemented to improve data retrieval and accessibility (Funkenberg et al., 2012). Additionally, data standardization plays a crucial role in facilitating information exchange, particularly in industries where cross-firm and cross-industry data exchanges are essential (Gal & Rubinfeld, 2019). Waters et al.'s work includes a proposal for a common decision exchange protocol but offers very little details beyond high-level infrastructure elements including representational state transfer protocol (REST), use of unified resource locators (URL), and extensible markup language (XML) as the suggested markup language (Waters et al., 2009b). The Object Management Group® maintains Decision Model and Notation, DMN™, which is a process-oriented standard optimized for enterprise implementations of operational decision-making automation (Biard et al., 2015). As summarized by Calvanese et al., "The Decision Model and Notation (DMN) is a standard notation to capture decision logic in business applications in general and business processes in particular. A central construct in DMN is that of a decision table." (Calvanese et al., 2016). While DMN™ is a detailed and implementable standard, it is not suitable for decision data exchange in distributed environments. Proposals for decision ontologies include the work of Konaté et al. and Guizzardi et al. who establish semantic foundations for potential new decision data standards. (Guizzardi et al., 2020; Konaté et al., 2020) However, the existing research literature as of March 2024 does not include a practically usable data standard optimized for the creation, sharing, and usage of globally distributed decision data elements.

The documented benefits of data standardization and the lack of an effective distributed decision data standard for decision support systems present a problem with profound implications in an increasingly interconnected world, where the ability to efficiently access and utilize data generated from past decisions is crucial for effective decision-making. Given the limited existing standardization for decision data, current systems and frameworks fall short in facilitating seamless exchange and integration of decision data across diverse stakeholders, systems, and platforms which results in lost opportunities to share, discover, and utilize relevant decision data beyond existing information silos.

This research aims to tackle the underexplored area of developing a universally applicable data standard that not only enhances decision-making processes in the global context but also addresses the complexities of distributed information systems. The absence of such standards impedes the potential for more informed, collaborative, and agile decision-making processes, highlighting the necessity for a novel approach to data standardization in the context of global-scale decision support platforms.

I.2 Research Question

To enhance the real-world decision-making process, this study aspires to establish a new paradigm for creating, communicating, sharing, and processing of information related to real-world decisions. More specifically, this study answers the following research question:

"How can we design a data standard for distributed decision support systems?"

This question is centered on the creation of a tangible artifact—a data standard—that can directly influence and improve decision-making processes on a global scale. It underscores the practical aim of the research to design, develop, and assess a solution that can be applied to real-world decision-making challenges.

I.3 Research Motivation

The motivation for this research stems from recognizing the immense costs associated with sub-optimal decisions—a prevalent issue that impacts individuals, groups, and societies at large. Sub-optimal decisions invariably lead to outcomes that fall short of the best possible results, thereby incurring significant tangible and intangible losses. To explain the motivation in detail, I offer field observations regarding sub-optimal real-world decisions and insights from the research literature linking sub-optimal decisions with information sharing limitations.

Observations from the real world underscore the urgency and relevance of this research. For instance, the decision by leaders of nations to initiate armed conflicts, often resulting in widespread death and destruction, starkly illustrates the consequences of inadequate communication and consideration of decision alternatives. Domestic strife can be a key driver, with violent strife increasing the likelihood of a diversionary conflict and nonviolent strife increasing the likelihood of repression (Davies, 2002). Economic factors, such as recessions, can also influence the decision, with leaders potentially initiating conflict to improve their reelection prospects (Benlian et al., 2009). It is conceivable that such drastic and detrimental decisions might be averted with more effective communication and a thorough evaluation of alternatives, values, and points of disagreement.

Similarly, on an individual level, misinformed people often fall prey to predatory educational institutions, gambling, lotteries, multi-level marketing schemes, and timeshares—each scenario a testament to the costly sub-optimal decisions made due to a failure to properly synthesize and evaluate available decision information and options. Blaszczynski et al. and Willis both highlight the role of limited information in gambling and predatory lending, respectively (Blaszczynski et al., 2013; Willis, 2005). Rivalan et al. and Caroselli et al. provide insights into the cognitive and emotional factors that contribute to poor decision-making, particularly in gambling tasks (Caroselli et al., 2006; Rivalan et al., 2009; Rivalan et al., 2013). Hogarth and Kunreuther et al. further discuss the challenges of decision-making under ignorance and in high-stakes situations, respectively (Hogarth & Kunreuther, 1995; Kunreuther et al., 2002).

These examples, ranging from global political decisions to personal financial choices, highlight the pervasive impact of sub-optimal decision-making across various spheres of life. They emphasize the critical need for a standardized approach to decision information that enhances the clarity, accessibility, and evaluation of alternatives, aiming to mitigate the far-reaching consequences of such decisions.

Sub-optimal decisions due to information sharing and synthesis problems can arise in various contexts. Kondratyev et al. and Wittenbaum et al. both highlight the impact of resource sharing and the tendency of groups to favor shared information over unshared information, respectively (Kondratyev et al., 2013; Wittenbaum et al., 2004). Abele et al. and Xiao et al. further explore the effects of information distribution and utilization, with the former finding a bias towards common information and the latter suggesting that information sharing may not always lead to optimal outcomes (Abele et al., 2008; Xiao et al., 2016). Zhang et al. and Chen et al. both discuss the challenges of information pooling and the potential for misrepresentations in decision-making, particularly in the context of new product development and humanitarian disaster response (Chen et al., 2012; Zhang et al., 2014).

A range of studies have explored the outcomes of sub-optimal decisions due to a lack of decision information standards. Summerfield & Tsetsos suggest that suboptimal choices may result from the efficient coding of decision-relevant information, leading to robust but non-optimal decisions (Summerfield & Tsetsos, 2015). Multiple authors highlight the challenges of acquiring and using information effectively in decision-making, with humans often under-purchasing or mis-purchasing information (Connolly & Thorn, 1987; Potter & Beach, 1994).

Papadimitriou and Vetschera et al. explore the effectiveness of decision rules and the impact of incomplete information in group decision models (Papadimitriou, 1991; Vetschera et al., 2014).

A critical factor contributing to these inefficiencies is the lack of standardization in the handling and exchange of decision-making information. Without universal data protocols, the creation, discovery, reuse, and integration of pertinent decision information remain cumbersome and inconsistent, obstructing the pathway to optimal decision-making. By facilitating easier creation, discovery, re-use, and integration of relevant decision information, this research aims to fundamentally transform decision-making processes. Enabling a frictionless exchange of decision information through distributed, interactive, real-time decision models holds the promise of significantly improving critical areas such as multi-stakeholder decision speed, time to consensus, information saturation, decision acceptance, and the reduction of cognitive load necessary to reach a decision. At its core, the high-level motivation is to exert a positive impact on real-world decision-making processes, enhancing efficiency, inclusivity, and the overall quality of decisions made in complex, multi-faceted environments.

I.4 Similar Research

Similar research in the domain of decision-making highlights two significant streams: decision ontology and standards for structuring decision information.

Research on decision ontology, exemplified by the work of Renata Guizzardi et al., delves into the foundational aspects of decision-making processes, proposing a core ontology that underpins the nature and dynamics of decisions. (Guizzardi et al., 2020) This ontology aids in the formalization of decision-making knowledge, supporting more coherent and informed decision-making practices across various contexts. Expanding on the ontology for collaborative decision making, research such as Jacqueline Konaté's work on "An Ontology for Collaborative Decision Making" explores the intricate dynamics of decision-making within groups, proposing an ontology that encapsulates the key elements of collaborative processes. This research underscores the complexity of decision-making in collaborative environments, identifying critical factors like roles, decision-making stages, and communication patterns that influence the efficacy of collective decisions. By providing a structured framework for understanding and analyzing collaborative decision-making, such ontologies play a pivotal role in designing systems and protocols that enhance the quality and outcomes of group decisions, aligning closely with the objectives of optimizing decision-making processes through improved data standardization and integration. (Konaté et al., 2020)

Another vital area of similar research focuses on the development and application of standards such as Business Process Model and Notation (BPMN) and DMN™ for structuring decision information. (Biard et al., 2015) This standard facilitates the documentation, analysis, and optimization of decision-making processes, ensuring that decision information is accessible, interpretable, and reusable. As previously mentioned in the research motivation segment, “A central construct in DMN is that of a decision table.” (Calvanese et al., 2016). While DMN™ appears to be an accepted standard for enterprise implementations of operational decision automation, it does not appear to be suitable for decision data exchange in open distributed environments. Waters et al.’s work proposed a common decision exchange protocol including representational state transfer protocol (REST), use of unified resource locators (URL), and extensible markup language (XML) as the suggested markup language but provides very vague recommendation on the data schema level (Waters et al., 2009b).

Together, these research streams form a foundation for the proposed study, emphasizing the importance of a unified data standard for decision-making information. The development of such a standard, grounded in the insights from decision ontology and informed by existing structuring standards, aims to address the challenges of creating, discovering, re-using, and integrating decision-making information on a global scale.

I.5 Research Scope

The scope of this research is precisely delineated to the development and proposal of a universal decision data standard artifact. This encompasses the initial conceptualization of the standard, its architectural design, and the establishment of guidelines for its implementation and usage in enhancing decision-making processes globally. Evaluation of the proposed standard's design will be conducted through demonstrations using a sample implementation with artificial data. These demonstrations aim to validate the standard's applicability, effectiveness, and potential benefits in real-world decision-making scenarios, albeit within a controlled environment to facilitate rigorous assessment and refinement. The research will not extend to large-scale real-world implementations or the assessment of its integration within existing systems, maintaining a focused approach on the artifact's foundational development and preliminary evaluation.

Additionally, it is important to clarify that aspects related to user authentication, decision content validation, and access management fall outside the scope of this project. These critical yet complex facets of decision support systems demand a dedicated focus on security, accuracy, and permissions that extend beyond the immediate objectives of developing and evaluating a universal decision data standard. Addressing these components would necessitate a broader exploration of information security, data integrity, and privacy considerations that are not covered within the confines of this research project's objectives and methodology.

I.6 Research Approach

The Design Science Research Methodology (DSRM) underpins this study's approach, emphasizing the iterative development of innovative solutions to address complex problems. DSRM is a framework that guides the creation and evaluation of artifacts designed to solve identified issues, blending theoretical knowledge with practical application. It consists of six core activities: problem identification and motivation, objectives definition, design and development, demonstration, evaluation, and communication. This methodology not only fosters the creation of impactful technological solutions but also ensures that these solutions are rigorously tested and refined in response to stakeholder feedback. By adopting DSRM, this research adheres to a structured and systematic process that not only aims to develop a universally applicable decision data standard but also contributes to the body of knowledge by documenting the artifact's design and efficacy. The phased approach described above reflects DSRM's principles, ensuring that each stage of the artifact's lifecycle, from conceptualization through validation to refinement, is anchored in both theoretical underpinnings and empirical evidence. The core of this research project is a rigorous and systematic development and evaluation of the proposed universal decision data standard artifact in three phases.

Phase 1 - Research Question Validation and Requirements Gathering: This phase leveraged semi-structured interviews with a diverse group of decision support experts to validate the research question and gather essential requirements for the data standard. The aim was to ensure the artifact is grounded in the real needs and challenges faced in decision-making processes.

Phase 2 - Artifact Development: Based on insights from the first phase, artifact development proceeded with input from computer science experts through semi-structured interviews. This collaborative approach ensures the technical feasibility and robustness of the standard, incorporating cutting-edge practices and theories in data standardization.

Phase 3 - Artifact Evaluation: The final phase re-engaged subjects from Phase I for a comprehensive evaluation of the developed artifact. Demonstrations of the standard using artificial data were conducted to provide tangible insights into its functionality and impact. Feedback from these experts was instrumental in assessing the standard's effectiveness and identifying areas for refinement.

This structured approach ensures that the research is grounded in expert insights throughout, from conception to evaluation, aligning with design science methodologies.

I.7 Dissertation Overview

This dissertation embarks on a quest to explore the optimization of decision-making information through the development of a universal data standard. The journey begins with a background section that delves into the existing corpus of knowledge surrounding decision-making, with a keen focus on decision support systems. It then progresses to a theoretical framing section that introduces two pivotal theoretical perspectives: the conceptualization of real-world decision-making as a distributed cognition phenomenon, and the significance of information architecture as the foundational theory behind the proposed data standard. This section also highlights existing artifacts and methodologies relevant to decision data standardization, such as Decision Model and Notation (DMN) and Semantic Web technologies.

The methods section delineates the application of the Design Science Research Method (DSRM), detailing the execution of a series of semi-structured expert interviews as the primary avenue for qualitative data collection. These interviews are framed within the contexts of problem validation, refinement of solution requirements, elicitation of expert design feedback, and artifact evaluation.

The results section offers a narrative on the outcomes of the research's three phases, encapsulating the insights from expert consultations in phase I, the development journey of the artifact in phase II, and the synthesis of evaluation feedback in phase III.

Finally, the dissertation concludes with a discussion on the contribution of this research, articulating the practical implications, potential impact of the study on real-world decision-making processes, acknowledgments of limitations, and suggestions for future research.

II BACKGROUND

II.1 Decision-making Theory

The theoretical foundations for this study are found in the publications on decision-making and decision support systems. One of the widely used models of decision-making activities is based on Simon's decision theory, resulting in a Nobel Prize award in 1978, from 1960 which highlights three major stages of the process: intelligence activity, design activity, and choice activity (Simon, 1960). Another view compatible with Simon's theory is offered by Fülöp. He describes the general decision-making proces as consisting of the following steps: define the problem, determine requirements, establish goals, identify alternatives, define criteria, select a decision-making tool, evaluate alternatives against the criteria, validate solutions against the problem statement (Fülöp, 2005). A similar set of steps is offered by Baker et al: define the problem, determine the requirements the solution must meet, establish goals that the solution should accomplish, identify alternatives that will solve the problem, develop evaluation criteria based on the goals, select a decision-making tool, apply the tool to select a preferred alternative, check the answer to make sure it solves the problem (Baker et al., 2001). Similar to these descriptions, all major research articles include the steps of identifying alternatives, defining criteria, and evaluating the alternatives using the criteria to determine the optimal option.

According to Triantaphyllou, an optimal choice in multiple criteria decision-making (MCDM) refers to a decision alternative that achieves the best possible balance among various, possibly conflicting, criteria based on the decision-maker's preferences and objectives. It should be the result of a systematically evaluation of identified alternatives across the criteria to identify the one that most closely aligns with the decision-maker's goals, considering the trade-offs required among the criteria. This choice maximizes the decision's overall value to the decision-maker, considering all relevant factors and constraints. (Triantaphyllou, 2000)

Aruldos lists major multiple criteria decision making methods to select the optimal choice from a set of alternatives including Analytical Hierarchical Processing, TOPSIS, ELECTRE, FMCDM and others (Aruldoss et al., 2013). Multiple-criteria decision-making literature also offers a basic data representation of a decision. The foundational data elements which consistently appear in the literature since at least 1980's as documented by Barton include: alternatives, criteria, evaluations of alternatives according to each criteria, scores, and ranks (Barton, 1981, p. 234). Another foundational decision-making concept is the notion of bounded rationality.

Bounded rationality is simply the idea that the choices people make are determined not only by some consistent overall goal and the properties of the external world, but also by the knowledge that decision makers do and don't have of the world, their ability or inability to evoke that knowledge when it is relevant, to work out the consequences of their actions, to conjure up possible courses of action, to cope with uncertainty (including uncertainty deriving from the possible responses of other actors), and to adjudicate among their many competing wants. Rationality is bounded because these abilities are severely limited. (Simon, 1990, p. 25)

According to Zavadskas and Turkis quoting Elster, "Bounded rationality is the idea that in decision-making rationality of individuals is limited according to the information they have, the cognitive limitations of their minds, and the finite amount of time they have to make decisions (Elster 1983)" (Zavadskas & Turskis, 2011, p. 399). Building on Simon's bounded rationality, Kahneman's Prospect Theory, resulting in a Nobel Prize award in 2002, brings psychological insights into economics. Kahneman explores "…systematic biases that separate the beliefs that people have and the choices they make from the optimal beliefs and choices assumed in rational-agent models" (Kahneman, 2003, p. 1449). Despite the newer decision-making theories, most of MCDM literature is centered around computational methods for scoring and ranking alternatives based on a utility function. However, there are other areas that lack research coverage. Zeleny states the following about areas needing more attention: "Vitally more important are problem formulation, criteria selection, alternatives generation, feasible set design, weights, priorities and preferences assessment, decision process, sequencing and timing, decision context capturing, problem reformulation and reframing, post-decision, regret assessment, implementation strategy, etc." (Zeleny, 2011, p. 78).

The literature also reflects the problems practitioners encounter in the decision-making space. Tavakoli et al list frequent decision analysis problems in clinical decision-making which may be indicative of similar problems in other areas: "In general, clinical decisions are problematic because they involve: (a) integration of complex information from a variety of sources; (b) imperfect or incomplete information; (c) the presence of uncertainty; (d) a complex interaction between the clinician and the patient, each of whom may bring widely different values to the decision; and (e) a growing imperative to take account of both the costs and effectiveness of alternative strategies." (Tavakoli et al., 2000, p. 112).

The exploration of decision-making theory, from Simon's seminal work to the detailed processes outlined by Fülöp and Baker et al., underscores a critical throughline: the systematic identification, evaluation, and selection of alternatives based on defined criteria are central to optimal decision-making (Baker et al., 2001; Fülöp, 2005; Simon, 1990). This iterative process, foundational to MCDM, highlights the necessity for a structured approach to decision analysis.

However, the literature reveals a recurring challenge—while the steps to reach an optimal decision are well-documented, the application of these theories often encounters practical difficulties due to the lack of standardized decision-making data protocols. This absence becomes particularly evident when considering the concept of bounded rationality introduced by Simon and expanded upon by Kahneman, which suggests that decision-makers operate within limitations of knowledge and cognitive capacity (Kahneman, 2003; Simon, 1990).

Standardization in decision-making information could mitigate some of these limitations by providing a consistent framework that aids in the clear definition of problems, criteria, and the comparative evaluation of alternatives, thereby reducing cognitive load and enhancing the accessibility and quality of decision-relevant information. Furthermore, as highlighted by Zeleny and echoed in the challenges faced in clinical decision-making detailed by Tavakoli et al., the absence of standardized approaches in areas such as criteria selection, alternatives generation, and preference assessment introduces significant barriers to effective decision-making (Tavakoli et al., 2000; Zeleny, 2011). These barriers are not unique to healthcare but resonate across various domains where decision-making is critical.

II.2 Decision Support Systems

A class of information systems, Decision Support Systems (DSS), has evolved to aid decision-making. Its evolution is well covered in the DSS literature. Arnot and Pervan summarize the genealogy of DSS field from the 1960s through 2010 in Figure 1.

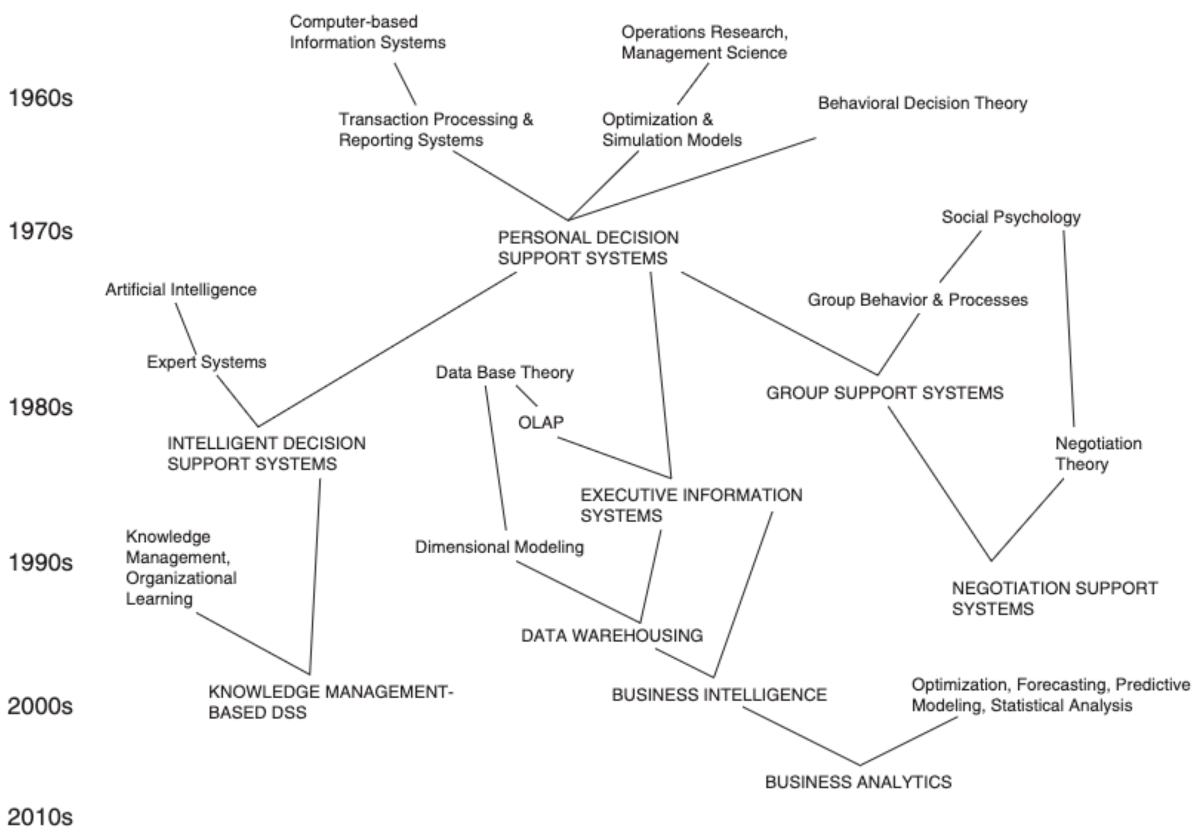


Figure 1 DSS Evolution (Arnott & Pervan, 2015)

The DSS literature offers several views on the structures and building blocks of DSS. The original view the DSS building blocks is described by Sprague and Carlsson (1982) as quoted by Zaraté and Liu. The components are a model-based management system, a database management system, and a human-computer interface (Zaraté & Liu, 2016). A diagram of a basic DSS structure by Holsapple is shown in Figure 2.

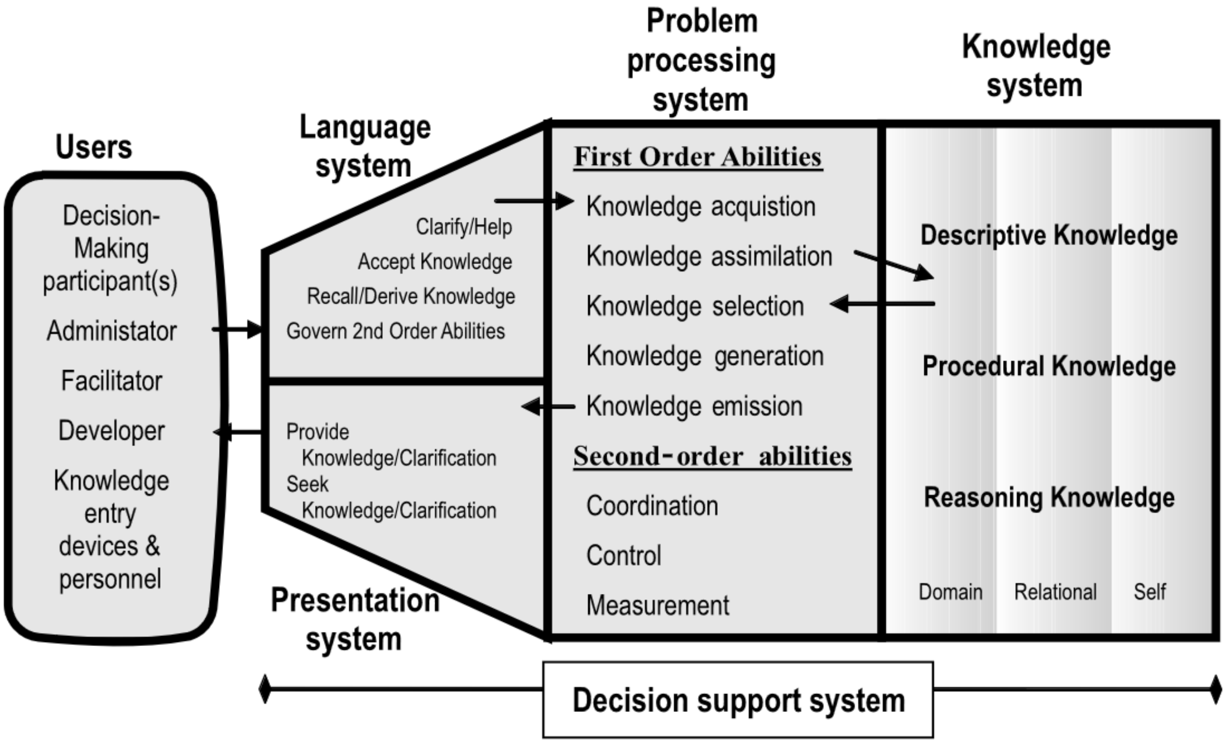


Figure 2 Basic DSS Structure (Holsapple, 2008)

A more recent and comprehensive view on DSS structure is offered by Zaraté and Liu in Figure 3.

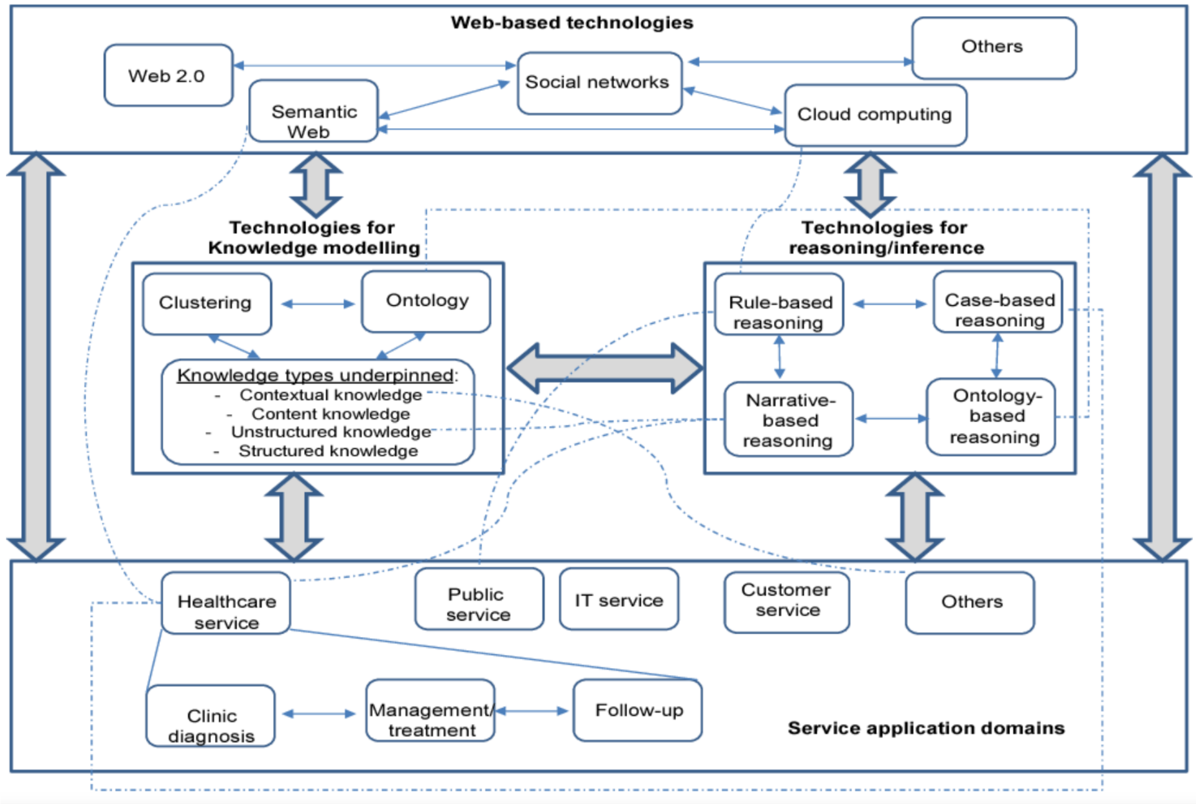


Figure 3 A more recent and comprehensive view on DSS structure (Zaraté & Liu, 2016)

One of the early taxonomies of DSS is provided by Alter. He sees all DSS as primarily data-oriented or model-oriented. His analysis of 56 systems in 1977 produced the following categories:

> *A. File drawer systems allow immediate access to data items.*
> *B. Data analysis systems allow the manipulation of data by means of operators tailored to the task and setting or operators of a general nature.*
> *C. Analysis information systems provide access to a series of data bases and small models.*
> *D. Accounting models calculate the consequences of planned actions based on accounting definitions.*
> *E. Representational models estimate the consequences of actions based on models which are partially non-definitional.*
> *F. Optimization models provide guidelines for action by generating the optimal solutions consistent with a series of constraints.*
> *G. Suggestion models perform mechanical work leading to a specific suggested decision for a fairly structured task.*

(Alter, 1977, pp. 41-42)

Holsapple also offers a breakdown of major DSS implementation types as:

- Text-oriented DSS
- Hypertext-oriented DSS
- Database-oriented DSS
- Spreadsheet-oriented DSS
- Solver-oriented DSS
- Rule-oriented DSS
- Compound DSS

(Holsapple, 2008)

Another critically important angle for DSS literature review in the context of decision content data standards is the DSS de-centralization perspective. "A distributed decision support system is a collection of services that are organized in a dynamic, self-managed, and self-healing federation of hard- and software entities working cooperatively for supporting the solutions of semi- structured problems involving the contributions of several actors, for improved decision-making." (Gachet & Haettenschwiler, 2003, p. 10).

The evolution of DSS and their diverse structures and taxonomies underscore the critical need for establishing a unified decision data standard. As DSS have transitioned from simple file drawer and data analysis systems to more complex distributed decision support systems, the importance of seamlessly integrating diverse data types and decision models has become increasingly apparent. A decision data standard would address the inherent challenges identified in the literature, such as the integration of various DSS components including model-based management systems, databases, and human-computer interfaces. Moreover, as DSS become more decentralized, as described by Gachet & Haettenschwiler, the necessity for a standardized framework that supports semi-structured problem-solving across multiple actors becomes even more critical (Gachet & Haettenschwiler, 2003). This standard would facilitate the efficient exchange and processing of decision information, enhancing the interoperability among the different types of DSS—ranging from text-oriented to compound DSS—and enabling a more cohesive and effective decision-making process. By aligning with the evolutionary path of DSS as depicted by Arnott & Pervan, and addressing the categorization and implementation types outlined by Alter and Holsapple, the implementation of a decision data standard represents a pivotal advancement in the field (Alter, 1977; Arnott & Pervan, 2010; Holsapple, 2008). It promises not only to streamline decision support across various domains and contexts but also to enhance the efficacy of decision-making.

II.3 Semantic Web

In an era marked by digital transformation, the concept of globally distributed content has become increasingly pivotal. This refers to the availability and accessibility of information across the vast digital landscape, transcending geographical, cultural, and technological boundaries. In essence, globally distributed content encompasses the data, knowledge, and insights shared and accessed across the World Wide Web, enabling a rich tapestry of interconnected information resources. The significance of this concept lies in its ability to facilitate unparalleled levels of collaboration, knowledge exchange, and decision-making across diverse global contexts. As organizations and individuals navigate the complexities of the digital age, the need for mechanisms that can efficiently organize, link, and make sense of this distributed content is paramount. This sets the stage for exploring how the semantic web, with its emphasis on machine-understandable information and intelligent agents, emerges as a critical framework for harnessing the potential of globally distributed content in enhancing decision support systems.

To further focus on the area of standardized global decentralized distributed data content, several architecture concepts from the semantic web theory need to be introduced along the existing DSS approaches. "…The Semantic Web is usually envisioned as an enhancement of the current World Wide Web with machine-understandable information (as opposed to most of the current Web, which is mostly targeted at human consumption), together with services - intelligent agents - utilizing this information…" (Hitzler, 2021, p. 1). According to Antunes quoting Kousetti et al, the 'sematic web' term "means a set of technologies that includes ontologies, software agents and rules of logic. These technologies can greatly improve the ability to connect and automatically organize the content of information spread across multiple pages or sites (Kousetti, Millard, & Howard, 2008)" (Antunes et al., 2016, p. 6). The same authors also offer an overview of fundamental semantic web concepts and technologies including: Extensible Markup Language (XML), Resource Description Framework (RDF), SPARQL Protocol and RDF Query Language, and Web Ontology Language (OWL).

Two properties of the semantic web approach need to be highlighted due to their relevance in the global distributed decision content context. First, one of the main ideas behind RDF is the use of universal resource identifiers which make it possible to link objects across sites and databases. Second, OWL facilitates semantic interoperability by mapping entities in different ontologies. Therefore, semantic web offers paradigms applicable to decision content in terms of using global identifiers and enabling translations of meaning contexts which use different terms to reference the same entity. Antunes et al claim that semantic web data can be used in DSS for the following functions:

(1) Information integration (several data sources, different formats, external data sources, high change rate, exchangeable data sources);

(2) Information filtering and selection (several large data sources, different tasks and roles of users, abstraction);

(3) Information extension, exploration, and explanation (data may be missing in internal sources, user explanations, browsing relations between data, drill-down of information);

(4) Information interpretation, event detection and prediction (large data sources, high change rate of data, abstraction and aggregation, situation detection, 'real-time' data, data analysis);

(5) Information tracking and post-event analysis (large data sources, abstraction and aggregation, situation detection, post-session evaluation and session follow- up, provenance);

(6) Models and model evolution (different changing data formats, external data sources, changing user tasks and views, model-based analysis, relations amongst information, browsing and linking);

(7) Sharing decisions (trust, provenance, accountability, user created data, interaction between users, delegation).

(Antunes et al., 2016, p. 10)

II.3.1 *Linked Data*

In the landscape of the Semantic Web, Linked Open Data (LOD) represents a transformative shift in how we publish and interact with structured data. Michael Hausenblas and Marcel Karnstedt outline in their work, "Understanding Linked Open Data as a Web-Scale Database," the evolution of LOD into a web-scale database. (Hausenblas & Karnstedt, 2010) This LOD paradigm is grounded on four core principles that align with Tim Berners-Lee's vision for a Web of Data:

1. **Uniform Resource Identifier (URI) Usage**: Every item in a dataset is assigned a URI, ensuring a unique global identifier for every piece of data.
2. **HTTP URI De-referenceability**: URIs should be dereferenceable, allowing users and agents to look up an item and access its representation directly over the Web.
3. **Provision of Additional Data**: Looking up a URI should yield relevant data in RDF (Resource Description Framework), providing a rich, machine-readable context.
4. **Inclusion of Links to Other URIs**: To foster data interconnection, datasets should include links to URIs across different datasets, thus weaving a web of interlinked data resources.

(Berners-Lee, 2006)

This concept transforms the Semantic Web into a massive, interconnected database where data consumption tasks like discovery, entity consolidation, and query can scale to the web's breadth. LOD's inherent distribution should be transparent to the user, echoing the need for distribution independence.

Importance of Schema Integration and Ranking

Application development within LOD must navigate and utilize various, sometimes overlapping domain vocabularies. This requires leveraging schema matching and mapping techniques to effectively utilize data from disparate sources. Moreover, LOD benefits from both database and information retrieval techniques, where ranking based on algorithms like PageRank or dataset-centric approaches plays a crucial role in application development.

Provenance and Identifiers

Understanding the provenance of data is essential for assessing credibility, disambiguating information, and making non-technical decisions like licensing. LOD systems leverage external mechanisms, such as Named Graphs, to track provenance, addressing this need. Moreover, the reuse of public identifiers for well-known entities enhances the efficiency and effectiveness of data integration processes.

The defining features of LOD are shown in Table 1 below.

Table 1 Features of Linked Open Data (Hausenblas & Karnstedt, 2010, p. 4)

Principle	Meaning
Web-scale Consumption	Discovery, entity consolidation, (distributed) query, etc. have to scale to the size of the Web
Schema Integration	Employment and tight integration of schema matching and schema mapping techniques
Ranking	Combinations of IR and DB approaches are required
Reusable Identifiers	Public identifiers of well-known entities should be reused
Provenance	Knowing the origin of the data is essential
Mapping Keywords to Resources	Support for keyword-based search and mapping to URIs is required

II.3.2 *JSON-LD and the Semantic Web*

JSON-LD 1.1, as delineated by Gregg Kellogg, Pierre-Antoine Champin, and Dave Longley, serves as a cornerstone in the web of linked data, offering a JavaScript Object Notation (JSON)-based serialization for Linked Data. (Sporny et al., 2020) This lightweight syntax is designed to easily integrate into existing JSON infrastructures, providing a smooth transition from JSON to JSON-LD. Its intention is to leverage Linked Data within web-based programming environments, enabling interoperable web services and storing Linked Data using JSON-based storage engines.

JSON-LD is conducive to the semantic web's vision, where a shared context - much like in human conversations - allows the use of compact terms (terms defined in the @context) to convey specific, unambiguous identifiers or concepts efficiently. This serialization format is compatible with existing JSON formats, ensuring already-deployed systems can adopt JSON-LD without significant alteration.

Simplicity and Usability

“No extra processors or software libraries are necessary to use JSON-LD in its most basic form. The language provides developers with a very easy learning curve. Developers only need to know JSON and two keywords (@context and @id) to use the basic functionality in JSON-LD.” (Sporny et al., 2020, p. 17).

Expressiveness for Linked Data

JSON-LD expresses complex, interlinked data structures, which is vital for the semantic web. It facilitates unambiguous data definition and interrelation, enabling machines to process, understand, and reason about web resources.

Semantic Annotation

A core feature of JSON-LD is its ability to annotate data semantically, using IRIs (Internationalized Resource Identifiers) for defining types of nodes and relationships within a graph. These IRIs provide global scope and, when dereferenced, may link to further information or definitions, aligning with the semantic web's goal of enhancing the web with descriptive metadata.

Integration with Existing Web Technologies

JSON-LD's design goals explicitly include the intention to be used directly as JSON, without needing RDF (Resource Description Framework) knowledge, while also being compatible with RDF-based tools for those who choose to use it. Thus, it bridges the gap between the ease of use of JSON and the rigorous semantic capabilities of RDF.

Scalability and Flexibility

The specification supports the extension of the vocabulary, allowing the definition of terms specific to particular domains. This flexibility is crucial for the semantic web, as it allows the representation of domain-specific concepts while maintaining interoperability across different systems and communities (Sporny et al., 2020, p. 24).

JSON-LD 1.1 aligns with the semantic web's aim to create a universal medium for the exchange of data where data can be shared and processed by automated tools as well as by people. By providing a method to represent Linked Data that is both human-readable and machine-understandable, JSON-LD plays a pivotal role in the realization of the semantic web's potential as a global platform for granular data sharing which can be leveraged for the purpose of creating a global shared repository of decision data.

II.3.3 *Schema.org's Pivotal Role in the Semantic Web*

Schema.org, initiated in 2011 through the collaboration of Google, Microsoft, Yahoo, and Yandex, stands as a crucial juncture in the evolution of the Semantic Web. The work by Andrew Iliadis and others critically examines Schema.org, not just as a metadata initiative aimed at structuring information for the web but as a conceptual model that underpins a significant portion of the knowledge representation on the web. “Schema.org is each of the following: (1) a universal metadata vocabulary, (2) an administrative body with people who work for large internet companies, volunteers, and a governance structure, and (3) a website with code examples, release his- tory, and term hierarchy. A final (4) category might be how Schema.org is applied and operationalized by web administrators and developers “in the wild” (Iliadis et al., 2023, p. 3). It provides a standardized way for developers to structure data so that search engines can better understand and therefore more accurately index, connect, and display web content. This universality facilitates interoperability and a more seamless integration of information across diverse internet domains, including commerce, publishing, and social media.

The development of Schema.org's metadata vocabulary has significant implications for how information is experienced on the web. With its goal to assist search engines and other applications in delivering rich, extensible experiences, Schema.org has become a de facto standard for structured data on the internet. The vocabulary includes a broad array of terms that cover a myriad of topics, thereby helping to shape the very infrastructure of the web as we know it.

By standardizing metadata vocabularies, Schema.org allows for the 'wrapping' of information to provide machine-readable signals for various applications. This functionality is critical not just for search engine optimization but also for the creation of knowledge panels, maps, and a myriad of services that rely on structured data to deliver information. As Iliadis et al. discuss, Schema.org acts as a gatekeeper for data on the web, thereby authoring vocabulary that everyday web users encounter in their searches, impacting visibility and discoverability in profound ways (Iliadis et al., 2023, p. 8).

The metadata hierarchy presented by Schema.org is not intended to be a 'global ontology' of the world, yet it plays a fundamental role in modeling the world for search engines and other platforms. By creating, maintaining, and promoting schemas, Schema.org shapes how data is structured across the web, which in turn influences how information is retrieved and understood by users globally. The semantic network visualization of Schema.org, as analyzed by Iliadis and his team, showcases its domain coverage and modularity, emphasizing its significance as a schema that models data for a variety of applications, including fact-checking and responding to global events like the COVID-19 pandemic (Iliadis et al., 2023, p. 11).

In summary, Schema.org is a cornerstone in the Semantic Web, providing a shared language and standards for describing the content on the web. Consequently, Schema.org offers a mechanism for standardizing decision data terminology on a global scale.

II.4 Bridging the Gap: Standardization in Distributed Decision Content

This study’s opportunity to make a contribution is based on an identified gap in the decision-making research and on a documented absence of a data standard for distributed decision content. While there are publications related to standardized decision model notation, these are designed and applicable for enterprise systems describing, automating, and executing enterprise business logic (Biard et al., 2015). Antunes et al articulate the potential for semantic web technologies to assist with exchangeable data sources, data exploration, incorporating external data into data models, data sharing, and data browsing and linking (Antunes et al., 2016). However, neither their research nor any other publication defines a data standard that would enable the sharing and interlinking options for distributed decision content. Distributed cognition research suggests that most of cognitive activity is distributed across individuals, systems, groups, and time (Hutchins, 2000). Therefore, introducing a standardized way to capture, share, and re-use decision content across individuals, systems, and groups is likely to positively affect decision-making, a subset of cognitive activities with an enormous impact on individuals and groups.

The expected artifact, a data standard, will make it possible to structure real-world decision content in a way that makes it effortless and convenient to collaboratively perform functions including sorting, ranking, filtering, re-weighting, discovering, visualizing, exploring, commenting on, and sharing decisions on the lowest possible level of granularity. The data structure should enable real-world decision representations accommodating any combination of dimensions including but not limited to alternatives, criteria, weights, stakeholders, authors, and scenarios in a way that maximizes the standardization of dimensions and values to enable global compatibility of decision data fragments.

III THEORETICAL FRAMING

III.1 Distributed Cognition

To cover the theoretical framing literature applicable to distributed decision content, I offer insights from publications related to distributed cognition.

The roots of distributed cognition are deep, but the field came into being under its current name in the mid-1980s. In 1978, Vygotsky's Mind in Society was published in English. Minsky published his Society of Mind in 1985. At the same time, Parallel Distributed Processing was making a comeback as a model of cognition (Rumelhart, et al, 1986). The nearly perfect mirror symmetry of the titles of Vygotsky's and Minsky's books suggests that something special might be happening in systems of distributed processing, whether the processors are neurons, connectionist nodes, areas of a brain, whole persons, groups of persons, or groups of groups of persons. (Hutchins, 2000, p. 2)

Boland et al offer a concise definition, "Distributed cognition is the process whereby individuals who act autonomously within a decision domain make interpretations of their situation and exchange them with others with whom they have interdependencies so that each may act with an understanding of their own situation and that of others." (Boland et al., 1994, p. 457). The same authors propose six design principles for systems intended to support distributed cognition structures:

- Ownership. An interpretation is always owned by an actor responsible for creating and maintaining it.
- Easy Travel. "An individual's interpretation should display a hypertext-like structure in which any element can be linked to any other, and the links can be followed quickly and easily."(Boland et al., 1994)
- Multiplicity. Each actor makes her own interpretations and can exchange and critique representations.

- Indeterminacy. Interpretations are not expected to be complete, correct, or precise. "…there is no final or stable understanding to be achieved, only a continuing interpretive process."(Boland et al., 1994)
- Emergence. Novel concepts emerge during the process of interpretation.
- Mixed Form. Actors should be able to express their understanding using their preferred media including text, visualizations, and multi-media.

(Boland et al., 1994, p. 466)

According to Nilsson and Ziemke who study information fusion in the context of distributed cognition, "…cognition can be considered as distributed in a threefold sense: distributed across individuals in a group or organization, distributed between human-internal (e.g. memory) and external mechanisms (e.g. computer systems, material and/or social environment), distributed over time." (Nilsson & Ziemke, 2006, p. 3). Regarding the concept of information fusion, the same authors state that "…there are individuals with usually well defined roles and tasks who interact with each other and with computer systems, e.g. information fusion systems; everyone possess their own expert knowledge but something more, something new emerges in the interaction between them, e.g. an information fusion process." (Nilsson & Ziemke, 2006, p. 3).

Bardone and Secchi advance and support three propositions which could provide a foundation for explaining why individuals may be interested in externalized distributed decision content. First, they argue that human cognition cannot be systematically captured on the individual level as it is influenced by and depends on external resources. Second, individuals overcome their internal cognitive limitations by externalizing their thoughts and finding new ways of thinking by re-projecting external occurrences internally. Third, individuals tend to depend on information from other individuals as well as provide information to others in the form of comments, suggestions, and perceptions (Bardone & Secchi, 2009).

III.2 Information Architecture in Multi-Criteria Decision-Making

"Information architecture (IA) is a professional practice and field of studies focused on solving the basic problems of accessing, and using, the vast amounts of information available today." (Resmini & Rosati, 2011, p. 33) IA plays a critical role in how information is structured, understood, and utilized. "The process of making quality choices using multi-criteria decision-making (MCDM) depends on the procedures for scoring alternatives, discovering relevant criteria, weighting criteria, and, not the least, for structuring criteria trees." (Brugha, 2004, p. 55) Within the domain of MCDM, the architecture of information becomes particularly vital as it directly influences the decision-maker's ability to evaluate options against a set of criteria. Given the complexities highlighted by Resmini & Rosati (2011) in the field of information architecture (IA) and the detailed processes described by Brugha (2004) in the domain of MCDM, there emerges a significant gap in current practices—a standardized format for decision-related data.

Conceptualizing Decision Spaces through Information Architecture

Information architecture provides a framework for conceptualizing decision spaces. In MCDM, decision spaces are complex, requiring a clear structure to ensure that decision-makers can navigate through criteria and alternatives efficiently. By applying principles of IA, we can create a system where decision-related data is not only accessible but also meaningfully organized to support the cognitive processes involved in decision analysis.

Introducing the Weighted Decision Matrix

The weighted decision matrix emerges as a tool that embodies both IA and MCDM principles. It is a structured format that presents criteria and alternatives in a matrix form, allowing for the systematic comparison of options. The matrix incorporates weights for each criterion, reflecting their relative importance in the decision-making process.

Information Hierarchy and Weight Distributions

In the context of IA, the weighted decision matrix is also about the hierarchy of information. Criteria are not treated equally; they are weighted to represent the decision-maker's priorities and the strategic importance of each factor. Furthermore, they can be organized as tree structures allowing low level criteria to “roll up” into higher level nodes representing composite decision factors. This hierarchical structuring of information assists in transforming complex decision variables into a comprehensible and manageable form.

IV RESEARCH METHODOLOGY

IV.1 Introduction to Methodology

Since the objective of this study is to deliver a candidate data standard, an artifact, I choose Design Science Research Method (DSRM) as my method of inquiry. "Design Science Research (DSR) is a problem-solving paradigm that seeks to enhance human knowledge via the creation of innovative artifacts." (Brocke et al., 2020, p. 1). Peffer's version of the DSRM process, shown in Figure 4, is one of the methodological backbones of this study as it is an established and accepted standard for Design Science projects.

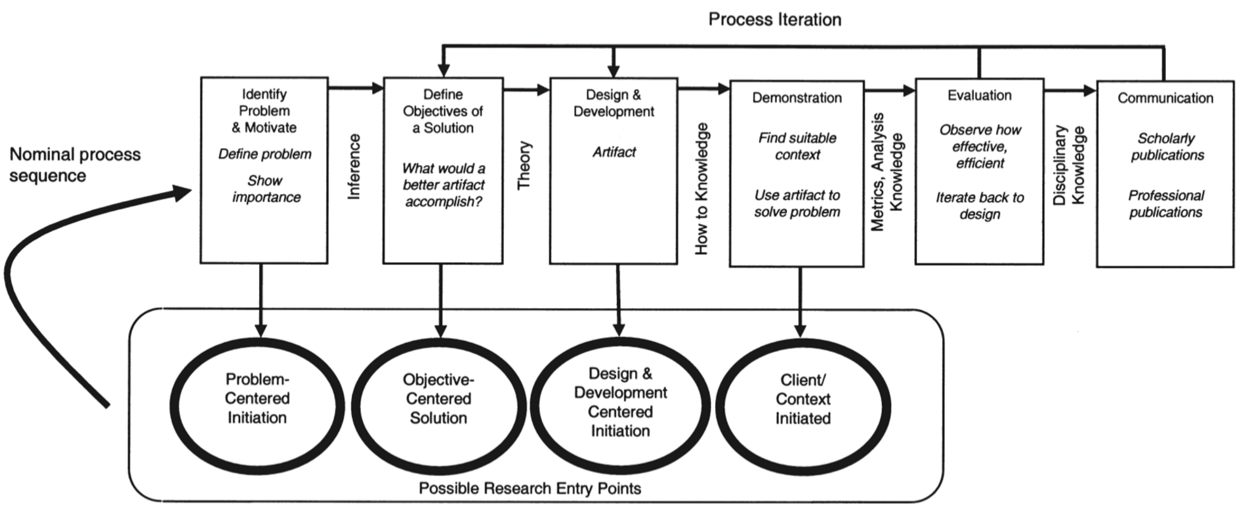


Figure 4 DSRM Process by Peffers (Peffers et al., 2007)

This method was executed via a set of semi-structured expert interviews and simulations guided by Sonnenberg & vom Brocke's template of evaluation activities within the DSR process shown in Figure 5.

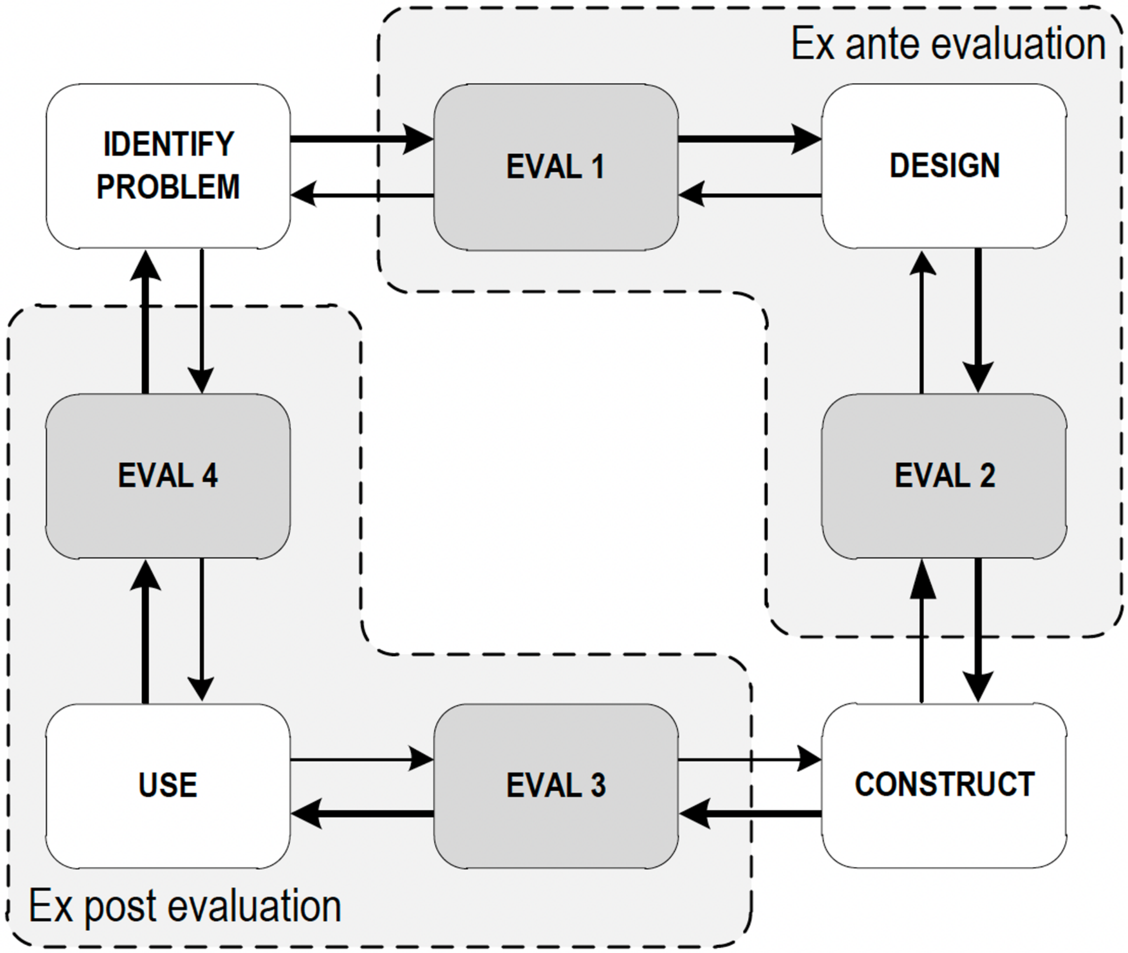


Figure 5 Evaluation activities within DSR process (Sonnenberg & vom Brocke, 2012a, p. 6)

IV.2 Research Design and Approach

The research project was carried out in the following four phases: problem justification, objective definition, design and development, and data standard evaluation. The problem justification phase was executed via a thorough literature review focused on data structures used with DSS. The objective definition phase is what is represented in Sonnenberg & vom Brocke's diagram as "EVAL 1". This phase consists of expert interviews with decision-makers and DSS experts. The objective definition phase concludes after a strong decision-information bottleneck theme emerges and gets confirmed across multiple interviews.

The design and development phase covers “DESIGN” and “EVAL 2” from Sonnenberg & vom Brocke’s diagram. In this phase, the data standard was created with the help of expert input iteratively obtained from another group of experts. These groups consisted of professionals with expertise in computer science, management information systems, and distributed systems. The design phase concluded when the design team concluded that the data standard met the requirements identified by the decision support expert group.

The evaluation phase consisted of expert interviews with the DSS expert group who had been previously interviewed in the objective definition phase. The data standard was presented during the interview via technical documentation as well as a simulation of a decision environment using the new standard. This phase corresponds to “EVAL 3” in Sonnenberg & vom Brocke’s diagram. The “USE” and “EVAL 4” phases from the diagram are not going to be performed in order to keep the dissertation scope realistic given the available time frame. However, these phases will be heavily reflected in the future research section of this study.

Figure 6 below shows the actual research process after adjustments.

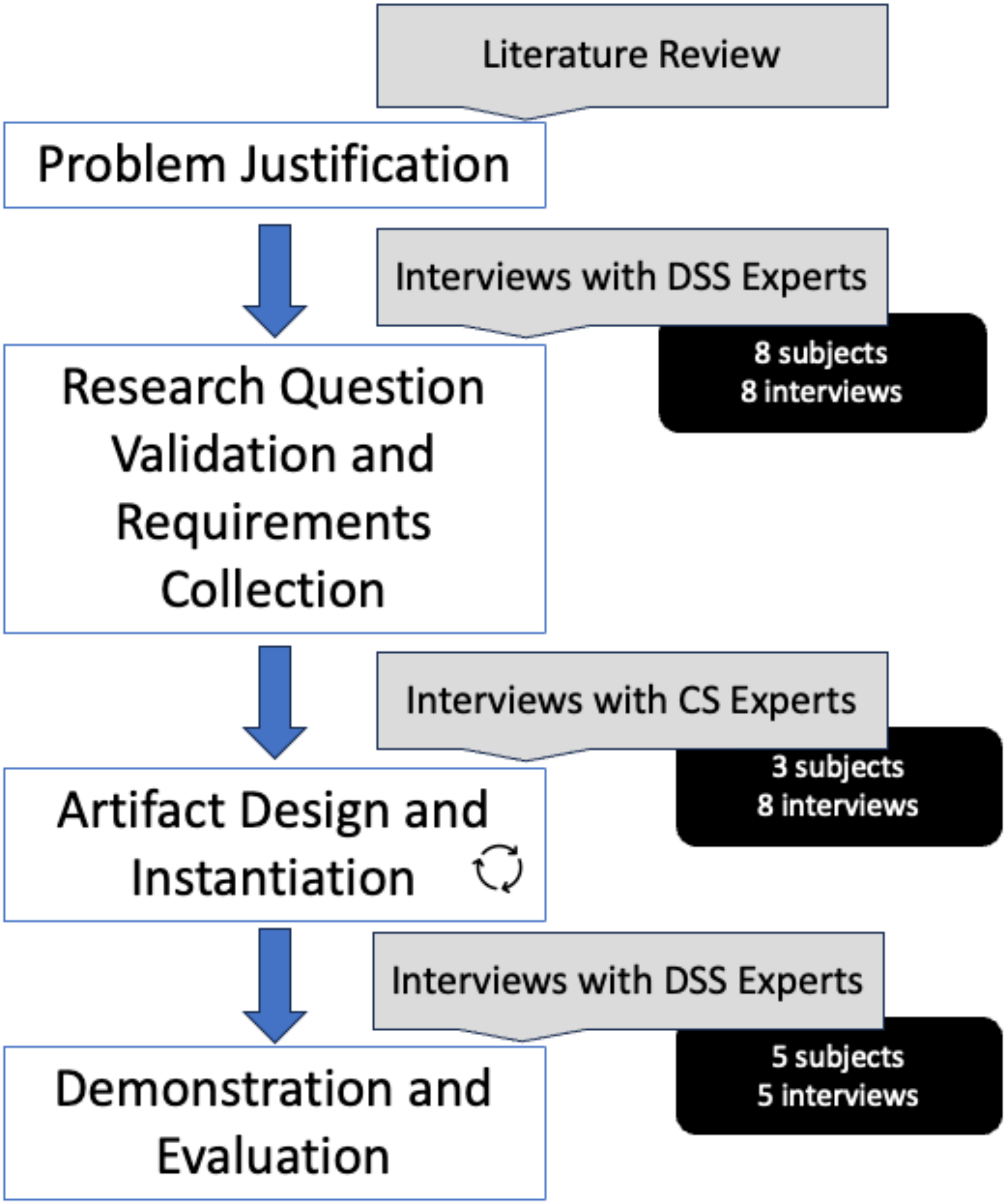


Figure 6 Adjusted DSRM Process

IV.3 Expert Group Descriptions

IV.3.1 *Decision Support Practitioner Group*

The expert group assembled for this study comprises a distinguished panel of professionals who hold substantial expertise in the domain of decision support systems (DSS). These experts have been identified based on their significant experience with the construction, operation, utilization, and maintenance of DSS tools and frameworks.

Selection Criteria: Individuals were chosen for their practitioner expertise as decision support architects, data scientists, and strategic directors who have firsthand involvement in developing and managing DSS initiatives.

Recruitment Strategy: The experts were recruited from the researcher's personal network, ensuring a diverse range of insights from various sectors including higher education, professional services, technology, manufacturing, and finance.

Decision Support Expert Group:

- **DS-PRAC-AB**: With a role as a Decision Support Architect from Slalom, bringing insights from professional services.
- **DS-PRAC-CB**: Serving as a director of country intelligence index project at Georgia State University, with expertise in designing and operating a DSS tool in both instructional and commercial contexts.
- **DS-PRAC-RS**: A Solutions Architect from Elastic, providing a technology industry perspective on decision support systems.

- **DS-PRAC-PB**: Director at the Fiscal Research Center of Georgia State University, with experience in professional services.
- **DS-PRAC-ZZ**: A Data Scientist affiliated with the University of Georgia, contributing an academic viewpoint on decision data.
- **DS-PRAC-SH**: Practice Leader at Deloitte and Actionable Results Research team, offering a consultancy perspective.
- **DS-PRAC-EF**: Director of Point of View (PoV) and Strategy at Georgia Pacific, bringing a manufacturing angle to DSS.
- **DS-PRAC-MK**: Director at Advent International, providing insights from the finance sector into decision support.

This selection ensures a rich collection of perspectives to inform the development and evaluation of the decision data standard artifact.

IV.3.2 *Computer Science Expert Group*

The computer science expert group for this research is comprised of highly educated professionals, each holding advanced degrees and specialized expertise in the fields of computer science, management information systems, and distributed systems.

Selection Criteria: These individuals were selected for their extensive academic and practical experience, specifically within the realms of system architecture, research computing, high-performance computing, and enterprise software development.

Recruitment Strategy: The professionals were recruited via the researcher's personal network, ensuring a diverse representation of perspectives from different industries.

Computer Science Expert Group:

- **CS-PRAC-SH**: A Senior Cloud Solutions Architect from Slalom, with a strong background in enterprise software system architecture.
- **CS-PRAC-SP**: The Associate Director at Georgia State University's Advanced Research Computing Technology & Innovation Core, bringing a deep understanding of computational physics, research computing, and high-performance computing to the table.
- **CS-PRAC-SHS**: A Senior Software Engineer from Home Depot, whose doctoral research in computer science and extensive knowledge in physics, math, and enterprise software development are invaluable to this research.

Each member contributes a wealth of knowledge crucial for the technical design and feasibility assessment of the proposed decision data standard.

IV.4 Data Collection Methods

IV.4.1 *Semi-Structured Interviews: An Introduction*

In the quest to develop a universally applicable decision data standard, this study employed semi-structured interviews as a primary data collection method. Semi-structured interviews are characterized by a pre-defined set of open-ended questions that provide a framework for the interview but allow for in-depth discussions based on the respondent's answers. This method facilitates a flexible yet focused dialogue between the interviewer and the participant, enabling the exploration of complex topics like decision data standardization in depth.

IV.4.2 *Justification for Choosing Semi-Structured Interviews*

The decision to employ semi-structured interviews as the primary method of data collection was driven by several considerations, vital among them being the depth and complexity of the research topic. The development of a decision data standard touches on both the technical aspects of data standardization and the nuanced, context-dependent nature of decision-making processes. Semi-structured interviews, with their balance of structure and flexibility, are ideally suited to exploring such multifaceted issues.

Firstly, the explorative nature of semi-structured interviews was invaluable in uncovering the implicit needs, preferences, and challenges faced by experts in decision support systems. This method allowed for the elicitation of detailed insights into current practices, perceived gaps, and the potential impact of a standardized decision data format. Such rich qualitative data are essential for informing the development of a practical, applicable data standard.

Secondly, the flexibility of semi-structured interviews facilitated the adaptation of the discussion in real-time, enabling the deep dive into emerging themes and the exploration of unforeseen areas of interest. This adaptability was critical in ensuring that all relevant aspects of the decision data standardization process were comprehensively explored, contributing to a more robust and informed artifact design.

Finally, the choice of semi-structured interviews reflected the need for a methodology that could capture the nuanced perspectives of a diverse expert group. The decision support and computer science fields encompass a wide range of viewpoints, and semi-structured interviews provided a conducive environment for these to be expressed and understood in their complexity.

In conclusion, semi-structured interviews were chosen for their ability to generate in-depth, nuanced data critical for the development of a decision data standard. This method provided the necessary flexibility and depth of exploration to understand the complex interplay between technical feasibility, practical applicability, and the diverse needs of stakeholders involved in decision support systems.

IV.4.3 *Data Collection Execution*

Interviews were conducted using Microsoft Teams or Webex, chosen for their robust virtual collaboration capabilities and compliance with data management protocols as approved by GSU Internal Review Board (IRB). The IRB identification number for this study is H24029. Sessions were recorded and transcribed with otter.ai, ensuring accuracy in capturing verbal nuances and facilitating ease of data analysis. The data collection for this study was conducted methodically over a period of six months starting in September 2023 and concluding in March 2024. It included 21 interviews with 12 subjects. See Appendix F for a timeline of interviews and interview metadata.

IV.4.3.1 Interview Structure Across Phases

Research Question Validation and Requirements Gathering: The interviews initiated with an orientation on the research objective. Experts were then queried about their background to establish relevance to the topic. The dialogue was steered using seeding questions designed to unravel insights pertinent to the research objectives.

Artifact Development Phase: This phase commenced with a reiteration of the research objective and a debrief on the requirements surfaced in the discovery phase. Experts were updated on the artifact's current state, including recent modifications. The session was interactive, soliciting the experts' feedback and recommendations for enhancements.

Evaluation Interviews: Experts were re-familiarized with the research objective and introduced to the data standard artifact within a custom online demonstration platform. The focus was on assessing the artifact's alignment with the requirements and its performance against evaluation criteria from Sonnenberg & vom Brocke such as completeness, ease of use, and understandability. (Sonnenberg & Vom Brocke, 2012b, p. 391)

IV.5 Research Question Validation and Requirements Gathering Phase

In this phase of the study, the primary aim was to validate the research question and to gather detailed requirements for the decision data standard. A semi-structured interview methodology was employed to provide flexibility in discussions while ensuring that the core research objectives were addressed.

Interview Execution:

- The interviews commenced with a briefing on the research objective to provide context to the experts.
- Participants' relevant backgrounds were discussed to acknowledge their expertise and to steer the conversation effectively.
- A series of seeding questions related to the desirability and feasibility of a matrix-based decision data standard was presented. This helped to prompt detailed discourse and uncover nuanced perspectives on the subject.

The following seeding questions were used to guide the conversations and explore the experts' insights:

1. "Do you believe that a standardized way to exchange and publish decision data would enhance overall decision-making processes in the real world?" - This question aimed to understand the perceived value and impact of a standard on decision-making.
2. "How do you currently capture and share decision information in your organization, and what are the limitations of these methods?" - This question was directed at understanding current practices and identifying gaps that the standard could fill.
3. "Can you describe a decision-making situation where a standardized decision data format would have been beneficial?" - This question sought practical examples of where and how a data standard could be applied.
4. "In your experience, how does the lack of a standardized decision data format affect efficiency and outcomes in decision-making?" - This sought to gather evidence of the practical implications of not having a standardized format.
5. "What features would be essential for a decision data standard to be useful in your context?" - The goal here was to gather specific functional requirements from the users' perspectives.

The interviews were conducted with the understanding that these seeding questions would elicit detailed discussions that could reveal implicit needs and opportunities for standardization in decision-making processes. The semi-structured nature of the interviews allowed for the emergence of topics that were not preconceived by the researchers, providing a richer understanding of the problem space and more informed requirements for the proposed decision data standard.

IV.6 Artifact Development Phase

This phase centered on advancing the decision data standard artifact, leveraging the insights gained from the first phase. Expert consultations were instrumental in refining the proposed standard and its alignment with practical applications.

Interview Structure:

- Experts were briefed on the research objective's progression and the distilled requirements from the initial phase.
- Discussions were framed around the artifact's current state, allowing experts to comprehend recent advancements and provide informed feedback.
- Seeding questions focused on the artifact's viability, integration with existing systems, scalability, and potential enhancements, drawing from experts' knowledge in technology and application development.

Developmental Insights:

- Interviews explored the suitability of JSON LD as a foundational structure, examining its compatibility, extensibility, and potential to facilitate global decision-making processes.
- Experts evaluated the integration capabilities of the proposed standard with current data systems and platforms, assessing the ease of adoption and potential performance implications at scale.

- Potential improvements were identified, ensuring the artifact remained flexible and capable of accommodating future changes in the technology landscape.

This phase was pivotal in iteratively shaping the artifact to be robust, scalable, and adaptable, qualities essential for a universally applicable decision data standard.

IV.7 Artifact Evaluation Phase

In this phase, evaluation interviews were conducted to assess the effectiveness and practicality of the developed decision data standard artifact.

Interview Execution:

- Reminding the experts of the research objective, they were shown the developed artifact in action, within a specially designed online demonstration environment.
- The demonstration included a walkthrough of the decision model's use, the structure of decision information as granular cells within a matrix, and the implementation of the standard in realistic decision scenarios.

Assessment Criteria:

- Experts were asked to evaluate the artifact against specific criteria such as ease of use, effectiveness, efficiency, and understandability—key metrics adapted from Sonnenberg & vom Brocke. (Sonnenberg & Vom Brocke, 2012b, p. 391)
- Experts were presented with a summary of the requirements from the requirement gathering phase and asked to evaluate if the artifact meets the requirements.

- Particular attention was paid to the artifact's ability to foster a common language for decision-making, its integration with other data systems, and its adaptability across various decision-making contexts.

Through this evaluative process, the artifact's design was rigorously assessed, ensuring its readiness for broader application and its potential for enhancing decision-making practices.

IV.8 Analysis Methodology

The analysis of qualitative data derived from the semi-structured interviews was conducted meticulously, employing a dual coding strategy to ensure a comprehensive understanding of the narratives provided by the participants. This methodological approach facilitated the extraction of meaningful insights critical to the development of the decision data standard.

IV.8.1 *Open and Pattern Coding:*

1. **Open Coding**: The analytical process began with open coding, where the transcribed data was examined line by line to identify distinct concepts, categories, and initial themes as they naturally emerged from the interview transcripts. This granular approach was crucial for uncovering nuanced information, subtle distinctions, and unexpected patterns within the data.
2. **Pattern Coding**: Subsequent to open coding, pattern coding was employed as described by Miles et al. (Miles et al., 2014, p. 78) This step involved aggregating the initial codes into more abstract, higher-order themes. By synthesizing the fragmented data into cohesive patterns, this method facilitated the conceptual structuring of data, aligning

closely with the study's research objectives and revealing broader trends that informed the artifact's development.

IV.8.2 *Analysis Tools*

- **NVivo Software**: NVivo played a pivotal role in the organization, coding, and analysis of the qualitative data. Its advanced features allowed for an efficient and systematic exploration of the data, supporting the identification of relationships and themes that emerged from the expert interviews.
- **Microsoft Excel**: For tasks related to data visualization and manipulation, Microsoft Excel was utilized. Excel's capabilities in sorting, filtering, charting, and summarizing data were instrumental in illustrating the connections between different data elements and presenting the emerging patterns in a visually interpretable manner.

IV.8.3 *Data Validation*

To ensure the accuracy and reliability of the analysis, two primary validation methods were employed: member checking and triangulation.

- **Member Checking**: Following the initial analysis, each interview subject received an email summarizing the key points and themes identified during their interview. This process allowed participants to verify the accuracy of the interpretation and to provide additional insights or clarifications. Furthermore, a summarized report of the collective insights from all interviews was shared with the group, enabling a cross-verification among participants and reinforcing the validity of the findings.

- **Triangulation**: The study also employed triangulation, cross-referencing the qualitative data from interviews with existing literature and theoretical frameworks related to decision data standardization. This method ensured that the findings were not only grounded in the participants' insights but also aligned with established research and practices in the field. By comparing and contrasting different data sources, the study enhanced its credibility and contributed to a more robust and well-rounded understanding of the research topic.

Through these comprehensive data analysis and validation methods, the study achieved a rich, detailed, and substantiated understanding of the expert knowledge, which was instrumental in the iterative development and refinement of the decision data standard artifact.

IV.9 Ethical Considerations

The methodology employed in this research adheres to the highest standards of ethical considerations, as outlined by the Institutional Review Board of Georgia State University (GSU). Prior to conducting interviews, all subjects were provided with a comprehensive interview consent document, which had been previously approved by the GSU IRB through submission H24029. This document detailed the nature of the study, the voluntary basis of participation, the measures taken to ensure confidentiality, and the intended use of the data collected. Subjects gave their informed consent by electronically signing this document or by verbally acknowledging their consent at the beginning of the interview session, which was then recorded for verification purposes.

To further uphold the ethical integrity of the study, explicit permission was obtained from each participant to record the interviews. This permission was documented in the signed consent forms and was also verbally confirmed at the start of each recording session. Such meticulous documentation ensures that the research upholds the principles of informed consent and respects the autonomy of each participant.

The confidentiality of the participants has been a paramount consideration throughout the study. To protect the identities of the interview subjects, pseudonyms are employed in the dissertation. This measure safeguards the privacy of the participants, allowing them to share their experiences freely without concern for personal or professional repercussions.

The storage and handling of the recorded media and transcripts have been meticulously designed to ensure data security and confidentiality. All data are stored on GSU's cloud resources, including MS Office 365 platforms like Teams and OneDrive, otter.ai for transcription services, and Cisco Webex for video interviews. Access to these data is strictly limited to authorized users, thereby preventing unauthorized access and ensuring that the data are used solely for the purposes of this research. Moreover, all stored data are encrypted both at rest and in transit, providing an additional layer of security and further ensuring the protection of participants' information.

In summary, this research has been conducted with a firm commitment to ethical principles, prioritizing informed consent, confidentiality, and data security. These measures not only comply with the requirements set forth by the GSU IRB but also reflect the ethical standards expected of scholarly research.

IV.10 Methodology Summary

This dissertation employs a Design Science Research Methodology (DSRM) to address the gap in standardized data protocols for decision-making information on a global scale. The research unfolds in several meticulously planned phases, each contributing to the development and validation of a novel decision data standard aimed at enhancing global decision-making processes. The methodological approach is outlined as follows:

1. **Research Design and Approach:**
    - The study adopts a design science research approach, iterating through problem identification, objective definition, design and development, and artifact evaluation.
    - Semi-structured expert interviews are the primary method for qualitative data collection, ensuring depth and breadth in gathering insights.
2. **Expert Group Descriptions:**
    - Two distinct expert groups were engaged: decision support practitioners and computer science experts. These groups provided valuable perspectives on the practical and technical aspects of decision support systems and the proposed decision data standard.
3. **Data Collection Methods:**
    - Data were collected through semi-structured interviews conducted via Microsoft Teams or Webex. These platforms were selected for their robustness and compliance with GSU IRB data management protocols.
    - Interviews were structured to validate the research question, gather requirements, solicit design feedback, and evaluate the developed artifact.

4. **Artifact Development and Evaluation:**
   - The development phase was informed by insights from the initial expert interviews, focusing on technical feasibility, practical applicability, and alignment with stakeholder needs.
   - The evaluation phase involved demonstrations of the proposed standard using artificial data, assessing its functionality, impact, and areas for refinement based on specific criteria like completeness, ease of use, and understandability.
5. **Analysis Methodology:**
   - Data from interviews were analyzed using open and pattern coding, facilitated by NVivo software for organization and thematic analysis, and Microsoft Excel for data visualization.
   - Validation methods included member checking and triangulation, enhancing the credibility and robustness of the findings.
6. **Ethical Considerations:**
   - Ethical standards were upheld throughout the research process, with informed consent obtained from all participants. Participant confidentiality was ensured through pseudonyms, and data were securely stored and encrypted using GSU's cloud resources.
7. **Limitations:**
   - The study acknowledges limitations such as the scope of expert group selection, the evaluation process's reliance on artificial scenarios, and the broader technological and implementation considerations not fully explored.

This summary encapsulates the methodological rigor, ethical diligence, and the systematic approach taken to explore and develop a universal decision data standard, acknowledging the contributions and limitations of the study in advancing knowledge in the field of decision support systems.

V ARTIFACT DESIGN AND DEVELOPMENT

V.1 Informing the Design Stage

The interviews conducted with decision support experts in various fields revealed significant insights into decision-making processes, the importance of capturing and standardizing decision data, and the potential impact of such standardization on decision quality and efficiency.

V.1.1 *Validation of the Design Objective*

Figure 7 encapsulates the synthesized findings from the first round of interviews, representing the frequencies with which various expected effects of a potential global decision data standard were mentioned by the experts interviewed. The conclusions drawn in this figure are based on a methodical analysis of interview transcripts, where instances of discussions related to the expected effects on decision-making were meticulously coded and quantified. For example, the positive effects were referenced 15 times across all interviews, highlighting a presence of a favorable attitude among participants toward the anticipated benefits of a standardized approach to decision data. Example fragments of an interview with DS-PRAC-AB are “It's giving people a common language through which to define what they're looking at.” and “So I think I will forever be on the side of yes to standards, I think it removes a lot of what ends up being grunt work off of people's plates, and allows them to focus on the stuff that really matters, which is making whatever decision they need to make.” DS-PRAC-ZZ noted “if everyone's working from the same kind of decision matrix space, then I think that, you know, that, that creates a lot more shared language.” To show the other side of the attitude spectrum, I include an example fragment illustrating concerns about potential negative outcomes from the interview with DS-PRAC-SH, “…but if you're going to be that rigorous, they're only going to have a few data points to look at. So, you don't want to handcuff the data to a certain model." These references provide tangible evidence that reinforces the validity of the design objective to establish a global decision data standard, aiming to optimize the decision-making landscape by fostering uniformity, clarity, and efficiency in how decision information is accessed and utilized worldwide.

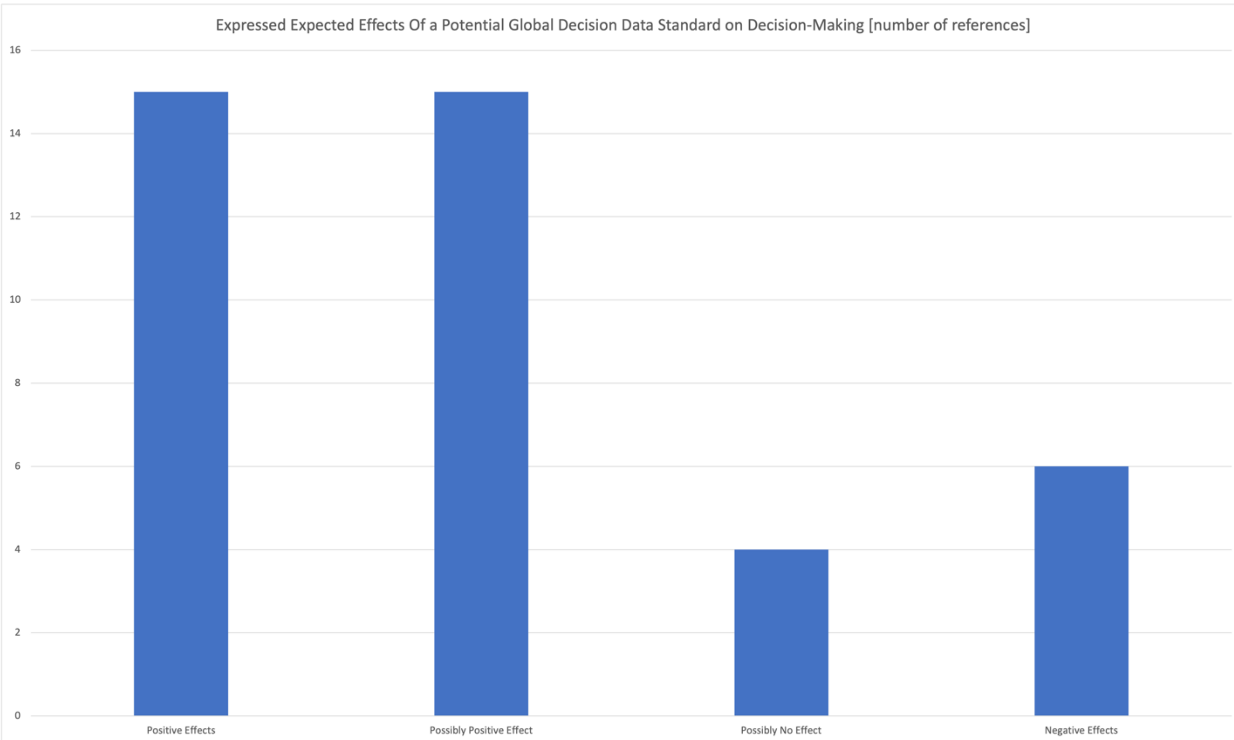


Figure 7 Expected Effects of a Potential Global Decision Data Standard on Decision-Making

This analysis shows a mostly positive sentiment of the decision expert group toward the idea of a global decision standard.

V.1.2 *Incorporating Design Principles from Literature*

Building upon the theoretical insights identified in the literature review, the design of the artifact was guided by a set of principles for distributed cognition systems that ensure its efficacy and relevance to the decision-making context. These principles, drawn from seminal work by Boland et al. (1994), serve as the cornerstone for the development of the artifact, influencing its design at a fundamental level and ensuring that it aligns with the complex nature of interpretive decision-making processes. (Boland et al., 1994, p. 466) Boland et al.'s design principles detailed in the literature review chapter include:

• **Ownership**: Reflecting the principle of ownership, the artifact enables each decision-maker to 'own' their input, ensuring accountability and traceability for every interpretation made within the system.

• **Easy Travel**: In adherence to the principle of easy travel, the artifact was engineered with a user-centric interface that allows for seamless navigation, akin to a hypertext structure, facilitating quick and intuitive access to linked decision elements.

• **Multiplicity**: Embracing the multiplicity of perspectives, the system supports diverse user interpretations, offering a platform for the exchange and critique of representations, thus enriching the collective decision-making process.

• **Indeterminacy**: Recognizing the principle of indeterminacy, the design of the artifact accepts the evolving nature of decision content, allowing for interpretations to be iterative, non-final, and adaptable to new information.

• **Emergence**: The system design anticipates the emergence of novel concepts, providing a flexible framework that supports the evolution of understanding as the decision-making process unfolds.

• **Mixed Form**: Finally, the principle of mixed form is embodied in the artifact's ability to capture and display data in various formats, catering to the individual preferences of actors and the multifaceted nature of decision content.

V.1.3 *Summary of The Requirements Gathering Interviews*

Key findings from the requirements gathering interviews are summarized below with supporting quotes from the interviews:

1. **Standardization's Role in Decision Making**: Experts agreed that a standardized global decision data format could significantly enhance real-world decision-making processes for individuals and organizations. The lack of a common language in decision data was cited as a major hurdle in achieving efficiency and effectiveness in decision support systems. Supporting quotes include the following:

    - **DS-PRAC-AB**: "Standardization removes a lot of what ends up being grunt work off of people's plates, allowing them to concentrate on what they're good at."
    - **DS-PRAC-SH**: "In my experience, having a standardized approach cuts through the noise, helping everyone to focus on the decision at hand rather than getting lost in translation."
    - **DS-PRAC-ZZ**: "A unified decision data language could be a game-changer. It's not just about efficiency; it's about making sure we're all on the same page, which in itself can drive better decision-making."

2. **Challenges in Implementation**: While the potential benefits of standardization were widely recognized, experts also highlighted several challenges in implementing such a

standard. These included the inherent diversity in data structures and use cases across different systems, the difficulty in aligning core values between disparate data systems, and the need to sometimes sacrifice lower-level efficiency for higher-level coherence.

- DS-PRAC-CB: “I'm still interested in how you're gonna harvest this data and turn it into the [standard]... the challenge is... how are you going to harvest data? Where are you going to get your information from?”
- DS-PRAC-EF: “If you have a very straightforward easy decision that the model... is structured is very... it saves you a lot of time... but when you get to really complex decisions... sometimes have shortcomings...”
- DS-PRAC-PB: "I think it could be useful...if it worked across disciplines and enabled interdisciplinary collaboration," hinting at the challenge of designing a standard flexible enough to be relevant across various fields.

3. **Consequences of Lack of Standardization**: The absence of standardized decision data formats was noted to cause inefficiencies, especially when integrating data from multiple systems. For instance, the need to translate and validate data across systems was identified as a significant workload that could be mitigated with standardized formats.

- **DS-PRAC-AB** expressed that without a common standard, there's a "ships in the night" phenomenon, where people might debate outcomes while the actual disagreement lies in how data is interpreted differently at the input level. This results in a cycle of misunderstanding that complicates decision-making processes due to varying foundational interpretations.

- **DS-PRAC-CB** discussed the challenges that arise from not having a standard. He mentioned the necessity of creating reports or using consulting firms to make organizational decisions and suggested that having a standard might alleviate some of these dependencies and simplify decision-making.
- **DS-PRAC-ZZ** highlighted the additional work required to align data from different systems, pointing out the practical difficulties when there's a lack of standardization. He gave an example of having to navigate between separate financial and student systems, which requires additional efforts to translate and validate information, thus causing inefficiencies.

4. **Matrix Structure for Decision Models**: The proposed matrix structure, incorporating alternatives, criteria, weights, and possibly other dimensions, was generally seen as a positive step towards standardizing decision information. However, there were concerns about the potential for disagreement among team members regarding the weighting of criteria and the interpretation of data. The flexibility of the matrix to accommodate multiple dimensions was seen as a strength, allowing for a more nuanced approach to decision modeling.

- DS-PRAC-AB expressed a personal bias towards matrix structures, relating his background in logistics engineering and his comfort with navigating complex tensors and matrices. He acknowledged, however, that this approach might not resonate with everyone, especially those from different backgrounds or business functions: "I agree with that notion of if I can define a solution space and then navigated towards the right answer, I know that I'm in a good spot. Now the tricky part is...if it doesn't resonate with the people that I'm trying to make a decision with, [I] quickly pivot to something else...".

- DS-PRAC-EF acknowledged that matrices are already a commonly used tool in decision-making, especially for presenting concise financial information. He also pointed out the need for context when presenting matrix information, as it adds color and understanding to the numbers: "I mean like even like when we present like a decision right there'll be usually a some form of a matrix with financial information in there... And it's usually a concise way to kind of show findings particularly for financial information or key drivers".
- **DS-PRAC-SH:** "I like the matrix structure. But what I was getting with your third dimension...it's almost that is kind of the behavioral economic or the subjectivity there's an effort accuracy or there's a short term versus long term or there's a subjectivity..."

5. **Properties for Effective Adoption**: For a global decision data standard to be effectively adopted, it needs to simplify complex decision scenarios into accessible formats, be championed by clear-minded individuals within organizations, be flexible enough to be implemented across various platforms, and offer real-time updating capabilities to remain relevant.

    - DS-PRAC-PB: "Sometimes there can be things that... we have to give our best advice on within a one or two-day period... So it just really depends... How engaged we are and what project it is." - This reflection suggests that in advisory roles where timely responses are critical, real-time collaboration capabilities are highly valuable.

- DS-PRAC-MK: "Pre-investment stage it's quite real-time. Because things need to move quickly... if we can only... be seen if we create a more aggressive business plan and on that basis are willing to pay more for the business rather than decrease the IRR expectations... So it needs to be real-time and it needs to be quick." - DS-PRAC-MK discussed the urgency and the necessity for real-time collaboration and decision-making in private equity, particularly during the high-pressure pre-investment phase.
- DS-PRAC-CB: "Not wholly different from build your own index...we're allowing folks to bring in new parameters and reshape everything given the information that they're getting." - DS-PRAC-CB highlights the need for flexibility.

6. **Importance of Addressing Disagreements**: The interviews highlighted the importance of addressing potential disagreements within teams, especially regarding the weighting of decision criteria. A standardized approach could facilitate more constructive conversations by making the bases for different perspectives clear.
    - DS-PRAC-ZZ: "I could imagine this might be difficult to use as part of a team just because I think there might be major disagreements [...] about how you should weight each of the outcomes which can lead to kind of different results".
    - DS-PRAC-AB: "People arriving at conclusions based on different interpretations of what should be the same data right. And what oftentimes happens is people think they're arguing about outputs [...] when the crux of the disagreement has to do more with the inputs than the outputs."

7. **Feedback and Iteration**: The inclusion of a feedback loop in the standardization process was suggested to ensure the standard remains adaptable to future changes in decision-making processes and technologies. Continuous feedback from users and stakeholders is crucial for refining and improving the standard.
    - DS-PRAC-SH: "The only the only thing I would add to that is a feedback loop. And, you know, that feedback loop may be whether that's from you know, and again, we you and I haven't talked too much. I mean, I'm guessing most of your, your target audience is it you or you know, people in the trenches, but some sort of feedback loop to provide feedback on the model along the way."
    - DS-PRAC-EF: "…it's becoming a lot more synchronous, where than it used to be used to be where you draft something, send it off with feedback, now everyone's in the, in the model at the same time or in a presentation at the same time. And, and, you know, so it's the technology that has been more conducive to do that."

The insights from these expert interviews underline the complex interplay between data standardization, decision support systems, and organizational decision-making processes. The proposed matrix structure, with its flexibility and capacity for multi-dimensional analysis, offers a promising framework for addressing some of these complexities. However, the successful implementation of a global decision data standard will require careful consideration of the diverse needs and perspectives of all stakeholders involved.

V.1.4 *Design Criteria Formation*

The formation of design criteria for the development of the decision data standard artifact was substantially informed by qualitative analysis performed on expert interviews. The code frequency table, shown as Table 2 below, played a critical role in this process, summarizing the frequency of specific themes and issues raised by the experts.

Table 2 Code Frequency Table for Requirements Gathering Interviews

Code Name	Count of Experts	Count of References
Desired Properties of Data Standard	1	1
Compatibility	1	1
Flexibility	2	5
Reduction of Cognitive Load	3	4
Overcoming Data Harvesting and Implementation Challenges	0	0
Real-time Collaboration	1	1
Visual Appeal and User Engagement	1	2
Lack of Standardization	0	0
Issues in Sharing and Comparing Data	2	3
Specific Example of an Issue	5	5
Matrix Structure	0	0
Effective for Capturing Decision Data	5	6
Improvement Suggestion	3	6
Strength	0	0
Weakness	3	5
Real-time Collaboration	0	0
Desired Features	5	7
Importance	2	2

By triangulating these qualitative insights with the extant literature on decision-making and decision support systems, a set of robust design criteria was established for the artifact. These criteria are designed to ensure that the final artifact is not only theoretically sound and empirically grounded but also resonates with the practical requirements and preferences of its intended users. The structured approach to coding and theme identification ensured that each design criterion was directly linked to the articulated needs and suggestions of the experts. This linkage assures that the developed decision data standard will be relevant and valuable to practitioners, enhancing global decision-making processes with a novel and practical tool.

The resulting design criteria were directly informed by a consensus on the necessity for a common language in decision-making, standardization, and the facilitation of integration across diverse systems.

V.1.4.1 Common Language and Standardization

DS-PRAC-ZZ underscored the need for a unifying language that could bridge gaps across systems, suggesting that "[...] something unifying, absolutely would make my life way easier" and highlighting the human challenge in agreeing on standard definitions. DS-PRAC-CB noted "You go through a lot of pain when it comes to retrieving formatted data from a source and then getting them in a usable state... If I come up with a standard that can be easily applied, then you will not have to go to...spend days on formatting CSVs but you will be able to automatically pull stuff." These insights led to the development of design criteria that prioritize a common semantic framework to ensure compatibility and comprehension across various decision support systems.

V.1.4.2 Integration Across Systems

The design criteria were further shaped by the integration challenges outlined by practitioners, such as DS-PRAC-ZZ, who noted that crossing systems currently involves "a lot of extra work" and highlighted the additional work required to align data from different systems. He gave an example of having to navigate between separate financial and student systems, which requires additional efforts to translate and validate information, thus causing inefficiencies. The artifact, therefore, is designed with an architecture that aims to provide seamless data integration, mitigating the overhead associated with the current state of practice.

V.1.4.3 Decision Matrix and Weighting

The matrix structure's usefulness, as recognized by DS-PRAC-EF and the reservations about its universal applicability voiced by DS-PRAC-PB and DS-PRAC-MK, influenced the artifact's design to be inherently flexible. DS-PRAC-EF stated "Usually like you know I mean and it's not just true for GP I mean probably most decisions are made either through a PowerPoint deck pitch or some sort of investment memo. And I think some of the words that go that accompany that matrix is usually you know that provides more context and color." DS-PRAC-PB expressed his attitude toward the matrix feature like this: “I think a tool is only as good as the inputs that it has to make those decisions...I think it could be useful. But again, it really depends on or if it's decentralization we have the top experts here...it could be useful kind of like an interdisciplinary collaboration.” DS-PRAC-MK adds "I think you know definitely there is a use case [for the matrix approach] and if someone could create it I think you know people will try to use it." The design criteria accommodate additional dimensions and cater to complex fields by allowing for customization of the matrix structure to fit diverse decision-making scenarios.

V.1.4.4 Data Accessibility and Simplification

Echoing the sentiments of DS-PRAC-CB, the design criteria emphasize simplifying complex data while ensuring depth remains accessible, as detailed data is vital for certain stakeholders. "You go through a lot of pain when it comes to retrieving formatted data from a source and then getting them in a usable state. So, we can combine it with everything else right.

So that's the point that I'm addressing. If I come up with a standard that can be easily applied. Then you will not have to go to, you know, Michaels and greater systems to spend days on formatting CSVs but you will be able to automatically pull stuff it's not just about automation." DS-PRAC-CB's challenges with data blending informed the criteria for data formatting and usability, ensuring the artifact provides a pathway for in-depth analysis without overwhelming the user initially.

V.1.4.5 Real-Time Collaboration

The shift towards synchronous work environments, facilitated by technology and highlighted by DS-PRAC-EF, is embodied in the design criteria. He explained "…it's becoming a lot more synchronous, where than it used to be used to be where you draft something, send it off with feedback, now everyone's in the model at the same time or in a presentation at the same time. And, and, you know, so it's the technology that has been more conducive to do that. Usually, we still have one person own the model to ensure integrity, right? Of what goes in there. And then people can go vet it. And then you know, but yeah, it's probably moved more towards be more synchronous or live." DS-PRAC-PB stated "For the most part, I mean, we're collaborating in real-time all the time." According to DS-PRAC-AB, "For example, if you're doing commodities trading, then you know, the real time aspect becomes really important, right? Because you can, you can federate the decision making let the people that look at weather, focus on the weather and the people that look at minerals, focus on minerals, and all that stuff. But if they're all feeding their information to that same matrix, then the outputs of that that would go to a trader, for example, in real time would be enormously valuable." DS-PRAC-ZZ expressed support for real-time functionality as well: "Having it be real time enough, so that it could address the a lot of the questions that people have that more and more now, or just, you know, they need to know, updated very regularly." The artifact is built to support real-time collaboration, allowing stakeholders to contribute to and modify decision matrices dynamically.

V.1.4.6 Visual Appeal and User Engagement

According to DS-PRAC-CB, "The other thing I guess one more thing that I might mention, is the wow factor. Graphics something that makes it pop off the page to you. And that's why sometimes I complain about the RCI graphics because I say I want this to have more of a pop. I want this to be I mean, this might be able to please a computer science grad student but does it does it please a CEO who's got very little time?" Acknowledging the role of visual appeal and engagement in effective decision support tools, as suggested by DS-PRAC-CB, the design criteria ensure that the artifact's interface is not only functional but also visually engaging to enhance user experience and facilitate decision-making.

These design criteria, grounded in the articulated needs of experts and reflected in the rich qualitative data, establish a foundation for an artifact that is not only theoretically sound but also resonates with the practical requirements of users across various domains. The developed decision data standard will serve as a tool that enhances global decision-making processes, embodies a balance of simplicity and depth, and fosters collaboration and cognitive ease.

V.2 Artifact Design and Development Execution

The execution phase of the artifact's development commenced with a synthesis of insights drawn from in-depth discussions with computer science experts, focusing on the creation of a robust and scalable data standard for decision-making. These insights contributed significantly to refining the artifact's design criteria and determining its functional requirements.

The execution of the artifact's development was a collaborative effort, where feedback from seasoned computer science practitioners played a crucial role. Each iteration of the artifact was punctuated by insights from computer science experts referred to as CS-PRAC-SH, CS-PRAC-SP, and CS-PRAC-SHS, ensuring that the final design was both technically sound and practically valuable.

V.2.1.1 Iterative Approach with Expert Consultation

Adhering to an iterative development approach, the artifact underwent a series of enhancements, each iteration guided by expert feedback. Initially, the artifact — a decision matrix data standard — was conceived to be highly granular, treating every piece of decision-related information as an individual "cell". This modular design was inspired by the need for a flexible, adaptable system that could capture the multidimensional nature of decision spaces. Experts provided pivotal feedback on this approach, highlighting the necessity of ensuring that each cell could be globally identified and interlinked within a decision model. Following an iterative development approach, each feedback session with experts like CS-PRAC-SH led to incremental refinements. As CS-PRAC-SH highlighted, "It's like a Rubik's Cube, right?" This analogy underscored the need for a multifaceted and flexible data model that could handle the complexities of decision matrices.

V.2.1.2 Embracing JSON Linked Data (JSON-LD)

CS-PRAC-SP recognized the significance of JSON-LD for linking data, allowing for semantic context and creating a globally connected framework. They pointed out the potential for "projecting a multi-dimensional space to a lower-dimensional manifold," reflecting on how the standard could harness multi-dimensional decision-making. The inclusion of JSON-LD offers a compact and human-readable format that facilitates the construction and consumption of interlinked data over the web, adhering to the Linked Data principles by enabling the serialization of Linked Data using JSON. (Sporny et al., 2020, p. 6)

V.2.1.3 Vocabulary Development and Clarity

The execution phase also saw the adoption of Schema.org as a global standardized vocabulary baseline as it is a widely accepted “universal metadata vocabulary”. (Iliadis et al., 2023, p. 3) Furthermore, it included a creation of a comprehensive vocabulary that extends existing schema.org definitions, introducing new terms specific to decision matrices such as 'alternative', 'criterion', and 'weight'. These definitions were crafted to be clear and precise, ensuring that the artifact’s users — from decision-makers to developers — could readily understand and utilize the standard. Feedback sessions with experts, as reflected in the transcripts, were instrumental in refining this vocabulary, emphasizing the need for clear and actionable definitions. The development of a comprehensive vocabulary was informed by experts' emphasis on clarity and precision. CS-PRAC-SH suggested, "having clear definitions about what these things are." Responding to this, the artifact's vocabulary was refined to include precise terms for the unique components of decision matrices.

V.2.1.4 Solidifying the Data Model

The data model was then implemented with a focus on ensuring that each "cell" within the decision matrix had a unique identifier, a set of coordinates within the decision space, and a value. Figure 8 visualizes the fundamental construct of a decision cell object.

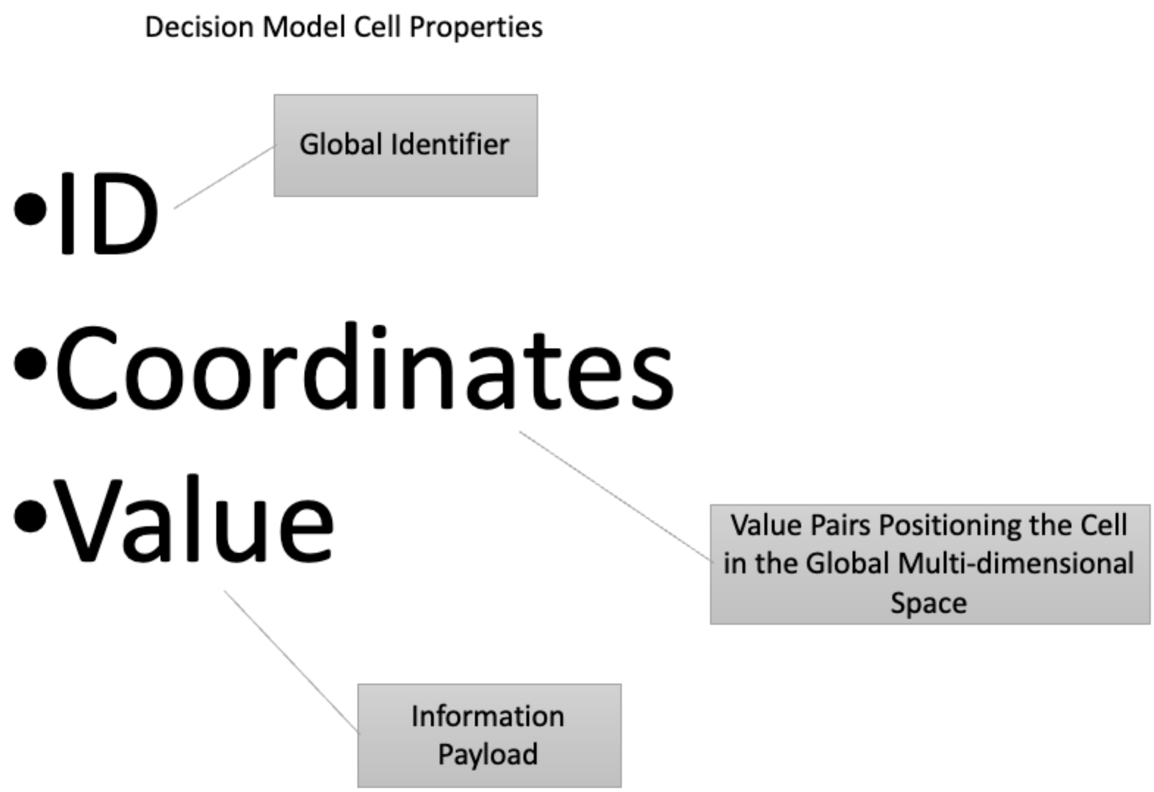


Figure 8 Object Structure for Capturing Fragments of Decision Information in Multi-dimensional Space.

This structure was confirmed and validated by computer science experts to be capable of capturing complex decision data in a standardized format. See appendix B for an instantiation of the cell construct in the form of a JSON schema using URIs as global identifiers for cells and dimensions in coordinates arrays. Implementation of the data model involved experts like CS-PRAC-SHS who provided insights on the structure and design including this note: “You've got this sort of abstract coordinates, where it's not like there's an axis that has a defined ordering, right, you've just, it's really more just, I forget what the word is. But like, there's a list of possibilities, that can be the value for that coordinate. Yeah. And each of those defined values are also cells in the greater system.” CS-PRAC-SHS's contribution to the concept of "cell" granularity within the decision matrix ensured that each piece of data was identifiable and interlinked within the model, reflecting the interconnectedness of decision-making factors. A detailed view the structure is shown in Figure 9.

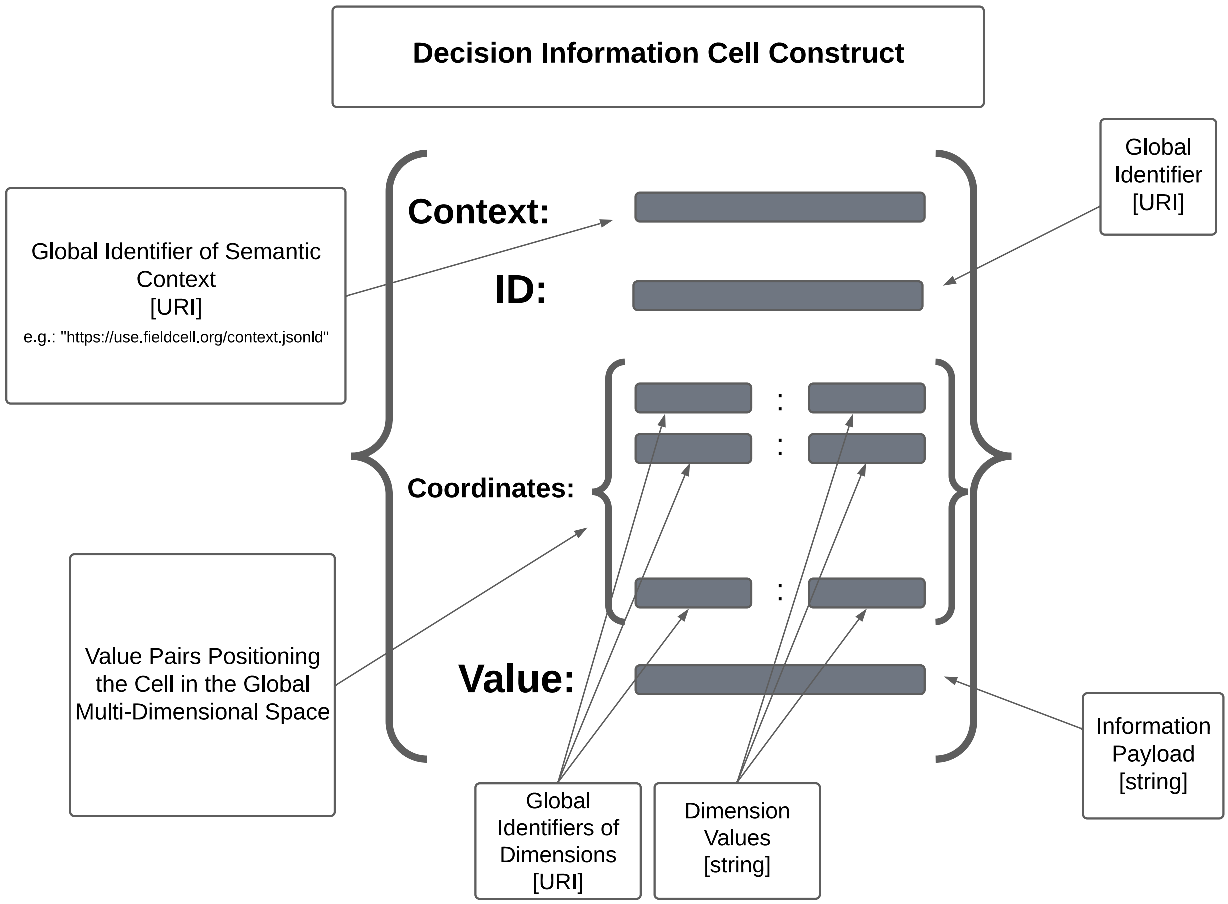


Figure 9 Detailed Decision Information Cell Construct

Given the construct of a cell object capable of holding a piece of decision information, a higher-level construct of a cell collection was formed to describe a data entity for holding cells describing a decision model. Since each cell uses a global identifier and global identifiers for dimensions specified in the coordinates array, a cell collection could be distributed across entities including internet domains, persons, groups, and institutions.

The artifact's design, focused on structuring decision information, is predicated on the concept that decision situations can be intricately described by a group of cells, forming a Cell Group. This type of cellular representation allows for detailing a decision at any required granularity. The Cell Group, an array of cells, offers a dynamic and flat data structure, serving as a comprehensive representation of a decision. Cells assume various roles such as criteria, alternatives, weights, and labels, each identifiable by URIs, to ensure global consistency and interoperability within the decision-making ecosystem. A root cell anchors each Cell Group, assigning its identity and linking to other cells via the "isPartOf" property, ensuring a coherent, navigable data structure. The limitless depth of cell relationships allows for a versatile decision-making matrix, accommodating complex structures with varying levels of criteria and alternatives. The model anticipates recursive algorithms to navigate and process data due to the potential complexity arising from unrestricted cell attachment.

This flexibility, however, necessitates a mindful approach to implementation to prevent the creation of nonsensical or unmanageable cell structures. The data standard establishes no prescriptive rules on cell types, emphasizing user discretion and the utility of logical design patterns to construct meaningful decision hierarchies. Figure 10 shows an example decision scenario with two criteria and two alternatives, showcasing the standard's approach to organizing decision data.

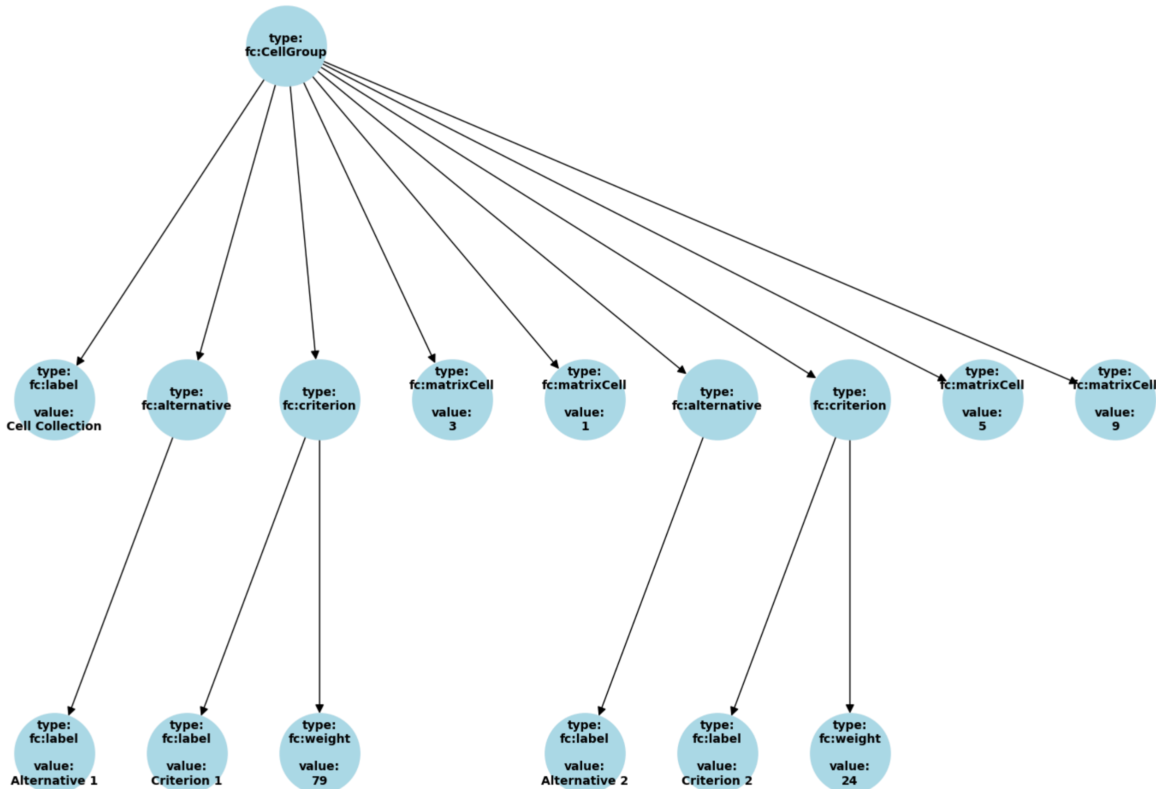


Figure 10 Graph Representation of a Cell Group with 16 Cells

The nodes in the graph represent decision cells. The nodes are labeled with the cell role value. The "fc:" prefix indicates a namespace. See appendices B and C for details. The value property is shown only for cells that carry a value. Cells of certain types, including "fc:CellGroup" and "fc:criterion", do not carry values. Their purpose is to establish identities for entities. Other types of cells containing values, like "fc:label" and "fc:weight", are attached to the identity cells. See Figure 11 in Appendix E for a visualization of a larger Cell Group as a unidirectional graph data structure.

The constructs of a cell and cell collection objects are consistent with the Linked Data principles:

1) All items in a dataset should be identified using URIs;

2) All URIs should be dereferenceable: using HTTP URIs allows looking up an item identified through an URI;

3) When looking up an URI, it leads to more data;

4) Links to URIs in other datasets should be included in order to enable the discovery of more data.

(Berners-Lee, 2006)

V.2.1.5 Collaborative Public Repository

A public repository for the artifact was established, containing essential files that define the vocabulary for the data standard and the schema for the cell object. The repository was structured to facilitate open-source collaboration and community involvement, resonating with expert suggestions about leveraging community-driven development to enhance the artifact's robustness and utility. The artifact's repository was shaped by the experts' consensus on community involvement and open-source collaboration. As CS-PRAC-SP pointed out, "building a basic block of a larger model," the repository was designed to be a foundation for widespread use and enhancement. In addition to the public version control repository, a dedicated second-level internet domain “fieldcell.org” was used for two purposes:

A. To anchor the decision standard in the internet domain name space using a dedicated domain. The URL for the schema was set to “https://use.fieldcell.org/cell.schema.json”.

B. To comply with the linked data principles and offer information regarding the data standard to users who follow the URLs contained in published cells.

V.2.1.6 Integration of Feedback for Refinement

The experts' insights led to critical refinements in the artifact, such as the introduction of JSON-LD which is optimized for linked data, the restructuring of the name spacing terms, and the conceptualization of the decision matrix in a global multi-dimensional space. Feedback from CS-PRAC-SH about considering "developer experience and performance aspects" was instrumental in ensuring that the artifact not only met theoretical standards, but also practical execution demands. This resulted in an artifact capable of effectively capturing decision data across various domains.

V.2.1.7 Preparation for Validation

With the artifact's structure and definitions established, the feedback from the computer scientists prepared the groundwork for the upcoming validation phase. This phase aims to leverage multi-criteria decision-making algorithms to showcase the practical application of the artifact, a crucial step that all experts agreed would significantly impact the effectiveness of decision-making processes.

VI ARTIFACT DEMONSTRATION AND EVALUATION

VI.1 Demonstration Environment Setup

The demonstration environment for evaluating the proposed data standard was constructed to facilitate a practical and comprehensive assessment of its functionality and effectiveness. The setup consisted of two pivotal components: interactive website implementation and creation of demonstration content.

VI.1.1 *Interactive Website Implementation*

The first component was the development of a fully functional website that embodied the proposed standard. This website served as a dynamic platform to demonstrate the standard's capabilities in a controlled environment. The website's features included:

- **User Interfaces**: These were designed to enable the intuitive creation and management of decision cells and cell collections. Users could easily input data, structure decision elements, and manage decision-making processes through a clean and user-friendly interface.
- **Back-End Real-Time Database**: The backbone of the website was a real-time database that allowed for the storage and synchronization of distributed decision-information. This ensured that any updates to the decision content were instantly reflected across the platform, showcasing the potential for real-time collaborative decision-making.
- **Implemented Cell Types**: The website supported various cell types, including Group collections, Alternatives, Criteria, Labels, Descriptions, Images, and External References. This diverse range of cell types demonstrated the standard's versatility in representing various aspects of decision-making content.

- **Visualization Tools**: For an effective presentation of decision data, the website incorporated several types of visualizations:
    - A matrix display view for an organized presentation of decision criteria and alternatives.
    - Criteria weight charts that depicted the relative importance of each criterion.
    - Alternative score charts that provided a visual summary of each alternative's performance across different criteria.
- **Calculation Functions**: The site enabled complex decision analytical methods, including:
    - Min-Max standardization to normalize matrix values.
    - Simple Weighted Average Scoring to calculate alternative scores based on criteria weights.
    - TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) to show another multi-criteria decision analysis approach to select the optimal alternative (or an optimal set of alternatives if more than one alternative gets the same value) given decisions matrix values and a vector of criteria weights.
- **Planned Functionality Placeholders**: To illustrate future capabilities, placeholders were included for:
    - Agreement analysis features to assess consensus among decision-makers or stakeholders.
    - Monte Carlo Simulation to address uncertainties in decision-making by running multiple scenarios and given user specified probabilistic properties of entered values.

Figure 11 below shows the top-level menu items of the demonstration website. See appendix G for an in-depth description of the main features.

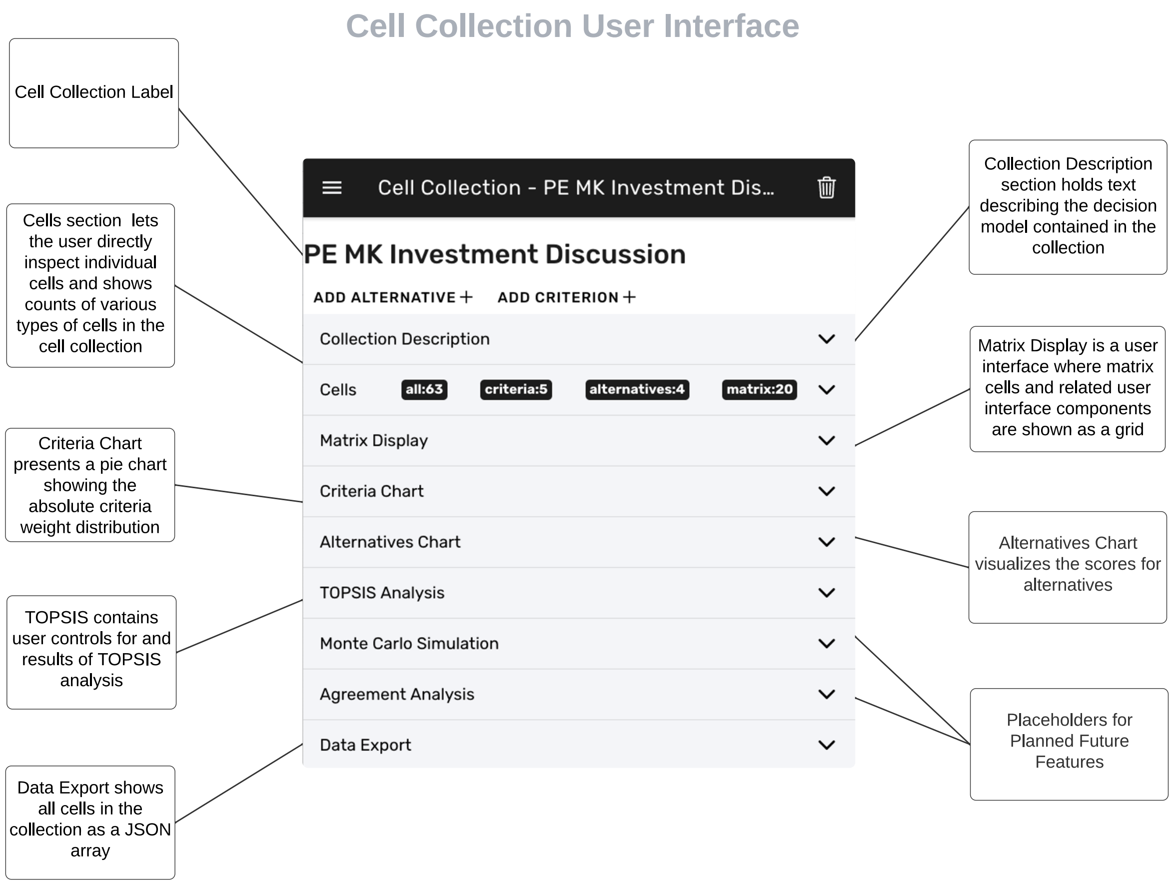


Figure 11 Top-level Cell Collection User Interface of the Demonstration Website

VI.1.2 *Sample Decision Content Creation*

To evaluate the standard in real-world scenarios, several sample decision models were created, including:

- **Hiring Decision Model**: This model was designed to evaluate five job candidates, showcasing the platform's ability to handle subjective criteria weights, and various data types like resumes (documents) and linking of public candidate profiles.
- **Private Equity Investment Opportunities Model**: Tailored to the nuances of financial decision-making, this model demonstrated the platform's ability to bring together information fragments related to investment opportunities.
- **Healthcare AI Adoption Model**: This decision model provided a framework for evaluating the adoption of AI in healthcare settings, highlighting the standard's utility in scenarios with high-stakes outcomes and technical data.
- **Potable Water Options in an Office Setting**: This model showed how the developed artifact can be applied to scenario as simple and basic as the choices of types of water available at an office building.

This demonstration environment was crucial in validating the proposed data standard's practicality. It offered a tangible means to explore the standard's application across various domains and decision types, thus serving as a foundation for rigorous evaluation and subsequent refinement of the standard.

VI.2 Demonstration and Evaluation Execution

The evaluation process was developed and executed to ensure a comprehensive assessment of the proposed data standard. Five interviews with decision support practitioners were conducted, each tailored to extract insights relevant to both the research study's aims and the practical implications of the data standard.

During the interviews, the subjects were reminded of the purpose of the study and the conceptual underpinnings of the data standard. A live demonstration on a purpose-built website was used to illustrate the data standard's implementation in a real-world setting. Following this, the interview subjects were encouraged to provide candid feedback, which was then used to evaluate the artifact against two distinct but complementary sets of criteria:

A. Requirements-Based Criteria**:**

- **Common Language and Standardization**: The standard’s capability to facilitate a universal lexicon for decision-making was critically evaluated, with subjects reflecting on the ease of integration and understanding across various decision-support systems.
- **Integration Across Systems**: Feedback highlighted the artifact's capacity to seamlessly integrate with existing systems, thus reinforcing its utility in diverse operational environments.
- **Decision Matrix and Weighting**: The practical implementation of decision matrices and the weighting of decision criteria were scrutinized, with particular emphasis on the standard's flexibility and adaptability to various decision-making contexts.
- **Data Accessibility and Simplification**: The artifact's ability to simplify complex data while maintaining accessibility was assessed, underscoring the balance between detail and usability.
- **Real-Time Collaboration**: The standard's real-time collaboration features were commended, aligning with the dynamic needs of modern decision-making practices.

- **Visual Appeal and User Engagement**: The aesthetic and engagement aspects of the tool were evaluated, recognizing the importance of user interface design in encouraging widespread adoption.

B. DSR Evaluation Criteria by Sonnenberg & Vom Brocke (Sonnenberg & Vom Brocke, 2012b, p. 391)

- **Completeness**: Each interviewee's insights contributed to assessing whether the standard captures all necessary components of decision-making.
- **Ease of Use and Understandability**: The artifact was reviewed for its intuitiveness and ease of understanding, with a focus on ensuring a smooth user experience.
- **Effectiveness and Efficiency**: The standard's ability to accurately represent decision-making data and streamline decision processes was critically evaluated.
- **Elegance and Simplicity**: The aesthetic and structural design of the standard were appraised, with a spotlight on the balance between simplicity and functional elegance.
- **Internal Consistency and Level of Detail**: Consistency in the artifact's approach to decision representation and the appropriate level of detail offered were validated.
- **Operationality and Robustness**: The standard's readiness for operational use and its resilience against varied decision-making scenarios were rigorously tested.

Feedback from the evaluation interviews affirmed the potential of the proposed data standard to revolutionize distributed decision-making. The artifact was praised for its alignment with both sets of evaluation criteria, though some areas for improvement were identified, such as the handling of complex scenarios with multiple variables and the need for further simplification to cater to non-expert users.

This demonstration and evaluation execution not only tested the artifact against the requirements but also provided practical, user-centered insights that will inform future development phases. The artifact's reception among experts suggests a promising future for its application in diverse decision-making environments.

VI.3 Artifact Evaluation Data Analysis

VI.3.1 *Artifact Evaluation Data Analysis: DSR Evaluation Criteria Assessment*

The artifact's evaluation centered on a detailed analysis of feedback gathered from decision support practitioners, with a focus on the Design Science Research (DSR) Evaluation Criteria. The feedback was methodically coded to categorize positive and negative aspects as perceived by the evaluators. See Appendix C for a table summarizing the evaluation analysis by the DSR criteria. See Table 3 below showing coding matrix for the evaluation of the artifact by expert practitioners using the DSR criteria.

Table 3 DSR criteria-based Artifact Evaluation Coding Matrix

Codes	AB	CB	MK	SH	ZZ	Total
Completeness	0	0	0	0	0	**0**
+	0	0	0	0	1	**1**
-	0	0	0	0	0	**0**
Ease of Use	0	0	0	0	0	**0**
+	0	0	0	0	0	**0**
-	0	0	0	0	1	**1**
Efficiency	0	0	0	0	0	**0**
+	0	0	0	0	0	**0**
-	0	0	0	0	0	**0**
Elegance	0	0	0	0	0	**0**
+	1	0	0	0	1	**2**
-	1	0	0	0	0	**1**
Fidelity with Re...orld Phenomena	0	1	0	0	0	**1**
+	3	1	1	0	4	**9**
Generality	0	1	0	0	0	**1**
+	1	1	0	0	0	**2**
-	0	0	0	0	0	**0**
Impact on the E...t and the Users	0	0	0	0	0	**0**
Internal Consistency	0	0	0	0	0	**0**
Level of Details	0	0	0	0	0	**0**
+	0	0	0	0	1	**1**
-	0	0	0	0	0	**0**
Operationality	0	0	0	0	0	**0**
+	0	0	0	0	1	**1**
-	0	0	0	0	0	**0**
Robustness	0	0	0	0	0	**0**
+	3	0	0	2	2	**7**
-	1	0	0	0	0	**1**
Simplicity	0	0	0	0	1	**1**
+	3	0	0	0	2	**5**
-	0	0	2	0	0	**2**
Understandability	0	0	0	0	0	**0**
+	0	0	1	0	0	**1**
-	0	0	0	0	2	**2**
Total	**13**	**4**	**4**	**2**	**16**	**39**

A synthesis of the insights drawn from the analysis supported by representative quotes from the interview transcripts is provided below in subchapters dedicated to individual criteria.

VI.3.1.1 Completeness

Positive feedback indicated an appreciation for the artifact's potential in reducing bias through objective criteria, noted by DS-PRAC-MK. DS-PRAC-AB highlighted the data model's ability to scale and manage a range of problems, and DS-PRAC-ZZ commended the nesting of values within the JSON structure for added depth.

- **DS-PRAC-MK**: “I think what would be nice as criteria...if this addresses or...potential removes people's biases because if you have a system [for] decision making...in a more scientific sort of way or more objective way and it provides people with a comprehensive assessment that is based on the data set and not on people’s...limited experience or limited preferences, that will be cool...if you could show that...if you rank those...assess that...opportunities along the criteria you come to a different outcome than or better outcome that people will be able to do themselves...that will be a cool benefit.”
- **DS-PRAC-AB:** “In terms of completeness, that's actually what I appreciate about the data model and the way that it was built out that you can it's it's scalable right. So I really do appreciate how the solution is built to handle whatever problem you wanted to tackle right? So so on that regard I love the way that it was architected.”
- **DS-PRAC-ZZ:** "And then you also mentioned nested values. I think that's really fascinating, to be able to nest these together especially since you already have, I saw in the JSON, you have like a belongs to, you can create a very cool... Yeah, it's just, it's very interesting organizational way especially with your example, you know, having different... I mean you have categorized these different things under various like education, relevant experience but I can imagine some things too and then folding up into a big one."

VI.3.1.2 Ease of Use

The artifact was praised for its clean display and simplicity, as liked by DS-PRAC-AB, and its user-friendly interface which allowed dynamic criteria adjustment, a point highlighted by DS-PRAC-SUH. DS-PRAC-CB saw the value and adaptability to structured decision-making, while DS-PRAC-ZZ proposed enhancing user engagement through color coding. On the flip side, concerns were raised by DS-PRAC-AB about managing numerous options and dimensions, and by DS-PRAC-ZZ about guiding users effectively through data entry. DS-PRAC-MK suggested that more intuitive visualizations, such as heat maps, would enhance usability.

- **DS-PRAC-MK:** "If you have this sort of dashboard, it would be good to construct to give a little bit like a heat map. So it becomes very clear from...the starting point which one is the winner? ...You can find the data there now but it's let's say quite not intuitively to find."
- **DS-PRAC-AB:** "In terms of elegance I think I think that displays clean right? I like the way it's laid out. I think it does a good job. I think everyone is familiar with this notion of a matrix. So I'm going to think it presents it in a very relatable way."
- **DS-PRAC-AB:** "So for the ease of use again like that's where my question around what happens if you have 20 dimensions and 100 candidates right like it can get kind of hairy but it sounds like you've already got that on your radar."
- **DS-PRAC-ZZ:** "One thing that I can think of...is like she does like heat maps and color. That can be very useful letting people really respond to that quickly. Because again, even though this is simplified, it's still a lot of numbers."
- **DS-PRAC-ZZ: "**I feel like when I listened to you talk I felt this like tug-and-pull between kind of numerical specificity and kind of building a collective idea. I think a lot

of times in these processes it's more important that everyone agrees rather than it being specific...sometimes you have to go to the lowest common denominator. So, if someone does really is not numerical then I think you have to adapt to be able to support them.**”**

- **DS-PRAC-SUH:** "I love that. And you came up with these? No, that's great. Okay." In response to seeing how new criteria can be added to a model.
- **DS-PRAC-CB:** "So essentially what you want to do is create a tool which will allow you to harvest data for any decision whatsoever whether it's what movie to go to or whether to get a dental implant or whether to do business in Mongolia. That you put in certain parameters and something it somehow artificial intelligence is going to go out there into the internet and pull enough data to actually populate a mini index given the parameters you've given it and allow you to play around.”

VI.3.1.3 Effectiveness

DS-PRAC-AB expressed interest in applying the tool for real-world scenarios, like compensation conversations. DS-PRAC-ZZ found potential in the tool for analyzing decision-making over time. DS-PRAC-MK saw benefits in automating the ranking of large datasets.

- **DS-PRAC-MK:** "this will become exciting...if you think...if I think about how we screen investment opportunities and you go and look at...databases of companies and we set...criteria that is somehow measurable from their financial statements and it helps us...automatically assess that and rank these companies for example by financial health...the large datasets would be would be good."

- **DS-PRAC-AB:** "I like this moment should be told I could use something like this right now for the compensation conversations we're in. So nowadays I think this is pretty slick. I really do."
- **DS-PRAC-ZZ:** “I feel like this could be a very useful tool to understand processes too, right? Using the matrix. So you could kind of, you could work backwards understand how different people can consolidate different types of information and how it changes over time”

VI.3.1.4 Efficiency

Real-time collaboration features were highlighted as a key efficiency factor by DS-PRAC-SUH, with DS-PRAC-MK also valuing the immediacy of updates in the decision-making process.

- **DS-PRAC-MK:** "Pre-investment stage it's quite real-time. Because things need to move quickly... if we can only... be seen if we create a more aggressive business plan and on that basis are willing to pay more for the business rather than decrease the IRR expectations... So, it needs to be real-time and it needs to be quick."
- **DS-PRAC-SUH:** "So the right screen is you what screen is me? If I change my Wait yep it changes on mine too. Yes. Okay. So, we are cooperating in real time.”

VI.3.1.5 Elegance

The matrix presentation's cleanliness and relatability were aspects DS-PRAC-AB found elegant, showcasing the tool's design appeal: "In terms of elegance I think I think that displays clean right? I like the way it's laid out. I think it does a good job.”

VI.3.1.6 Generality

Flexibility was noted as a strong suit, with DS-PRAC-AB envisioning applications for corporate strategy and DS-PRAC-SUH for sectors like customer service or healthcare.

- **DS-PRAC-AB:** “So so I guess the way this is built or the schema built the way it was the dimensions can be whatever you want them to be right? Like if you're doing a corporate strategy then your rows can be strategies one two and three. And your columns can be … sustainability, profitability, right? The different dimensions and you don't need to change a thing, right? The data, the data model accepts all of that.”
- **DS-PRAC-SUH:** "So, I could say, gosh, I'm thinking about using this for my businesses customer service or even patient experience. You're probably looking at health care something here. You know, so, I could see someone taking this tool and saying, Gosh, this is great and helping me figure out when to use AI.”

VI.3.1.7 Level of Detail

DS-PRAC-MK suggested breaking down criteria into measurable components for added objectivity.

- **DS-PRAC-MK:** “What could be an alternative is you break down the financial health into something that is more objective, you say revenue growth over 10%, profit margin whatever 15%, cash flows as Generation X percent. If you set those criteria in that way, it becomes clear on how any of this can be automated as to rating as well. So you can maybe set some boundaries and say, 'Look, financial health is seven if all of the three criteria are whatever above these rates...'”

VI.3.1.8 Operationality

Concerns about how the tool would perform with numerous options and dimensions were voiced by DS-PRAC-AB, with DS-PRAC-ZZ questioning compatibility with common data formats like Excel.

- **DS-PRAC-AB:** “So for the ease of use again like that's where my question around what happens if you have 20 dimensions and 100 candidates right like it can get kind of hairy but it sounds like you've already got that on your radar.”
- **DS-PRAC-ZZ:** "Does it talk with like an Excel spreadsheet?... I'm thinking about that lowest common denominator. How do you get how do you automate someone getting the data into this?"

VI.3.1.9 Robustness

DS-PRAC-AB appreciated the artifact’s suggestion capabilities, highlighting its potential to learn and adapt from past decisions to influence future ones: “Maybe it learns from previous decision approaches that you've done and say Hey listen back then like you know I know you're trying to use gross profit right now. But what about this other metric that that seemed to be really important in the past? Make sure making sure you didn't forget it? That notion of kind of coaching the user through what should really matter could also have a huge impact.”

VI.3.1.10 Simplicity

The built-in scalability and straightforward design were well-received by DS-PRAC-AB. Yet, he raised questions about the tool's manageability in complex scenarios, and DS-PRAC-ZZ remarked on the inherent complexity in data entry for end-users. DS-PRAC-CB also expressed concerns regarding the integration of the tool into existing workflows.

- **DS-PRAC-AB:** "…the way that it was built out that you can it's scalable, right. So, I really do appreciate how the solution is built to handle whatever problem you wanted to tackle, right?"
- **DS-PRAC-ZZ**: "… flexibility in terms of how much information you intake and simplifying it, I think, I think it's, I feel like they'll get like speaking up, I feel like that's the major thing that this is really helpful is it's kind of simplifying and consolidating these […] I'm just thinking about the hand holding part of it. But I think of ease of use, I'm just thinking about hand holding...How do you automate someone getting the data into this?"
- **DS-PRAC-ZZ**: "I'm still perplexed at how you're harvesting data but to input into your model but go ahead and maybe I'll figure that out as we go along."

VI.3.1.11 Understandability

DS-PRAC-AB found the artifact to be laid out in terms that were easy to understand without deep decision science knowledge. However, DS-PRAC-ZZ pointed out that the need to guide users could indicate potential issues, a sentiment echoed by DS-PRAC-CB, who emphasized the need for hands-on interaction for proper evaluation. DS-PRAC-SUH suggested that further development should include examples for better clarity, and DS-PRAC-MK recommended the use of heat maps for immediate comprehension of data assessments.

- **DS-PRAC-AB:** "I like that it's all dot simple dials and everything right? […] But I think again it's laid out in a very layman's terms kind of way right? You don't need to understand the decision science behind it. It's all translated into very simple things that anyone can just tweak. In a way that feels very familiar."

- **DS-PRAC-MK:** "…color the different results based on how high they rated."
- **DS-PRAC-ZZ:** "I'm just thinking about the hand holding part of it. But I think of ease of use, I'm just thinking about hand holding...How do you automate someone getting the data into this?"
- **DS-PRAC-SUH:** "it really helps how you tell the story up front and throughout? I think that's great."
- **DS-PRAC-CB:** "But we might think you can bring you can create your own data blend any data discovery without even knowing the structure and context of everything that is there is out there."

VI.3.1.12 Summary of Feedback by DSR Criteria

The feedback underscores the artifact's significant strides in meeting the DSR evaluation criteria while also revealing areas for further refinement. This feedback loop is crucial for the iterative development process, ensuring that the final design will be user-centric, operationally robust, and effectively bridge the gap between complex decision-making processes and user-friendly interfaces.

VI.3.2 *Artifact Evaluation Data Analysis: Analysis of Evaluation Feedback Based on Requirements*

The evaluation of the artifact was further informed by criteria established during the Requirements Gathering Phase. The practitioners' feedback, as distilled through the coding matrix, provided a nuanced view of the artifact's adherence to these requirements. See the coding matrix in Table 4 below.

Table 4 Artifact Evaluation by Requirements Coding Matrix

Codes	AB	CB	MK	SH	ZZ	Total
Adaptability and Flexibility	3	2	3	4	4	**16**
Common Language and Standardization	0	0	0	0	0	**0**
Data Accessibility and Simplification	0	0	1	1	0	**2**
General Attitude	2	0	1	2	0	**5**
+	2	0	1	2	0	**5**
Improvement Suggestion	1	0	3	1	4	**9**
Intention to Use the Artifact	3	2	0	1	2	**8**
+	3	2	0	1	1	**7**
-	0	0	0	0	1	**1**
Overcoming Data Harvesting and Implementation Challenges	0	0	0	0	0	**0**
Real-time Collaboration	1	0	0	0	0	**1**
Visual Appeal and User Engagement	2	0	0	0	0	**2**
Total	**17**	**6**	**9**	**12**	**12**	**56**

Here's an overview of the insights collected from the discussions:

VI.3.2.1 Adaptability and Flexibility

The artifact was commended for its adaptability and flexibility, as it could be tailored to fit various decision-making scenarios. Both DS-PRAC-SUH and DS-PRAC-ZZ noted its versatility, with DS-PRAC-ZZ finding the capability to adjust the artifact to multiple contexts particularly useful.

- **DS-PRAC-ZZ:** "…if you could change the axes, if you could, like, preview a 3d matrix, and you can look at it from different directions, right. […] Yeah, I do that a lot. Because, you know, it changes the way you think about the data. It's helpful, like kind of a bit of a different perspective."
- **DS-PRAC-SUH:** "So I think what you're saying is if you had gone with a question like and I think this is a great example and I think it's better to do the micro and then talk about the macro. But if it was like Where should a business's home country be? Then you

could have these objective measures? Like what are the tax laws? What are the tariffs? What are the implications?"

VI.3.2.2 Common Language and Standardization

There was a strong appreciation for the artifact's attempt to establish a common language and standardization across decision-making processes. However, feedback pointed to the need for further refinement to ensure ease of adoption across diverse systems and industries.

VI.3.2.3 Data Accessibility and Simplification

The feedback suggested a mixed response in this category. While DS-PRAC-ZZ recognized improvements in data accessibility, it became apparent that further simplification might be necessary to facilitate user interaction with the system: "I feel like that's the major thing that this is really helpful is it's kind of simplifying and consolidating these when you're considering there's just too many things to consider. And so it turns into a simple number. I think that's very helpful […] But I think of ease of use, I'm just thinking about hand holding...How do you automate someone getting the data into this?"

VI.3.2.4 Improvement Suggestions

Valuable suggestions were offered to refine the artifact. DS-PRAC-MK and DS-PRAC-SUH provided actionable insights, pointing towards enhancements that could make the artifact more intuitive and effective.

- **DS-PRAC-MK:** "What would be nice as a criteria but I think you can probably demonstrate it only over time or if this addresses or you know potential removes people's biases because if you have a system decision making system that is going through you know data sets of data let's say in a more scientific sort of way or more objective way and it provides people with a comprehensive assessment that is based on the data set and not on people’s own limited experience or limited preferences, that will be cool.”

- **DS-PRAC-SUH:** “… obviously that's not something I do, but the IT team, can they add that variable? You know as you know is there that opportunity to add that extra variable or factor into the criteria?"

VI.3.2.5 Intention to Use the Artifact

Enthusiasm was noted regarding the intention to use the artifact. DS-PRAC-AB and DS-PRAC-CB expressed clear interest, underlining the artifact's potential real-world application and value.

- **DS-PRAC-AB:** "I like this moment should be told I could use something like this right now for the compensation conversations we're in. "
- **DS-PRAC-CB: “**I mean, I like it. I think, I think it's good. I would use it […] let's implement this in Build Your Own Index right now.”

VI.3.2.6 Overcoming Data Harvesting and Implementation Challenges

DS-PRAC-ZZ identified challenges in data harvesting and the implementation process, suggesting areas where the artifact could evolve to offer more streamlined solutions: "Does it talk with like an Excel spreadsheet? I get... I'm thinking about that lowest common denominator. How do you get how do you automate someone getting the data into this?”

VI.3.2.7 Real-time Collaboration

The inclusion of real-time collaboration was highlighted as a positive feature, although it was mentioned less frequently in feedback. This functionality could be a pivotal aspect of the artifact's appeal, facilitating dynamic decision-making environments. DS-PRAC-CB's reaction to the real-time feature demonstration included the following fragment: "… let's implement this in Build Your Own Index right now."

VI.3.2.8 Visual Appeal and User Engagement

Visual appeal and user engagement were recognized as strengths of the artifact, with feedback encouraging continued attention to the user interface to ensure high levels of engagement. According to DS-PRAC-AB, "…it's laid out in a very layman's terms kind of way, right? You don't need to understand the decision science behind it. It's all translated into very simple things that anyone can just tweak. […] I think this is pretty slick. I really do. Awesome."

VI.3.2.9 Summary of Feedback by Requirements

In synthesizing the feedback against the gathered requirements, it's evident that while the artifact shows promise, the user experience could be enhanced with further simplification and more intuitive design elements. Practitioners have indicated a willingness to adopt the artifact, providing it aligns closely with their operational contexts and reduces complexity rather than adding to it. These insights will be instrumental in the iterative refinement of the artifact, ensuring that the final design not only meets the requirements of decision support practitioners but also integrates seamlessly into their existing workflows.

VII DISCUSSION

This dissertation embarked on addressing the critical challenge of synthesizing real-world decision information in distributed decision-making contexts, highlighting the significant role of information architecture in supporting efficient and effective decision-making processes. By leveraging distributed cognition as the conceptual framework, this study aimed to design an innovative data standard, culminating in the development of a global multi-dimensional decision matrix model. This artifact, designed through the Design Science Research Methodology (DSRM), integrates cellular decision modeling with semantic web technologies to standardize, integrate, and streamline decision information exchange and processing across various stakeholders and platforms. In essence, the research produced a novel data standard that not only facilitates the global sharing and utilization of decision information but also bridges the gap between theoretical concepts in distributed cognition and practical methodologies in design science research. Through this endeavor, the study sought to enhance collaboration, transparency, and efficiency in decision-making processes, addressing the dissertation's objective by providing a tangible solution to the articulated problem.

VII.1 Contribution

VII.1.1 *Contribution to Literature*

Positioning Against Existing Research

The Linked Decisions study stands distinct in the landscape of decision-making literature, pioneering the use of a cellular approach within the existing theoretical framework. While previous research, such as the decision ontologies and collaborative decision-making processes detailed by Guizzardi et al. and Konaté et al. (Guizzardi et al., 2022; Konaté et al., 2020), laid the foundation for structured decision analysis, this study carves a unique niche by applying these concepts in the design of a shared, semantic web-enabled decision matrix. Furthermore, it provides an applied architectural model that enhances the organization and accessibility of decision-related information, thereby addressing the practical complexities that organizations face in managing multi-criteria decisions.

Bridging Information Architecture and Decision-Making

In bridging the gap between conceptual understanding and practical application, this study elevates the discourse by interlacing the principles of information architecture with MCDM. The cellular model proposed here is more than a theoretical construct; it is a practical, internet-standard compliant framework that allows for the emergent, owned, and hyperlinked structuring of decision information, thus embodying Boland et al.'s principle of Easy Travel (Boland et al., 1994) and facilitating a hypertext-like exploration of decision spaces (Berners-Lee, 2006).

Bridging Theory and Practice through Design

This research contributes to the theoretical discourse on decision support systems by introducing a structured approach to the design and implementation of a decision-making framework. Drawing upon Simon's seminal work on the phases of decision-making—intelligence, design, and choice (Simon, 1960) —this study operationalizes these stages within a novel architectural model. Additionally, by incorporating the principles of Multi-Criteria Decision-Making (MCDM), as elaborated by Saaty in his Analytic Hierarchy Process (AHP) (Saaty, 1980), and extending these with the flexibility and inclusiveness of Distributed Cognition theory (Hutchins, 2000), the research weaves together a comprehensive framework that addresses both the cognitive and methodological aspects of decision support. This integration not only aligns with Zeleny's call for a more holistic consideration of decision environments (Zeleny, 2011) but also applies these theoretical insights to construct an architecture that is demonstrably applicable in various real-world scenarios. By doing so, it not only bridges the often-discussed gap between theoretical constructs and their practical application but also pushes the boundary of the theoretical conversation by demonstrating how abstract concepts can be translated into functional, user-centric decision support tools. This endeavor aligns closely with recent calls in the literature for providing better cognition support in DSS by incorporating updated design parameters for information systems (Phillips-Wren et al., 2022). Thus, the study presents a compelling case for the synergistic application of Distributed Cognition and MCDM theories, providing a detailed blueprint for the development of decision support systems that are both theoretically grounded and practically viable.

Introducing a Structured Framework for Decision Ownership

This study applies Boland et al.'s concept of ownership (Boland et al., 1994) from design principles in the information systems literature to the context of decision-making, contributing to the conversation on data governance and stewardship in decision support systems. This integration of ownership within the design of your decision-making framework underscores the importance of accountability and authorship in the decision-making process, a topic that has implications for both practical management and theoretical exploration.

Facilitating Easy Travel within Decision Information

Boland et al.'s principle of Easy Travel (Boland et al., 1994) is innovatively translated into the decision-making domain through this study. It contributes to the literature by providing a model where decision-related information exhibits a hypertext-like structure, allowing stakeholders to easily traverse through different layers of decision criteria and alternatives. This contribution to the literature emphasizes the importance of information architecture in enhancing the navigability and user experience of decision support systems.

Incorporating Multiplicity, Indeterminacy, and Emergence

By introducing a framework that embraces the multiplicity of interpretations, the indeterminacy of decision information, and the emergence of new concepts within the decision-making process, this study contributes a novel perspective to the literature on collaborative decision-making and the dynamics of group decision processes in accordance with Boland et al.'s design recommendations for systems supporting distributed cognition (Boland et al., 1994).

Promoting Mixed Media Forms in Decision Expression

Finally, by advocating for mixed forms of expression, another design principle from Boland et al. (Boland et al., 1994), within the decision-making process, this research enriches the literature on communicative practices within decision support. It emphasizes the need for systems that can handle and integrate diverse data types — from textual to multimedia — offering practical insights into designing more versatile and inclusive decision support tools.

In summary, this study not only contributes to the practice of designing decision support systems but also enhances the academic discourse by showcasing how theoretical principles from information architecture and MCDM can be effectively integrated and applied within a structured decision-making framework.

VII.1.2 *Practical Contributions of Applying Distributed Cognition and MCDM via Design Science*

This dissertation extends the realm of decision support systems by adopting the cellular approach to decision modeling, an innovative application of distributed cognition and MCDM, within the framework of DSR. The focus of this research goes beyond conventional practices by introducing a shared, global multi-dimensional decision matrix that operates seamlessly within internet standards and leverages semantic web technologies. This artifact stands ready for diverse decision-making contexts, offering a novel means to significantly streamline decision processes.

The developed artifact, poised for adoption in diverse decision-making contexts, has the potential to significantly streamline decision processes. By facilitating a common language and standardization, the data standard can reduce the cognitive load on decision-makers, enable seamless integration of decision data across systems, and enhance real-time collaboration among stakeholders. These improvements, stemming from the application of distributed cognition and MCDM within a DSR framework, underscore the study's value to practitioners who seek to enhance decision-making efficacy in a globalized, interconnected environment.

VII.1.2.1 Novelty of Cellular Decision Modeling

A key innovation introduced in this study is the cellular approach to decision modeling, which disaggregates complex decision scenarios into their most fundamental components—cells.

This granular approach enhances the flexibility and precision of decision modeling, allowing decision-makers to manage and manipulate individual decision elements independently and yet cohesively within a global framework. By embracing this approach, the artifact embodies the concept of distributed cognition in its most literal sense, distributing the cognitive load across a cellular matrix that is owned, populated, and manipulated by a network of stakeholders.

VII.1.2.2 Global Multi-Dimensional Decision Matrix and Internet Standards

The study's contribution is further accentuated by the development of a shared, global multi-dimensional decision matrix based on internet standards. This matrix exemplifies how semantic web technologies can be harnessed to elevate decision-making from a localized activity to a globally interconnected process. It facilitates a common language and standardization across different systems, which, combined with the rigor of MCDM, has the potential to vastly improve the clarity and efficiency of decision-making on a global scale.

VII.1.2.3 Refinement through Design Science

Utilizing DSR, the study iteratively refined the proposed data standard through engagements with practitioners and computer science experts. This hands-on, problem-centric approach facilitated the creation of an artifact that is both reflective of real-world needs and robust enough to withstand technical scrutiny.

VII.1.3 ***No Claims to Theoretical or Methodological Contributions***

Recognizing its roots in established theories and methodologies, this study does not claim novel theoretical insights or methodological innovations. Rather, it showcases the powerful potential of existing frameworks when applied to the creation of a practice-oriented artifact. The artifact’s design is a testament to the practical application of distributed cognition and MCDM—bringing the abstractions of decision-making into a structured, user-centric reality.

VII.1.4 *Comparative Analysis with Existing Research*

This study intersects with the foundational research on decision ontology by Renata Guizzardi et al., and extends it by translating ontological concepts into a practical, standardized framework for distributed decision-making. (Guizzardi et al., 2020) While Guizzardi's work provides a theoretical underpinning of the decision-making process, this study takes a step further by offering an implementable standard that organizations can readily use. It builds upon the formalization of decision-making knowledge and leverages it to support coherent and informed decision-making practices across diverse operational contexts.

Jacqueline Konaté et al.'s research on collaborative decision-making ontologies aligns with the objectives of this study, particularly in its effort to optimize decision-making processes. (Konaté et al., 2020) Where Konaté et al.’s work enriches our understanding of collaborative dynamics, this study provides the practical tools—through a standardized data format—that facilitate the implementation of such dynamics in real-world scenarios. By integrating a structured decision content standard, the research complements ontological models and enables the effective deployment of collaborative decision-making practices, emphasizing roles, stages, and communication patterns crucial for successful group decisions.

Building upon the applications of standards like BPMN for structuring decision information, this study positions itself as a complementary tool that focuses on the decision content rather than the process. (Biard et al., 2015) While BPMN provides a methodology for documenting and optimizing decision-making workflows, the artifact developed in this study is designed to enhance the quality and interoperability of the decision content itself, ensuring that such information is not only accessible and interpretable but also seamlessly integrated across systems and stakeholders.

This research sits at the nexus of theoretical exploration and practical implementation. It contributes to the creation of a cohesive ecosystem for decision support by synthesizing ontological insights with the structured standardization of decision content. By doing so, it addresses the nuances of multi-stakeholder decision environments and the necessity for accessible, standardized decision information that can be dynamically utilized and re-utilized across organizational boundaries.

In juxtaposition with existing research, this study acknowledges the complexities elucidated by ontological models and standards and extends them into a practical realm. It embraces the theoretical foundations laid by prior studies and transforms them into a pragmatic standard, catering to the distributed nature of modern decision-making. This study, therefore, not only complements existing research but also paves the way for future innovations in decision support system design and implementation.

VII.1.5 *Limitations and Future Research*

The study's claims are confined to the realm of practice, with an understanding that the long-term efficacy and adoption of the artifact in various domains would require extensive empirical validation. The limitations of this research, particularly concerning the generalizability of the artifact across all decision-making contexts, present opportunities for future research to expand the scope, test the artifact in real-world settings, and refine the standard based on user feedback and evolving technological landscapes.

VII.1.6 *Methodology Limitations*

While the research methodology employed in this study has been designed to rigorously explore the development of a universal decision data standard, several limitations must be acknowledged. These limitations are inherent to the research design and approach and may impact the generalizability and applicability of the study's findings.

VII.1.6.1 Expert Group Composition and Selection Bias

The study relied heavily on semi-structured interviews with two distinct expert groups: decision support practitioners and computer science experts. While efforts were made to ensure a diverse range of insights by selecting individuals with varied backgrounds and experiences, the selection process may inherently carry biases. The reliance on the researcher's personal network for recruiting participants could limit the diversity of perspectives, particularly those from underrepresented sectors or geographical regions not within the researcher's reach.

VII.1.6.2 Scope of the Artifact Evaluation

The evaluation of the developed artifact was conducted with a limited group of experts, using demonstrations and discussions based on artificial scenarios. While this approach provides initial validation of the artifact's feasibility and potential utility, it does not encompass extensive real-world testing or deployment. The feedback obtained, though valuable, may not fully represent the challenges and dynamics encountered in practical, large-scale implementations.

VII.1.6.3 Technological and Implementation Considerations

The research focused on the design and development of a decision data standard without delving into the detailed technical implications of its integration with existing systems and platforms. Issues related to compatibility, data privacy, security, and the technological readiness of organizations to adopt such a standard are beyond the scope of this study. These factors are crucial for the real-world application of the proposed standard and could significantly influence its success and acceptance.

VII.1.6.4 Changes in Technology and Standards

The field of information technology and data standards is rapidly evolving. While the study proposes a novel data standard based on current technologies and methodologies, it may not fully account for future advancements or shifts in industry practices. The proposed standard's relevance and applicability could be impacted by new technologies, standards, or regulations that emerge after the study's completion.

VII.1.6.5 Generalizability of Findings

Given the focused nature of the research and the specific context in which the methodology was applied, the findings and conclusions drawn from this study may not be universally applicable to all decision-making contexts or domains. The development and evaluation of the artifact were conducted within a controlled environment, which may not fully capture the complexities and nuances of diverse real-world settings.

VII.1.6.6 Methodology Limitations Conclusion

Recognizing these limitations is crucial for interpreting the study's findings accurately and for guiding future research. Future studies should aim to address these limitations by expanding the participant pool, conducting real-world pilot tests of the developed standard, exploring the technical and operational challenges of implementation, and continuously adapting to technological advancements. This approach will help to refine the proposed decision data standard and enhance its practical applicability and effectiveness in global-scale distributed decision support platforms.

VII.2 Future Research

The limitations of the current study open several avenues for future research. While the artifact demonstrates potential, its efficacy and versatility can only be fully understood through real-world application and longitudinal study. Therefore, future research should aim to explore the following areas:

- **Case Studies in Real-World Decision Situations**: Future research could involve conducting case studies where the artifact is deployed in real-world decision-making situations. These case studies would provide rich, contextual insights into how the data standard operates within various domains, allowing researchers to observe its practical implications and potential barriers to adoption.
- **Experiments on Multi-Stakeholder Decision Processes**: It would be beneficial to conduct experiments studying the artifact's impact on multi-stakeholder decision processes. These experiments could measure the effect of the artifact using metrics such as time to decision, consensus achievement, decision acceptance, and time to information saturation. Quantitative data from these metrics would offer a robust assessment of the artifact's performance and its ability to streamline the decision-making process.
- **Design Science Studies for Infrastructure Components**: For a global-scale implementation, future design science research could focus on developing the necessary infrastructure components. Such studies could look into designing an identity

management system for decision participants, implementing a blockchain-based framework for integrity assurance of decision models, and developing robust access control mechanisms for decision information.

- **Public and Private Hosting for Decision Content**: Research could explore the implications of hosting decision content on public versus private platforms. Issues around governance, data sovereignty, and control could be investigated to establish best practices and protocols for managing and disseminating decision content securely and efficiently.
- **Multi-Site Search Functionality**: The ability to search across multiple sites for structured decision content is a critical component for a decision support system operating on a global scale. Future research could design and evaluate multi-site search algorithms and interfaces that facilitate the discovery and integration of decision content from various sources.
- **Transformations of Pre-Existing Content**: There is also a need for research into the transformation of pre-existing, unstructured, or semi-structured decision content into the standardized structured cellular decision content proposed by this study. This would involve creating tools and techniques for data mining, natural language processing, and machine learning to automate the standardization of legacy decision content.

Through these suggested future research paths, scholars and practitioners can continue to build upon the foundation laid by this study, pushing the boundaries of what is possible in distributed decision-making and contributing to the development of more efficient, transparent, and participatory decision support systems.

VIII CONCLUSION

This dissertation has ventured into the realm of distributed decision-making, an area burgeoning with complexity yet ripe for innovation. At its core, the study was guided by a pragmatic objective: to harness the strengths of distributed cognition and MCDM through the methodological lens of DSR. The culmination of this research is the creation of a data standard—an artifact designed to encapsulate and streamline the multifaceted processes of decision-making on a global scale.

Synthesizing Theories and Methods for Practice

The journey began with an exploration of existing theories and methodologies, not with the intent to redefine them, but to apply them in a manner that directly addresses a gap in the practice of decision support. By drawing on the tenets of distributed cognition, the study acknowledged the shared and extended nature of cognitive work in decision-making. MCDM principles were interwoven to structure and clarify the often-chaotic interplay of decision variables. All the while, the DSR method provided a structured, iterative pathway to evolve the artifact from concept to prototype.

A Tool for the Global Village

In an era where decisions are increasingly global and interconnected, the need for a tool that can cross borders, systems, and languages became apparent. The resulting data standard is envisioned as a digital Rosetta Stone for decision-making, enabling diverse stakeholders to contribute, interact, and arrive at informed conclusions with unprecedented ease and clarity.

Evaluating the Artifact

The artifact's demonstration and evaluation were not mere formalities but pivotal steps in understanding its real-world applicability. Feedback from decision support practitioners provided valuable insights, illuminating the artifact's strengths in adaptability, efficiency, and user engagement, while also revealing areas where further refinement is needed. The positive reception of the artifact, along with constructive criticism, has set a solid foundation for its ongoing development.

Reflections and Forward-Looking Statements

Reflecting on the research undertaken, this study stands as an application of theory to practice, with no claims of theoretical or methodological expansion. Instead, its contributions are measured by the tangible utility it offers to practitioners in the field of decision support—a testament to the potential for applied research to make meaningful strides in professional practice.

The Path Ahead

Looking ahead, I see the horizon alight with possibilities. The suggestions for future research outlined in this dissertation—case studies, experiments, and infrastructure development for a global-scale implementation—chart a course for continued innovation and exploration. The next steps involve not only technical development but also the fostering of a community ready to embrace and advance the use of the standard.

In conclusion, this research embodies a bridge between theoretical frameworks and practical application. It does not end with the final page of this dissertation; rather, it marks a beginning, an invitation to the global decision support community to take up the baton and carry it forward into a future where decision-making is a shared, streamlined, and strategic endeavor.

APPENDICES

Appendix A - Research Design Summary Table

Research Design Table Adapted from Mathiassen (Mathiassen, 2017)

Component	Definition	Specification
Journal	The target journal defines the audience for the research and the conversation in which the work participates.	International Journal of Information Technology & Decision Making
Title	The title expresses the essence of the research design, with emphasis on C.	Linked Decisions: A Data Standard for Distributed Decision Support Systems
P	The problem setting represents people's concerns in a real-world problematic situation.	When faced with complex decisions, individuals engage in a cognitive process of gathering and analyzing information relevant to their circumstances to make informed choices. However, the limited cognitive and information resources available can result in suboptimal decisions arising from low-quality information or flawed analysis. As of now, there is a lack of a widely accepted and implemented data standard for efficient large-scale access and processing of real-world decision-making data. The development and implementation of such a standard could potentially improve the quality and efficiency of decision-making.
A	The area of concern represents some body of knowledge in the literature that relates to P.	Information Architecture for Distributed Decision-Making
F	The conceptual framing helps structure collection and analyses of data from P to answer RQ; FA draws on concepts from A, whereas FI draws on concepts independent of A.	Fa – Distributed Cognition
M	The method details the approach to empirical inquiry, specifically to data collection and analysis.	Design Science Research project to design, build, and evaluate a decision data standard enabling distributed decision information sharing.
RQ	The research question relates to P, opens for research into A, and helps ensure the research design is coherent and consistent.	How can we design a data standard for distributed decision support systems?
C	Contributions influence P and A, and possibly also F and M.	Cp – a new usable real-world data standard enabling global decision information exchange and processing

(Mathiassen, 2017)

Appendix B - Decision Data Standard Schema Documents

Decision Data Standard Specification, Cell Object Schema (v0.5.2)

"$schema": "https://json-schema.org/draft/2020-12/schema",

"$id": "https://use.fieldcell.org/cell.schema.json",
"title": "Fieldcell Object",
"description": "This schema is for Fieldcell objects. All 'fc:' prefixed properties refer to terms defined in the Fieldcell context located at https://use.fieldcell.org/context.jsonld",
"type": "object",
"required": ["fc:id", "fc:coordinates", "fc:value"],
"properties": {
"@context": {
"type": "string",
"const": "https://use.fieldcell.org/context.jsonld",
"description": "The URL of the Fieldcell context defining the 'fc:' namespace"
},
"fc:id": {
"type": "string",
"format": "uri",
"description": "The unique identifier of the Fieldcell object"
},
"fc:coordinates": {
"type": "object",
"description": "Coordinates map, where each key is a URI (defined in Fieldcell context) representing a dimension",
"additionalProperties": {
"type": "object",
"required": ["fc:isPartOf", "fc:author", "fc:dateCreated"],
"properties": {
"fc:isPartOf": {
"type": "string",
"format": "uri",
"description": "URI indicating a larger structure or collection this cell is part of"
},
"fc:author": {
"type": "string",
"description": "The author or creator of the cell's content"
},
"fc:dateCreated": {
"type": "string",
"format": "date-time",

```
          "description": "The date and time when the cell was created"
        }
      }
    }
  },
"fc:value": {
    "type": "object",
    "required": ["@type", "value"],
    "properties": {
      "@type": {
        "type": "string",
        "const": "PropertyValue",
        "description": "Indicates that the type of the value is a PropertyValue"
      },
      "value": {
        "type": "string",
        "description": "The actual value of the object"
      },
      "fc:propertyID": {
        "type": "string",
        "format": "uri",
        "description": "A URI that uniquely identifies the property"
      }
    },
    "description": "The value of the Fieldcell object, following the PropertyValue structure as defined in
the Fieldcell context"
  }
 }
}
```


(Klc, 2024)

Decision Data Standard Specification, Context Document (v0.5.2)


```
{
 "@context": {
  "schema": "http://schema.org/",
  "fc": "https://use.fieldcell.org/",
  "Cell": "fc:Cell",
  "CellGroup": "fc:CellGroup",
  "id": "@id",
  "type": "@type",
  "isPartOf": {
   "@id": "schema:isPartOf",
   "@type": "@id"
  },
  "value": {
   "@id": "schema:PropertyValue",
   "@type": "@json"
  },
  "citation": "schema:citation",
  "coordinates": {
   "@id": "fc:coordinates",
   "@container": "@index"
  },
  "PropertyValue": "schema:PropertyValue",
  "propertyID": "schema:propertyID",
  "dateCreated": "schema:dateCreated",
  "author": "schema:author",
  "additionalType": "schema:additionalType",
  "alternative": "fc:alternative",
  "criterion": "fc:criterion",
  "weight": "fc:weight",
  "matrixCell": "fc:matrixCell",
  "role": "fc:role",
  "externalReference": "fc:externalReference",
  "cells": {
   "@id": "fc:cells",
   "@container": "@list"
  },
  "validFrom": {
   "@id": "schema:validFrom",
   "@type": "schema:DateTime"
  },
  "validThrough": {
   "@id": "schema:validThrough",
   "@type": "schema:DateTime"
```

```
    },
    "timeClaimedTrue": "fc:timeClaimedTrue",
    "label": "schema:name",
    "description": "schema:description",
    "comment": "schema:comment",
    "AgreeAction": "schema:AgreeAction",
    "DisagreeAction": "schema:DisagreeAction",
    "DislikeAction": "schema:DislikeAction",
    "EndorseAction": "schema:EndorseAction",
    "LikeAction": "schema:LikeAction",
    "WantAction": "schema:WantAction"
  }
}
```


(Klc, 2024)

Appendix C – Example Instantiated Cell Object

The JavaScript Object Notation (JSON) FieldCell object below is an example of a real-world instantiation of the cell construct. It includes a reference to the context document, a global identifier, a set of coordinates, and a value property.


```
{
        "@context": "https://use.fieldcell.org/context.jsonld",

        "fc:id": "https://cells.trxtl.com/CP6JVEh2ewTnt34t4UwIZx2O7ok1/08381b41-
ee5b-4e24-9380-50cb8a7e95bf",

"fc:coordinates":

        {
        "fc:isPartOf":
"https://cells.trxtl.com/CP6JVEh2ewTnt34t4UwIZx2O7ok1/3797d9e7-de8a-4229-b9ed-
11c6f7d0b3bf",
                "fc:dateCreated": "2024-02-22T04:18:12.616Z",
                "fc:criterion":
"https://cells.trxtl.com/CP6JVEh2ewTnt34t4UwIZx2O7ok1/24eea4ce-0b8e-4fac-9de2-
a7eb735c1b3b",
                "fc:CellGroup":
"https://cells.trxtl.com/CP6JVEh2ewTnt34t4UwIZx2O7ok1/3797d9e7-de8a-4229-b9ed-
11c6f7d0b3bf",
                "fc:author": "https://cells.trxtl.com/CP6JVEh2ewTnt34t4UwIZx2O7ok1",
                "fc:role": "fc:matrixCell",
                "fc:alternative":
"https://cells.trxtl.com/CP6JVEh2ewTnt34t4UwIZx2O7ok1/de0d661f-8a02-47aa-b34a-
f8c58018a6f3"
        },

        "fc:value":

        {
         "fc:propertyID": "https://schema.org/Rating",
         "minValue": 0,
         "@type": "PropertyValue",
         "maxValue": 10,
         "description": "Rating value on a scale of 0 to 10",
         "value": "1"
                }
}
```

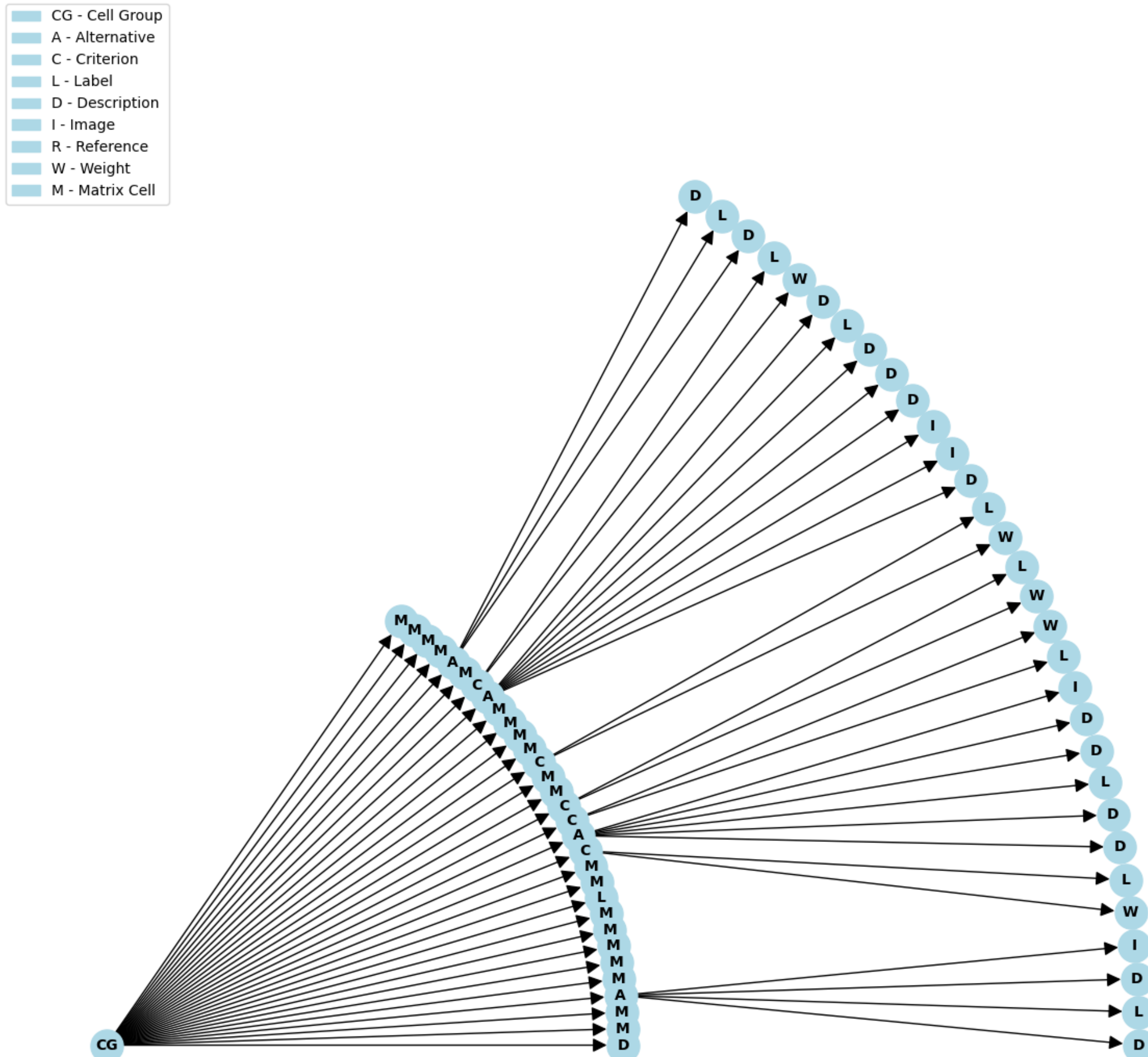
Appendix D – Evaluation Summary

Artifact Evaluation Summary by DSR Criteria

Category	Positive Feedback	Negative Feedback
Completeness	MK: Potential to reduce bias with objective criteria. AB: Appreciation for the data model's ability to scale and handle various problems. ZZ: Appreciation for nesting values in JSON structure.	
Ease of use	AB: Likes the clean display and simplicity. SUH: User-friendly interface, dynamic criteria adjustment. CB: Potential value and adaptability to structured decision-making. ZZ: Suggested enhancement with color for user engagement.	AB: Concerns about handling many options and dimensions. ZZ: Concerns about guiding users through data entry. MK: Recommends more intuitive visualizations like heat maps.
Effectiveness	AB: Interested in real-world application for compensation conversations. ZZ: Potential for analyzing decision-making over time. MK: Sees automation as beneficial for ranking large datasets.	
Efficiency	SUH: Real-time collaboration feature. MK: Values real-time updates.	
Elegance	AB: Finds the matrix presentation clean and relatable.	
Fidelity with real world phenomena		ZZ: Balance between numerical specificity and consensus needed.
Generality	AB: Flexibility for various scenarios like corporate strategy. ZZ: Applicability in replicating search criteria. SUH: Flexibility in application for customer service or healthcare.	
Impact on the environment and on the artefact's users		
Internal consistency		

Category	Positive Feedback	Negative Feedback
Level of detail	AB: Plans to accommodate nesting for more detailed criteria and alternatives. MK: Suggests breaking down criteria into measurable components for further objectivity.	
Operationality		AB: Curiosity about the tool's performance with numerous options and dimensions. ZZ: Compatibility with common data formats like Excel.
Robustness	AB: Likes the idea of the tool suggesting what's important and learning from past decisions.	
Simplicity	AB: Appreciates the solution's built-in scalability and straightforward design. SUH: Real-time feature and dynamic adjustments.	AB: Questions about the tool's manageability with complex scenarios. ZZ: Complexity in data entry for users. CB: Concerns about integration complexity.
Understandability	AB: Finds the tool laid out in layman's terms and easy to understand without needing to know decision science.	ZZ: Guiding users indicates a potential issue. CB: Needs hands-on interaction for proper evaluation. SUH: Suggests further development to include examples for clarity. MK: Recommends heat maps for immediate understanding of data assessments.

Appendix E – Cell Group Nested Tree Visualization



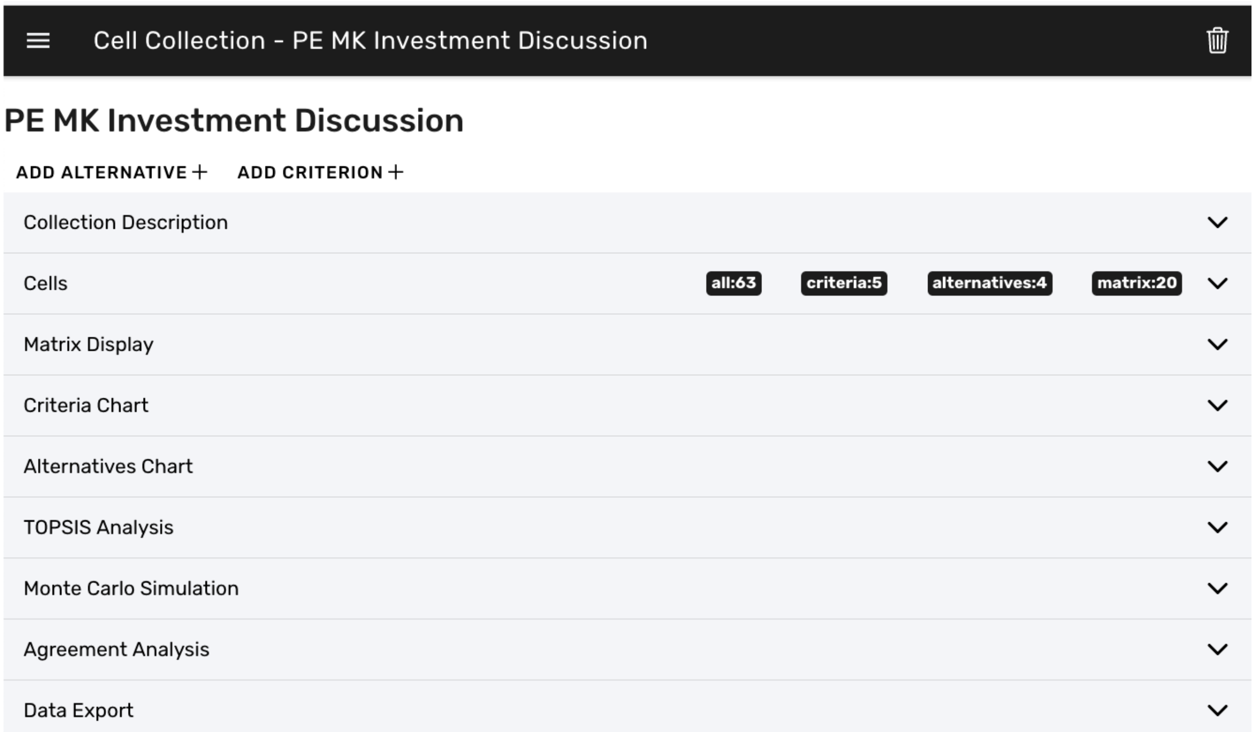
Visualization of Parent-Child Relationships in an Example Cell Group with Two Nesting Layers

Appendix F - Timeline of Interviews

9/21/23	DS-PRAC-AB	17.2	Audio	Requirements Gathering
10/17/23	DS-PRAC-RS	12.8	Audio	Requirements Gathering
10/23/23	DS-PRAC-CB	23.4	Audio	Requirements Gathering
10/25/23	DS-PRAC-ZZ	89.4	Video	Requirements Gathering
10/31/23	DS-PRAC-PB	21.3	Audio	Requirements Gathering
11/10/23	DS-PRAC-SUH	44.8	Video	Requirements Gathering
11/10/23	DS-PRAC-EF	49.2	Video	Requirements Gathering
11/14/23	CS-PRAC-SHS	54.4	Video	Design and Development
11/17/23	CS-PRAC-SP	156.8	Video	Design and Development
12/12/23	CS-PRAC-SH	200.3	Video	Design and Development
12/12/23	CS-PRAC-SP	140.4	Video	Design and Development
12/15/23	DS-PRAC-MK	18.3	Audio	Requirements Gathering
1/8/24	CS-PRAC-SH	110.7	Video	Design and Development
1/16/24	CS-PRAC-SHS	119	Video	Design and Development
1/23/24	CS-PRAC-SP	174.8	Video	Design and Development
2/22/24	DS-PRAC-SUH	60.8	Video	Evaluation
2/22/24	DS-PRAC-CB	60.1	Video	Evaluation
2/26/24	DS-PRAC-ZZ	57.8	Video	Evaluation
2/29/24	DS-PRAC-AB	38.3	Video	Evaluation
3/2/24	DS-PRAC-MK	60.9	Video	Evaluation

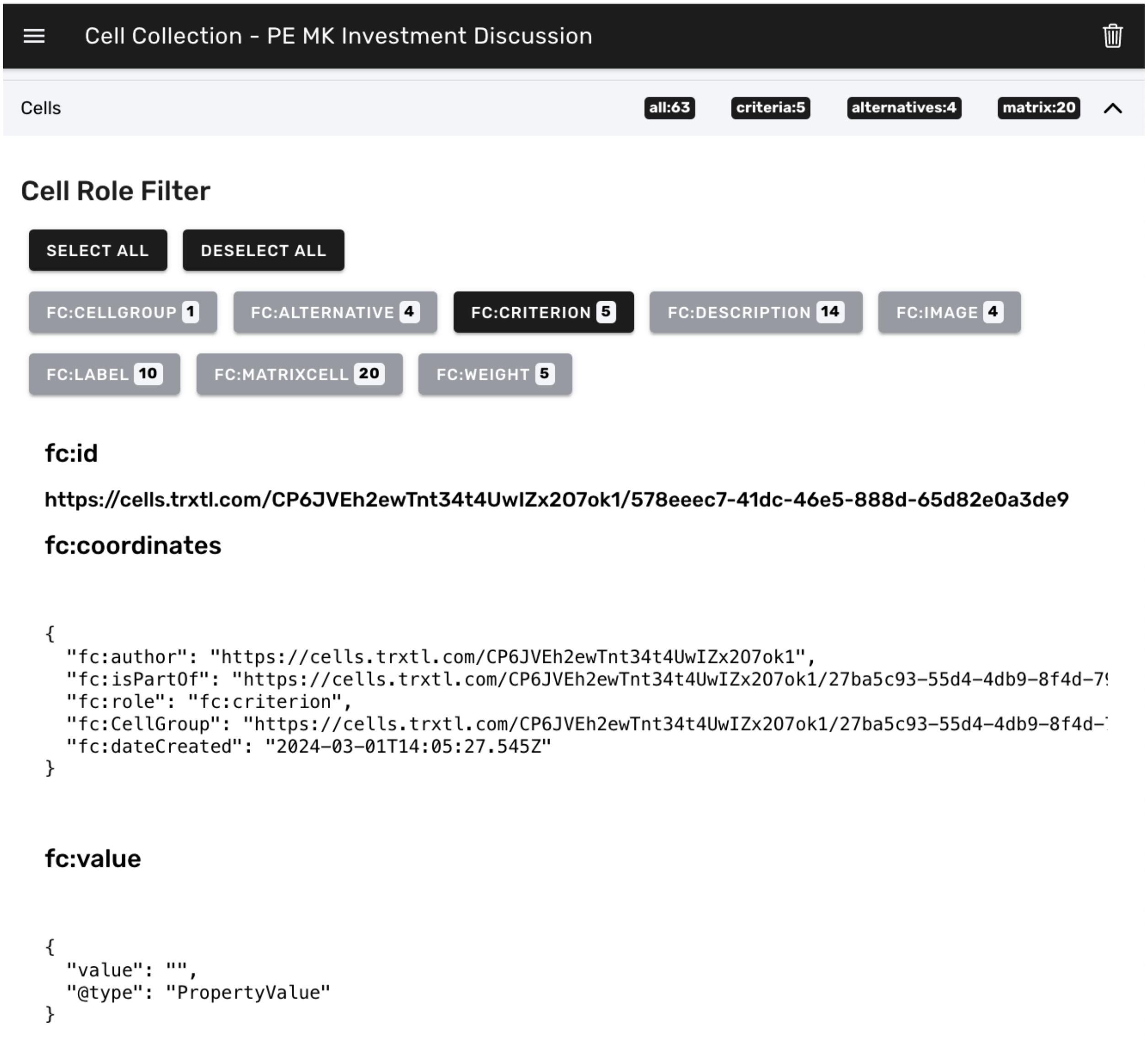
Appendix G – Artifact Evaluation Website Cell Collection User Interfaces

Top-Level Menu



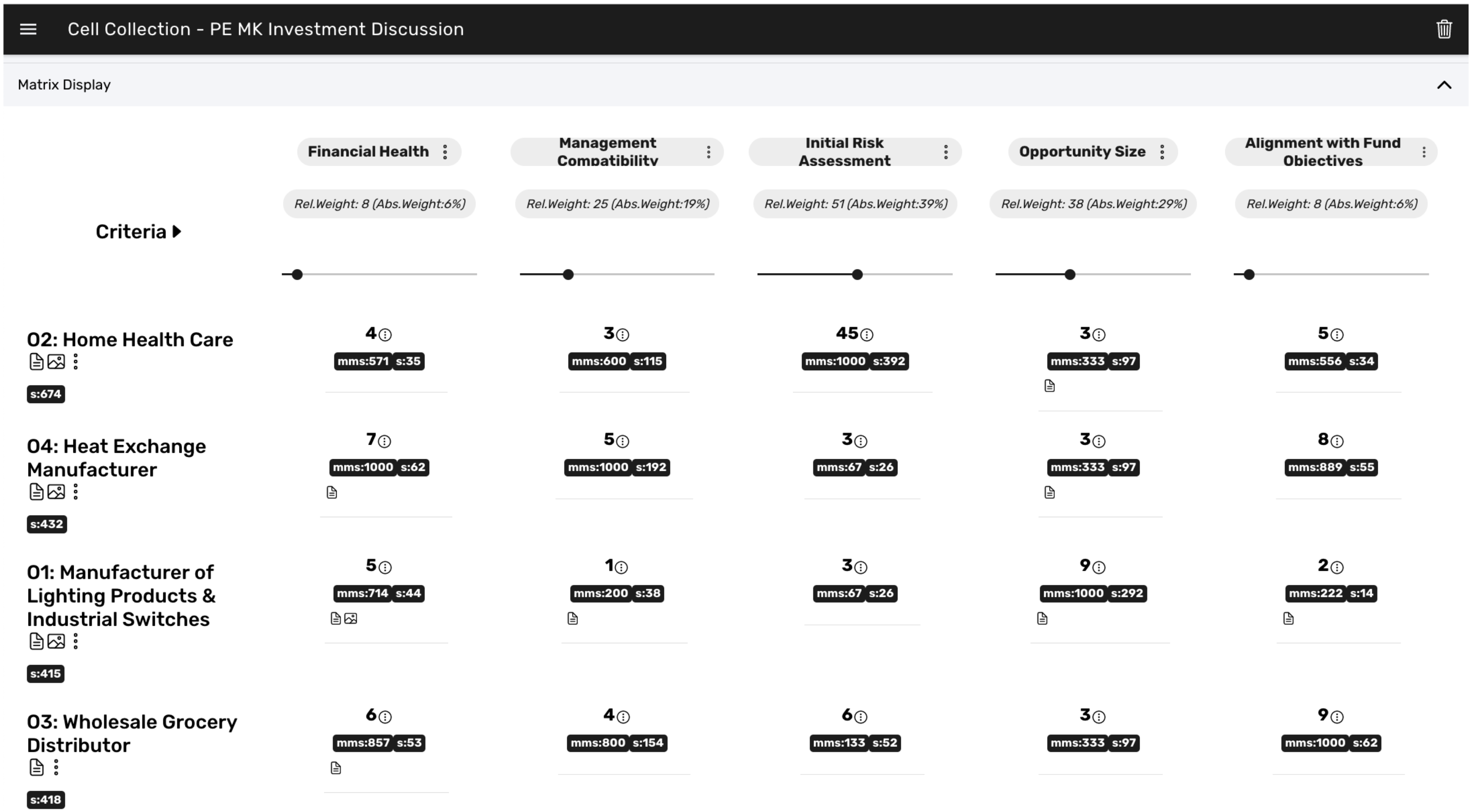
Collection Description Section

Cells Section

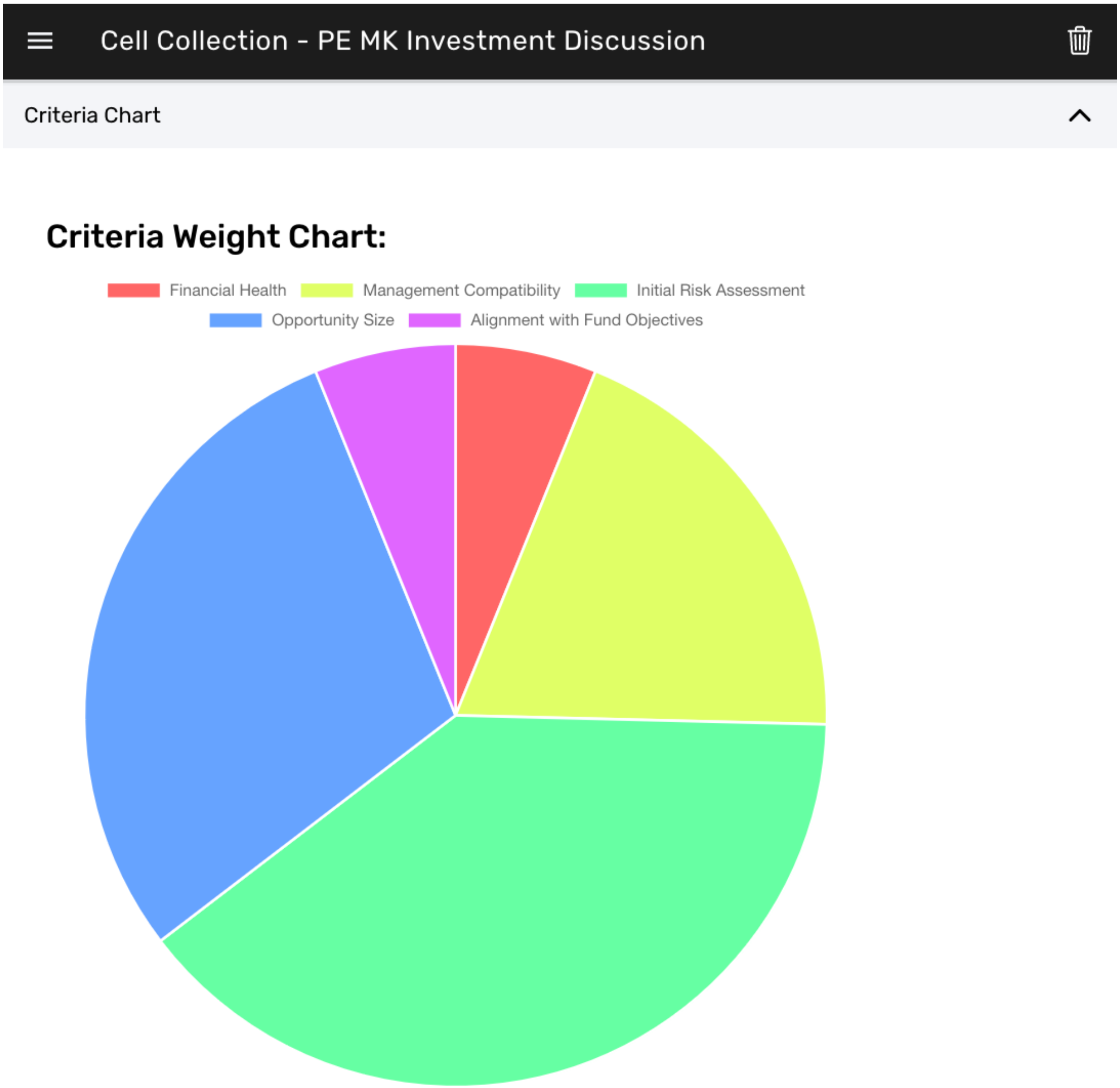


(shortened view for brevity)

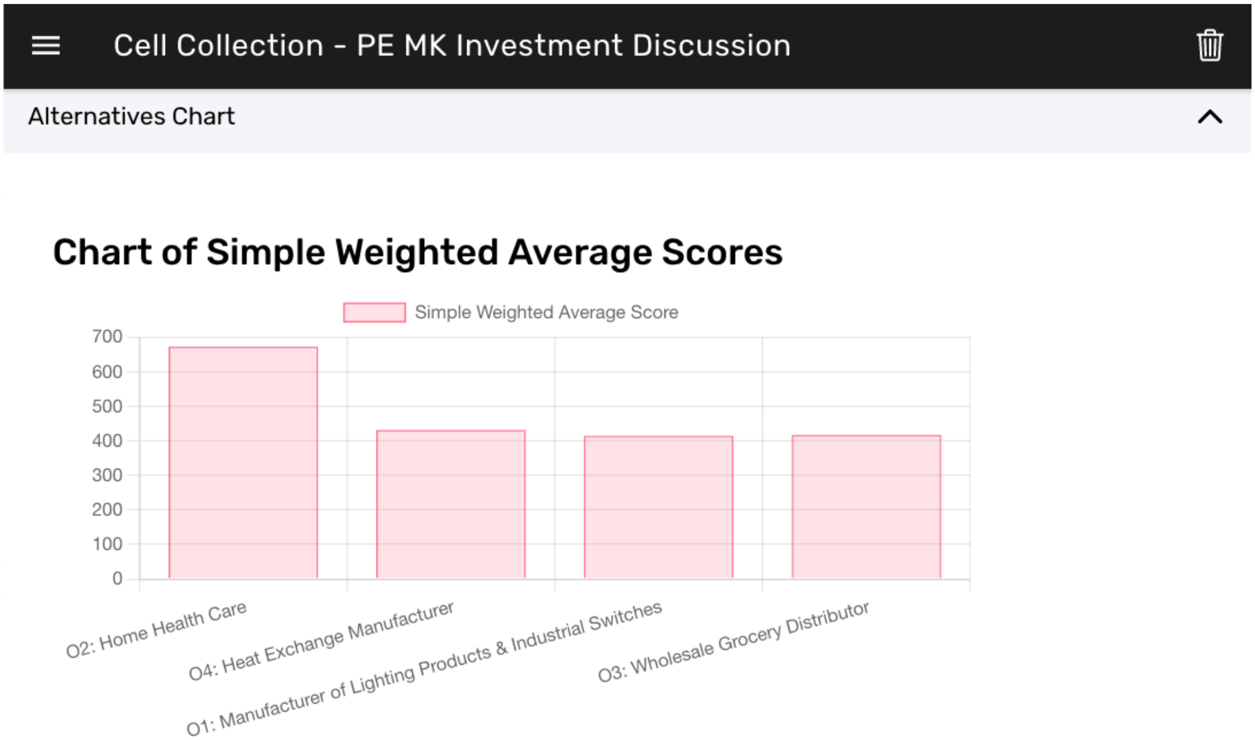
Matrix Display Section



Criteria Chart Section



Alternatives Chart Section



TOPSIS Analysis Section

Cell Collection - PE MK Investment Discussion

TOPSIS Analysis

TOPSIS for PE MK Investment Discussion

RUN TOPSIS

Best Alternative(s):

O2: Home Health Care

Details:

Matrix (m):

$$\begin{bmatrix} 4 & 3 & 45 & 3 & 5 \\ 7 & 5 & 3 & 3 & 8 \\ 5 & 1 & 3 & 9 & 2 \\ 6 & 4 & 6 & 3 & 9 \end{bmatrix}$$

Weights (w):

$$\begin{bmatrix} 0.06153846153846154 & 0.19230769230769232 & 0.3923076923076923 & 0.2923076923076923 & 0.06153846153846154 \end{bmatrix}$$

Impact (ia):

$$\begin{bmatrix} max & max & max & max & max \end{bmatrix}$$

Result:

$$\begin{bmatrix} 4 & 3 & 45 & 3 & 5 \end{bmatrix}$$

REFERENCES

Abele, S., Sandra, I. V.-P., & Garold, S. (2008). Information flow and influence during collective search, discussion, a nd choice.

Alter, S. (1977). A Taxonomy of Decision Support Systems. *Sloan Management Review (pre-1986)*, *19*(1), 39.

Antunes, F., Freire, M., & Costa, J. P. (2016). Semantic web and decision support systems. *Journal of Decision Systems*, *25*(1), 79-93.

Arnott, D., & Pervan, G. (2010). 12. An assessment of DSS design science using the Hevner, March, Park and Ram guidelines. *Information Systems Foundations*, 255.

Arnott, D., & Pervan, G. (2015). A critical analysis of decision support systems research. *Formulating Research Methods for Information Systems: Volume 2*, 127-168.

Aruldoss, M., Lakshmi, T. M., & Venkatesan, V. P. (2013). A Survey on Multi Criteria Decision Making Methods and Its Applications. *American Journal of Information Systems*, *1*(1), 31-43. https://doi.org/10.12691/ajis-1-1-5

Baker, D., Bridges, D., Hunter, R., Johnson, G., Krupa, J., Murphy, J., & Sorenson, K. (2001). Guidebook to Decision-Making Methods.

Bardone, E., & Secchi, D. (2009). PART III: CHAPTER 8: DISTRIBUTED COGNITION: A RESEARCH AGENDA FOR MANAGEMENT. In (Vol. 14, pp. 183-207). Center for Advanced Studies in Management.

Barton, R. F. (1981). An MCDM Approach for Resolving Goal Conflict in MBO [Article]. *Academy of Management Review*, *6*(2), 231-241. https://doi.org/10.5465/AMR.1981.4287799

Benlian, A., Hess, T., & Buxmann, P. (2009). Drivers of SaaS-adoption–an empirical study of different application types. *Business & Information Systems Engineering*, *1*(5), 357-369.

Berners-Lee, T. (2006). Linked data-design issues. http://www. *w3. org/DesignIssues/LinkedData. html*.

Biard, T., Le Mauff, A., Bigand, M., & Bourey, J.-P. (2015, 2015//). Separation of Decision Modeling from Business Process Modeling Using New "Decision Model and Notation" (DMN) for Automating Operational Decision-Making. Risks and Resilience of Collaborative Networks, Cham.

Blaszczynski, A., Ladouceur, R., Nower, L., & Shaffer, H. (2013). Informed Choice and Gambling: Principles for Consumer Protection. *The Journal of Gambling Business and Economics*, *2*(1), 103-118. https://doi.org/10.5750/jgbe.v2i1.527

Boland, R. J., Tenkasi, R. V., & Te'eni, D. (1994). Designing Information Technology to Support Distributed Cognition. *Organization Science*, *5*(3), 456-475. https://doi.org/10.1287/orsc.5.3.456

Brocke, J. v., Hevner, A., & Maedche, A. (2020). Introduction to Design Science Research. In (pp. 1-13). https://doi.org/10.1007/978-3-030-46781-4_1

Brugha, C. M. (2004). Structure of Multi-Criteria Decision-Making. *The Journal of the Operational Research Society*, *55*(11), 1156-1168. http://www.jstor.org/stable/4101887

Calvanese, D., Dumas, M., Laurson, Ü., Maggi, F. M., Montali, M., & Teinemaa, I. (2016). Semantics and Analysis of DMN Decision Tables. International Conference on Business Process Management,

Carneiro, J., Alves, P., Marreiros, G., & Novais, P. (2021). Group decision support systems for current times: Overcoming the chall enges of dispersed group decision-making. *Neurocomputing*, *423*, 735-746. https://doi.org/10.1016/j.neucom.2020.04.100

Caroselli, J. S., Hiscock, M., Scheibel, R. S., & Ingram, F. (2006). The Simulated Gambling Paradigm Applied to Young Adults: An Examinatio n of University Students' Performance. *Applied Neuropsychology*, *13*(4), 203-212. https://doi.org/10.1207/s15324826an1304_1

Chen, L., Marsden, J. R., & Zhang, Z. (2012). Theory and Analysis of Company-Sponsored Value Co-Creation. *Journal of Management Information Systems*, *29*(2), 141-172. https://doi.org/10.2753/MIS0742-1222290206

Connolly, T., & Thorn, B. K. (1987). Predecisional information acquisition: Effects of task variables on su boptimal search strategies. *Organizational Behavior and Human Decision Processes*, *39*(3), 397-416. https://doi.org/10.1016/0749-5978(87)90031-8

Cuza, A. (2013). Decision-making support systems : actual implementations , limits and requirements sabina-cristiana necula.

Davies, G. A. M. (2002). Domestic Strife and the Initiation of International Conflicts. *Journal of Conflict Resolution*, *46*(5), 672-692. https://doi.org/10.1177/002200202236169

Eckermann, S., & Willan, A. R. (2013). Optimal Global Value of Information Trials: Better Aligning Manufactur er and Decision Maker Interests and Enabling Feasible Risk Sharing. *PharmacoEconomics*, *31*(5), 393-401. https://doi.org/10.1007/s40273-013-0038-5

Fülöp, J. (2005, 2005). Introduction to decision making methods.

Funkenberg, T., Klinger, V., & Künzer, C. (2012). Data standardization and modeling in a web based information system. *2012 IEEE International Geoscience and Remote Sensing Symposium*, 5282-5284.

Gachet, A., & Haettenschwiler, P. (2003). A decentralized approach to distributed decision support systems. *Journal of Decision Systems*, *12*(2), 141-158.

Gal, M. S., & Rubinfeld, D. L. (2019). Data Standardization. *Law*.

Gil-Garcia, J. R., Chun, S. A., & Janssen, M. (2009). Government information sharing and integration: Combining the social a nd the technical. *Information Polity*, *14*(1,2), 1-10. https://doi.org/10.3233/ip-2009-0176

Guizzardi, G., Botti Benevides, A., Fonseca, C. M., Porello, D., Almeida, J. P. A., & Prince Sales, T. (2022). UFO: Unified foundational ontology. *Applied ontology*, *17*(1), 167-210.

Guizzardi, R., Carneiro, B. G., Porello, D., & Guizzardi, G. (2020, 2020). A core ontology on decision making.

Hausenblas, M., & Karnstedt, M. (2010, 2010). Understanding linked open data as a web-scale database.

Hitzler, P. (2021). A review of the semantic web field. *Communications of the ACM*, *64*(2), 76-83.

Hogarth, R. M., & Kunreuther, H. (1995). Decision making under ignorance: Arguing with yourself. *Journal of Risk and Uncertainty*, *10*(1), 15-36. https://doi.org/10.1007/bf01211526

Holsapple, C. (2008). DSS architecture and types. *Handbook on Decision Support Systems 1*, 163-189.

Hutchins, E. (2000). Distributed cognition. *International Encyclopedia of the Social and Behavioral Sciences. Elsevier Science*, *138*.

Iliadis, A., Acker, A., Stevens, W., & Kavakli, S. B. (2023). One schema to rule them all: How Schema. org models the world of search. *Journal of the Association for Information Science and Technology*.

Kadenko, S., Tsyganok, V., Andriichuk, O., Aleksandr, K., & Minglei, F. (2020). An Overview of Decision Support Software: Strategic Planning Perspecti ve. *International Conference on Intelligent Tutoring Systems*.

Kahneman, D. (2003). Maps of bounded rationality: Psychology for behavioral economics. *American Economic Review*, *93*(5), 1449-1475.

Karla Mendes, C., Karina, M. C., Fillottrani, P., & Elsa, E. (2012). Information Sharing - Benefits.

Klc, J. (2024, 01/08/2024). *Fieldcell Context Document Draft*. Retrieved 04/9/2024 from https://use.fieldcell.org/

Konaté, J., Zaraté, P., Gueye, A., & Camilleri, G. (2020, 2020//). An Ontology for Collaborative Decision Making. Group Decision and Negotiation: A Multidisciplinary Perspective, Cham.

Kondratyev, A., Lavagno, L., Meyer, M., & Watanabe, Y. (2013, 2013). Share with Care A Quantitative Evaluation of Sharing Approaches in Hig h-level Synthesis.

Kunreuther, H., Meyer, R., Zeckhauser, R., Slovic, P., Schwartz, B., Schade, C., Luce, M. F., Lippman, S., Krantz, D., Kahn, B., & Hogarth, R. (2002). High Stakes Decision Making: Normative, Descriptive and Prescriptive C onsiderations. *Marketing Letters*, *13*(3), 259-268. https://doi.org/10.1023/a:1020287225409

Mathiassen, L. (2017). Designing engaged scholarship: From real-world problems to research publications. *Engaged Management Review*, *1*(1), 2.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook*. SAGE Publications. https://books.google.com/books?id=p0wXBAAAQBAJ

Myers, M., & Cheung, M. (2008). Sharing Global Supply Chain Knowledge.

Nilsson, M., & Ziemke, T. (2006, 10-13 July 2006). Rethinking Level 5: Distributed Cognition and Information Fusion. 2006 9th International Conference on Information Fusion,

Papadimitriou, C. H. (1991). Decision-making with incomplete information. In *Lecture Notes in Computer Science* (pp. 1-1). Springer Berlin Heidelberg. https://doi.org/10.1007/3-540-54945-5_42

Peffers, K., Tuunanen, T., Rothenberger, M., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, *24*, 45-77.

Phillips-Wren, G. E., Daly, M., & Burstein, F. (2022). Support for cognition in decision support systems: an exploratory historical review. *Journal of Decision Systems*, *31*, 18 - 30.

Potter, R. B., & Beach, L. R. (1994). Imperfect Information in Pre-choice Screening of Options. *Organizational Behavior and Human Decision Processes*, *59*(2), 313-329. https://doi.org/10.1006/obhd.1994.1062

Resmini, A., & Rosati, L. (2011). A Brief History of Information Architecture. *Journal of Information Architecture*.

Rivalan, M., Ahmed, S. H., & Dellu-Hagedorn, F. (2009). Risk-Prone Individuals Prefer the Wrong Options on a Rat Version of th e Iowa Gambling Task. *Biological Psychiatry*, *66*(8), 743-749. https://doi.org/10.1016/j.biopsych.2009.04.008

Rivalan, M., Valton, V., Seriès, P., Marchand, A. R., & Dellu-Hagedorn, F. (2013). Elucidating Poor Decision-Making in a Rat Gambling Task. *PLOS ONE*, *8*(12), e82052. https://doi.org/10.1371/journal.pone.0082052

Saaty, T. L. (1980). The analytic hierarchy process (AHP). *The Journal of the Operational Research Society*, *41*(11), 1073-1076.

Serwadda, D., Ndebele, P., Grabowski, M. K., Bajunirwe, F., & Wanyenze, R. K. (2018). Open data sharing and the Global South—Who benefits? *Science*, *359*(6376), 642-643. https://doi.org/10.1126/science.aap8395

Simon, H. A. (1960). *The new science of management decision* ([1st] ed.). Harper.

Simon, H. A. (1990). Bounded rationality. *Utility and probability*, 15-18.

Sonnenberg, C., & vom Brocke, J. (2012a). Evaluation Patterns for Design Science Research Artefacts. In *Practical Aspects of Design Science* (pp. 71-83). https://doi.org/10.1007/978-3-642-33681-2_7

Sonnenberg, C., & Vom Brocke, J. (2012b, 2012). Evaluations in the science of the artificial–reconsidering the build-evaluate pattern in design science research.

Sporny, M., Longley, D., Kellogg, G., Lanthaler, M., & Lindström, N. (2020). JSON-LD 1.1. *W3C Recommendation, Jul*.

Summerfield, C., & Tsetsos, K. (2015). Do humans make good decisions? *Trends in Cognitive Sciences*, *19*(1), 27-34. https://doi.org/10.1016/j.tics.2014.11.005

Tang, Y., Cerutti, F., Oren, N., & Bisdikian, C. (2014). Reasoning about the impacts of information sharing. *Information Systems Frontiers*, *17*(4), 725-742. https://doi.org/10.1007/s10796-014-9521-6

Tavakoli, M., Davies, H. T. O., & Thomson, R. (2000). Decision analysis in evidence-based decision making [https://doi.org/10.1046/j.1365-2753.2000.00233.x]. *Journal of Evaluation in Clinical Practice*, *6*(2), 111-120. https://doi.org/https://doi.org/10.1046/j.1365-2753.2000.00233.x

Triantaphyllou, E. (2000). *Multi-Criteria Decision Making Methods: A Comparative Study* (Vol. 44). https://doi.org/10.1007/978-1-4757-3157-6

Vetschera, R., Sarabando, P., & Dias, L. (2014). Levels of incomplete information in group decision models – A comprehe nsive simulation study. *Computers & Operations Research*, *51*, 160-171. https://doi.org/10.1016/j.cor.2014.05.021

Waters, J., Patel, R., Eitelberg, J., & Ceruti, M. G. (2009a, 2009). A Proposed Common Decision-Exchange Protocol for Representing, Managin g, and Sharing Organizational Decisions.

Waters, J., Patel, R., Eitelberg, J., & Ceruti, M. G. (2009b). A proposed common decision-exchange protocol for representing, managing, and sharing organizational decisions.

Willis, L. E. (2005). Decisionmaking & the Limits of Disclosure: The Problem of Predator y Lending. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.748286

Wittenbaum, G. M., Hollingshead, A. B., & Botero, I. C. (2004). From cooperative to motivated information sharing in groups: moving be yond the hidden profile paradigm. *Communication Monographs*, *71*(3), 286-310. https://doi.org/10.1080/0363452042000299894

Xiao, Y., Zhang, H., & Basadur, T. M. (2016). Does information sharing always improve team decision making? An exami nation of the hidden profile condition in new product development. *Journal of Business Research*, *69*(2), 587-595. https://doi.org/10.1016/j.jbusres.2015.05.014

Yoon, S. W., Matsui, M., Yamada, T., & Nof, S. Y. (2009). Analysis of effectiveness and benefits of collaboration modes with inf ormation- and knowledge-sharing. *Journal of Intelligent Manufacturing*, *22*(1), 101-112. https://doi.org/10.1007/s10845-009-0282-x

Zaraté, P., & Liu, S. (2016). A new trend for knowledge-based decision support systems design. *Int. J. Inf. Decis. Sci.*, *8*, 305-324.

Zavadskas, E. K., & Turskis, Z. (2011). Multiple criteria decision making (MCDM) methods in economics: an overview. *Technological and economic development of economy*, *17*(2), 397-427.

Zeleny, M. (2011). Multiple Criteria Decision Making (MCDM): From Paradigm Lost to Paradigm Regained? [https://doi.org/10.1002/mcda.473]. *Journal of Multi-Criteria Decision Analysis*, *18*(1-2), 77-89. https://doi.org/https://doi.org/10.1002/mcda.473

Zhang, H., Basadur, T. M., & Schmidt, J. B. (2014). Information Distribution, Utilization, and Decisions by New Product Development Teams. *Journal of Product Innovation Management*, *31*(S1), 189-204. https://doi.org/10.1111/jpim.12200

VITA

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Interests and Future Plans

I intend to implement an open, distributed, decentralized global architecture for cellular decision information, focusing on making real-world decisions better informed through easier methods of capturing, creating, sharing, and connecting bits of information that comprise decision models. This effort, based on my dissertation work, aims to facilitate better real-world decision-making processes by streamlining the synthesis and sharing of globally distributed decision information.

Declaration of Usage of AI-assisted Technologies in the Writing Process

During the preparation of this work the author used Open AI's GPT-4 (https://openai.com/gpt-4) to improve the organization and academic tone of the text. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the dissertation.