5-25-2023

A Hierarchical Decision Model to Evaluate Healthcare Organization's Readiness to Implement Clinical Decision Support Systems

Mohammed Oussama Laraichi
Portland State University

https://doi.org/10.15760/etd.3562

A Hierarchical Decision Model to Evaluate Healthcare Organization's Readiness to Implement Clinical Decision Support Systems

by

Mohammed Oussama Laraichi

A dissertation submitted in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy
in
Technology Management

Dissertation Committee:
Tugrul U. Daim, Chair
Liliya Hogaboam
Saeed Alzahrani
Robert Fountain

Portland State University
2023

ABSTRACT

Clinical Decision Support Systems (CDSS) are essential tools for healthcare organizations as well as for healthcare providers to improve clinical care. However, successful implementation of CDSS can be challenging. Therefore, before implementing CDSS, it is crucial to assess the readiness of healthcare organizations to implement these tools.

Through a literature review, the first step of this research explores the concept of clinical decision support and CDSS, discussing their features, characteristics, and organizational hurdles to implementation. It also provides perspectives on CDSS adoption in the context of Information Systems and Health Technology. The review helped identify research gaps, objectives, and questions.

To address these gaps and attempt to answer the research questions, a Hierarchical Decision Model (HDM) is proposed. The model allows us to assess the readiness of healthcare organizations for CDSS implementation. It presents four perspectives and sixteen criteria for a multi-dimensional assessment. The methodology involves expert panels for the HDM model's refinement, validation, and quantification.

Two case studies are then presented to demonstrate the HDM model's application in identifying real-world CDSS implementation challenges and providing insights and recommendations. The research contributions are evaluated against the identified gaps in the literature review, with limitations and future research presented.

In conclusion, this research provides valuable insights into CDSS implementation readiness assessment and highlights the need for careful consideration and planning. The proposed HDM model offers a valuable framework for healthcare organizations to evaluate their readiness for CDSS implementation.

DEDICATION

To the memory of my beloved mother, Dr. Fatiha Daoudi, I dedicate this dissertation with all my heart. You were and still are a guiding light and source of strength throughout my life. You instilled in me a love for learning and a passion for knowledge, which has driven me to pursue this academic journey guided by the values of ethics and resiliency I inherited from you.

To my dearest father, Mohammed Khalid Laraichi, I am grateful for the unwavering guidance and inspiration you have given me, leading me to achieve this academic milestone. You are a true role model in every sense of the word, and I am honored to call you my father.

To my beloved partner, Nisrine Jorio, I cannot thank you enough for the unconditional love and support you have shown me throughout this journey. None of this would have been possible without you by my side, and I am forever grateful to have you in my life.

To my children, Elias and Noah, you brought me the joy that kept me going through these years of hard work and perseverance.

To my brothers, Soufiane and Saâd, with whom I share the values instilled in us by our parents, values that have guided me throughout this journey.

ACKNOWLEDGEMENTS

I want to express my deep gratitude and appreciation to my mentor, adviser, and dissertation committee chair, Professor Tugrul U. Daim. Thank you for all the guidance, support, and encouragement you have provided throughout my Ph.D. journey. Your expertise and mentorship have been invaluable, and I could not have accomplished this milestone without your assistance. Your guidance, encouragement, and support have been instrumental in helping me achieve my research goals. I will never forget your contributions to my academic journey, and I hope to continue to benefit from your mentorship and friendship in the years to come.

Dr. Liliya Hogaboam, Dr. Saeed Alzahrani, and Dr. Robert Fountain, I would like to express my sincere appreciation and gratitude for serving on my dissertation committee and for the invaluable contributions you have made to my academic journey. Your expertise, guidance, and support have been instrumental in shaping the direction and focus of my research, and your feedback and constructive criticism have helped me to refine and improve my work. I am grateful for your time and effort dedicated to reviewing my work, providing thoughtful feedback, and sharing your insights and experiences. Your encouragement and support have been invaluable, and I could not have achieved this milestone without your help.

I would also like to express my sincere gratitude to Dr. Antonie J. Jetter for her support and encouragement throughout the first part of my academic journey. I feel privileged to have had Dr. Jetter as my advisor during this crucial phase of my academic journey.

Moreover, I would like to thank my fellow Ph.D. students: Dr. Amir Shaygan, Dr. Husam Barham, Dr. Joao Ricardo Lavoie, Dr. Ahmed Alibage, and Mark Ryan. I am grateful for the countless hours spent discussing ideas, sharing experiences, and providing feedback, which has helped refine and improve my work.

I want to express my deep appreciation to Dr. Daim's Research Group members. I am deeply grateful for the opportunity to work alongside such a talented and dedicated group of individuals. The knowledge and skills I gained from them will be invaluable to my future academic and professional endeavors.

Finally, I would like to extend my appreciation to the faculty and staff of the Engineering and Technology Department of Portland State University. I am grateful for the countless hours the faculty have dedicated to teaching and mentoring students, providing us with the tools, knowledge, and skills necessary to succeed in our academic pursuits. I also would like to acknowledge the contributions of the departmental staff, whose tireless efforts in organizing events, managing resources, and providing administrative support have enabled us to focus on our academic goals.

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CHAPTER 1 – INTRODUCTION

In the past century, technology has transformed entire professional fields and industries (Marakas, 2003). It has shaped new ways to approach business day-to-day work and has also been used to support critical decisions (Andersen, 2001). With the increased complexity of modern decision-making, technology now plays a crucial role (Daim & Kocaoglu, 2016). Medecin and healthcare are no exception. Healthcare professionals were among the first community to embrace technology breakthroughs to enhance the quality and efficiency of care (Bernstein et al., 2007). Industrialized countries have implemented technology-driven national policies and pioneered international initiatives that have revolutionized the patient-provider relationship and care delivery (Burney et al., 2010).

Like any other complex decision-making process, clinical decision-making evolves in an environment where a multitude of actors, components, and factors intervene (Smith et al., 2008). The critical nature of decision outputs that have direct human health impacts increases clinicians' pressure and, therefore, the need for support (Zavala et al., 2018).

Within decision-making systems, technology now intervenes in consolidating knowledge, making it available, computing massive information, alerting from threads, and more

(Bonczek et al., 2014). This specific technology intervention in decision-making is often referred to as Decision Making Support Systems in the literature (Walsh et al., 2019). More specifically, support systems for healthcare or Clinical Decision Support Systems (CDSS) have become a must-have for healthcare delivery in developed countries and beyond. Technological imperatives and an exponential increase in medical and healthcare knowledge have created momentum leading to the mass adoption of systems-based clinical decision support (Sutton et al., 2020).

Clinical Decision Support Systems have evolved exponentially since the early sixties when the first attempts to use computers to drive better and more efficient healthcare (Musen et al., 2014). Today, most healthcare providers in North America use Clinical Decision Support Systems in some form or shape (Sutton et al., 2020). The use and its intended impact vary significantly, given the wide range of features and tools clinical decision support systems provide. Nevertheless, Clinical Decision Support Systems aim to remain the same despite the different features and tools: delivering better and more efficient healthcare and, of course, reducing medical errors.

1.1 Problem Statement

The medical complexity of clinical decisions and their context has dramatically increased and now includes a multitude of inputs, regulations, and components (Rundo et al., 2020). Also, the increasing presence of technology in healthcare and, more specifically, in the day-to-day workflow of Clinicians calls for high integration capability. Indeed, the literature is unanimous in acknowledging these two factors and their impact on clinical providers' prerogatives (Sutton et al., 2020). In today's healthcare environment, clinical providers need to master multiple skill sets and build the ability to switch from one set to the other seamlessly. Moreover, in some industrialized countries, the Financial pressure on Healthcare Systems, private and public, calls for more efficiency (Tsani et al., 2021).

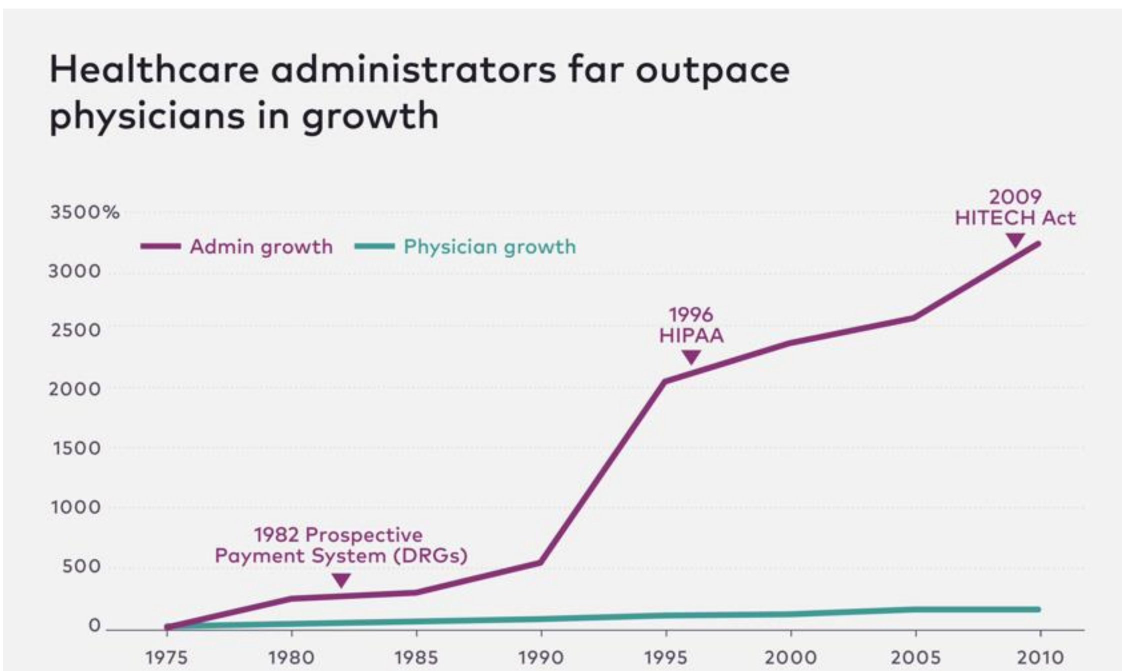

Figure 1 - Administrators vs. Physicians growth in the US (Bureau of Labor Statistics)

More recently, the Covid-19 pandemic has dramatically stressed the need for accessible, evidence-based knowledge (Sturmberg & Martin, 2020). Unfortunately, this pandemic continues to ravage the world and is far from ending anytime soon.

Clinical Decision Support Systems can help to manage all of these significantly impacting evolutions (Sutton et al., 2020). The literature research helps us to clearly understand these particular decision-support tools and the challenges they bring to healthcare organizations when being considered for implementation (Gold et al., 2020). These challenges are diverse and can end up being a blocker to the essential benefits CDSS are supposed to bring to healthcare organizations and patients. Therefore, organizations must assess the likeliness of these challenges to occur, and it is precisely what I am proposing to engage in through my research project. Indeed, I intend to build a model that will assess the readiness of healthcare organizations to overcome the CDSS implementation challenges and successfully use these decision support tools.

CHAPTER 2 – LITERATURE REVIEW

2.1 Clinical Decision Support Systems

2.1.1 History

When we consider Clinical Decision Support Systems as a holistic system that supports clinicians in making better clinical decisions, we can trace its ancestors back to the beginning of modern medicine in the 18th century (Berner, 2007). From that lance, clinical knowledge was the only component of the CDSS with the appearance of modern scientific biomedical research. Clinicians started to use this newly available research to make clinical decisions (Greenes, 2007b).

However, as defined today with its technological components, Clinical Decision Support Systems were introduced in the early seventies after the first attempts to include computerized methods to deliver healthcare in the late sixties (Bleich, 1969). Initially, healthcare providers and, more specifically, medical doctors have been early adopters of computerized clinical decision support driven by the technological imperative (Greenes, 2007a).

Over the last 50 years, aligned with the technological revolution, the use of CDSS has increased exponentially, embracing the computerization of healthcare, health informatics, and later big data and artificial intelligence (Devaraj et al., 2014).

2.1.2 Definition

Defining Clinical Decision Support Systems (CDSS) can be a challenge in itself. Giving the heterogeneous types and uses of CDSS, definitions can vary (Sutton et al., 2020). As presented in Table 1, definitions can either be oriented toward the purpose of the support, the underlying technology of the support, or the system components of the support (Berlin et al., 2006).

When focusing on the purpose, the literature underlines a system that is directly or indirectly helping clinicians and other components of a clinical decision system to increase the quality of the clinical outcome for patients (Kilsdonk et al., 2017). In that sense, the literature defines the Clinical Decision Support System as an added value to the clinical outcome for patients. The Purpose and Effects section of this review focuses more in detail on the efficacy of the decision support systems in achieving their purposes.

Another definition path in the literature is one that focuses on the decision system itself. Considering the CDSS a complex system, some literature will define its components and their interactions with little or no mention of the purposes and then goals of the decision support system (Yang et al., 2019). According to the literature, the system is composed of clinicians, staff, patients, and other individuals that constitute the system's human component (Sutton et al., 2020). This human component is, by definition, the component receiving the decision-making support.

Then comes the knowledge component, which centralizes all the necessary clinical and non-clinical knowledge to support the contextual decisions (Cánovas-Segura et al., 2019).

Finally, the components-oriented definitions present the technology, which can take various forms depending on the type of CDSS (Sutton et al., 2020). It ranges from classic database files to complex artificial intelligence algorithms interacting with clinical data. The technology piece is depicted in the literature as the most crucial component (Kilsdonk et al., 2017). It constitutes the bridge between the knowledge, and therefore the decision support, and the clinicians who are ultimately in charge of making the decision.

The last focus the literature offers when defining the CDSS is the technology itself (Kwan et al., 2020). The literature defines it as software or information systems developed for clinicians to facilitate their decision-making processes. It is here seen as a technological tool rather than a holistic system. Technology is central to decision support, which other schools of thought criticize.

Focus	**Definition**	**References**
Technology, Purpose	Software designed to be a direct aid to clinical decision-making, in which the characteristics of an individual patient are matched to a computerized clinical knowledge base and patient-specific assessments or recommendations are then presented to the clinician or the patient for a decision.	(Sim et al., 2001)
Purpose	Computer systems designed to impact clinician decision making about individual patients at the point in time that these decisions are made.	(Berner, 2007)
System Components	System that provides clinicians, staff, patients, or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and healthcare.	(Osheroff et al., 2007)
System and Technology	Any electronic system designed to aid directly in clinical decision making, in which characteristics of individual patients are used to generate patient-specific assessments or recommendations that are then presented to clinicians for consideration.	(Kawamoto et al., 2005b)
Technology	Clinical decision support (CDS) systems link patient data with an electronic knowledge base in order to improve decision-making, and computerized physician order entry (CPOE) is a requirement to set up electronic CDS.	(Beeler et al., 2014)

Table 1 - Literature Definitions of CDSS (Berlin et al., 2006)

Across the literature, there is a consensus on the purpose of Clinical Decision Support Systems, which is reflected in the different definitions. However, the technology involved and the system components create disparities in defining CDSS to the point where some available definitions are broadening the technology and system grounds with an exclusive focus on the purpose of CDSS: "variety of tools and interventions, computerized as well as non-computerized" (Wasylewicz & Scheepers-Hoeks, 2019). This particular aspect of defining CDSS reflects the heterogeneity of uses and solutions. The following section of this review analyses the literature to understand the reasons for the heterogeneity better.

2.2 Purpose and Effects of CDSS

2.2.1 Healthcare improvement

It is widely accepted that the number one purpose of Clinical Decision Support Systems is to improve healthcare outcomes (Jaspers et al., 2011). The idea is that clinical decisions will have a better outcome on the patient's healthcare if made with the support of CDSS (Varghese et al., 2018). The basis for the improvement of healthcare outcomes relies on several aspects.

First, let's consider the clinical context. Hospitals and healthcare systems, especially in developed countries, are stressed by patient volume (L. Chen et al., 2020). According to the American Hospital Association, the annual number of hospital admissions in the United States almost doubled in the last fifty years, reaching more than 36 million admissions in 2020. With the help of technology, CDSS are scalable and can evolve in a clinical context where high patient volume is processed.

Another aspect is technology, with the idea that technology has a large footprint in today's clinical processes, increasing the need for decision support that integrates with technology-driven processes (Aljarboa & Miah, 2020). Between the patient information contained in the electronic medical records and the technology used for the delivery of care, clinicians need a support system that embraces the technology turn that healthcare has taken. Therefore the technology aspect of CDSS is directly linked to enhancing the healthcare outcome for patients (Sulley, 2018).

Finally, the clinical knowledge aspect with the increasing complexity and volume of clinical knowledge that clinicians need to absorb calls for support, and the majority of Clinical Decision Support Systems provide that knowledge-based support (Larburu et al., 2017). Therefore, with the potential help of computerized algorithms, clinicians can receive targeted clinical knowledge that can be formatted to serve the patient's purpose driving positive healthcare outcomes (Ali & Lee, 2017).

2.2.2 Efficiency of care

Decision-making support systems, in addition, drive better decisions and optimize the efficiency of decision-making processes. In the case of Clinical Decision Support Systems, the purpose goes beyond the healthcare outcome and intends to increase the whole process's efficiency (Reis et al., 2017).

Healthcare systems and healthcare providers, in general, are confronted with particularly strict policies that govern the practice of medicine. Therefore, providing healthcare becomes a meticulous process where efficiency is critical. The feature of Clinical Decision Support Systems that is first in line to answer efficiency issues is technology (Olakotan & Yusof, 2020). Integration with Electronic Health Records (EHR) and other clinical information systems helps with the decision support's customization, increasing the efficiency of the decision-making system (Berlin et al., 2006).

Also, health systems are often subject to an increase in patient numbers. Here, the efficiency of care is to build the ability to absorb the increasing number of patients without decreasing the quality of the healthcare outcome for patients. CDSS provides a fully integrated vision of the decision-making system that offers clinicians a holistic view of the clinical conditions and parameters almost instantly (Vinks et al., 2020).

2.2.3 Reducing Unwanted Care Variability

Another purpose of Clinical Decision Support Systems is to reduce unwanted care variability by uniformizing healthcare and medicine practices. Studies have shown that drastically different approaches were taken for similar pathologies, ending in the same healthcare outcomes (Glaser, 2018). Clinical Decision Support Systems focus on evidence-based knowledge that is uniformized (Abidi, 2017). When medical treatment is given, the intention is to provide clinicians with similar guidance based on the latest accepted, peer-reviewed clinical knowledge. In the absence of uniformization, the difference in healthcare approaches often results in financial losses for the healthcare systems and governments when providers perform unnecessary clinical actions or when unnecessary drugs are prescribed (Glaser, 2018).

2.2.4 Reducing Medical Errors

Preventing Medical Errors is critical in healthcare. Human lives are at stake, and when medical errors are committed, irreversible effects impact patients. Clinical Decision Support Systems are intended to reduce medical errors by design (Belard et al., 2017).

The combination of up-to-date clinical knowledge, cutting-edge technology, and patients' medical information, as components of the CDSS, help in preventing medical errors (Berlin et al., 2006).

Indeed, medical errors are preventable adverse effects of clinical care. When provider care, clinicians' decisions have a direct impact on the well-being of patients. One of CDSS's purposes is to provide support so that adverse clinical decisions are reduced or completely eradicated from the point of care (Sutton et al., 2020).

2.3 Characteristics of CDSS

In this section, we will focus on the characteristics that compose Clinical Decision Support Systems. Berlin et al. developed a taxonomic description that breaks down CDSS into the following (Berlin et al., 2006).

2.3.1 The Context

The context drives the knowledge needed for a Clinical Decision Support System. A CDSS is a contextual system. The nature of clinical care provided is the initial step in defining the context of a CDSS. It is critical and needs to be thoroughly described and mapped out (Greenes, 2007c). Indeed, the context is where the CDSS intervenes and supports decision-making.

A thorough understanding and description of the context upstream will help with the implementation and the Support System's design. There are several components to the context. First comes the Clinical Setting. Healthcare can be provided in diverse manners, and each has its own needs and specificities as far as decision support is concerned. An example often shared in the literature is the difference between inpatient and outpatient care.

On the one hand, there is a need for greater coordination between the more significant number of providers (Sutton et al., 2020). On the other, the priority resides in the efficiency of care to provide more outpatient care (Sim et al., 2001). Another component of the CDSS context is the Clinical Tasks that are performed. The clinical tasks are the direct influencer of decision-making support. It could range from drug prescription to surgical intervention, and every position in the spectrum calls for specific clinical tasks and, therefore, particular support needs (Shortliffe & Sepúlveda, 2018).

Then comes the Unit of Optimization, as each Clinical Decision Support System has its way of measuring its successful impact. Reducing medical errors, improving healthcare outcomes, and making the clinical context more efficient remains at the literature's forefront (Kawamoto et al., 2005a).

2.3.2 Knowledge and Data Source

Knowledge is a critical component of all decision-making support systems (Jiang et al., 2017). For CDSS, clinical knowledge is intended to be used by the system to provide support to clinicians. Driven by the context, the clinical knowledge needed can take several forms (Jenders, 2017). Articles can be displayed to clinicians to assist in understating, assessing, and treating a particular clinical condition.

The knowledge is based on the latest medical academic research (Cornick et al., 2018). Also, the CDSS can propose customized guidelines based on the knowledge and the clinical context the provider is exposed to. Some CDSS suggest pathways to clinicians with clinical protocol recommendations (Hashi et al., 2017). Databases can also be considered as knowledge like drug interaction files which are hosted in the CDSS and queried by the clinicians to avoid drug conflicts when entering a prescription (Shen et al., 2018).

CDSS can potentially host multiple data sources. Various data sources can create a holistic system vision to support clinicians depending on the context (Punithavalli et al., 2019). Among others, electronic medical records or EMRs are often associated with CDSS, more so in a hospital or health system context.

In the United States, EMR usage is heavily regulated by health information privacy policies (HIPAA), which illustrates the complexity of integrating a data source into a CDSS (Sutton et al., 2020). Data sources integration requires data governance design to ensure compliance with the policies involved in the CDSS context.

Knowledge and data are often customized in CDSS. In fully integrated systems, the EMR data will be used to customize the knowledge presented to clinicians when caring for a patient so that only the relevant knowledge is displayed based on the patient's medical records (Mahadevaiah et al., 2020).

2.3.3 Decision Support

The output of the CDSS is decision support (Greenes, 2007c). In that sense, CDSS has various methods employed to generate decision support, which can be contextualized knowledge or recommendations. Decision support can be a series of simple rules or more complex algorithms to guide clinicians in the process of providing healthcare (Sutton et al., 2020).

The support could take several forms, from the simple display of knowledge to specific recommendations for care delivery. Some CDSS include an urgency component to the decision support, which is added to the recommendations and provides a timing dimension on when they should be executed (Berlin et al., 2006).

The CDSS has the ability to prioritize the recommendations based on the knowledge component. The decision support can also require interaction from the clinicians and adapt the decision support. Some CDSS vendors propose pathways formed as decision trees, guiding clinicians in a very interactive way (Belard et al., 2017).
Less interactive decision support can take the form of alerts aimed at clinicians to convey passive information guiding care delivery.

2.3.4 Information Delivery

Information delivery refers to the method used to deliver decision support. It is described as the user experience of Clinical Decision Support Systems (Greenes et al., 2018). The format of the delivery sets how the clinician receives the decision support. Different levels of technology involvement are possible.

An uncomputerized CDSS requires clinicians to consult knowledge on paper and cross-reference with the patient's condition to make a clinical decision. While this type of information delivery is not ideal, it is still considered a CDSS. A low-technology decision support system is more efficient in some contexts, like in developing countries (Guo & Li, 2018).

High-technology clinical environments require complex and heavily customized information delivery. Some scenarios require system integration with multiple information systems involved in the delivery of care. The delivery of the decision support happens on a different system than the one where the support is generated (Mahadevaiah et al., 2020).

2.3.5 Workflow

The workflow is the framework in which clinical decision support is offered to clinicians. It is a step-by-step events sequence that results in the CDSS generating decision support and applying it to deliver care (McCoy et al., 2015). The workflow itself is composed of all the components of the CDSS and describes each interaction between them, as shown in figure 1.

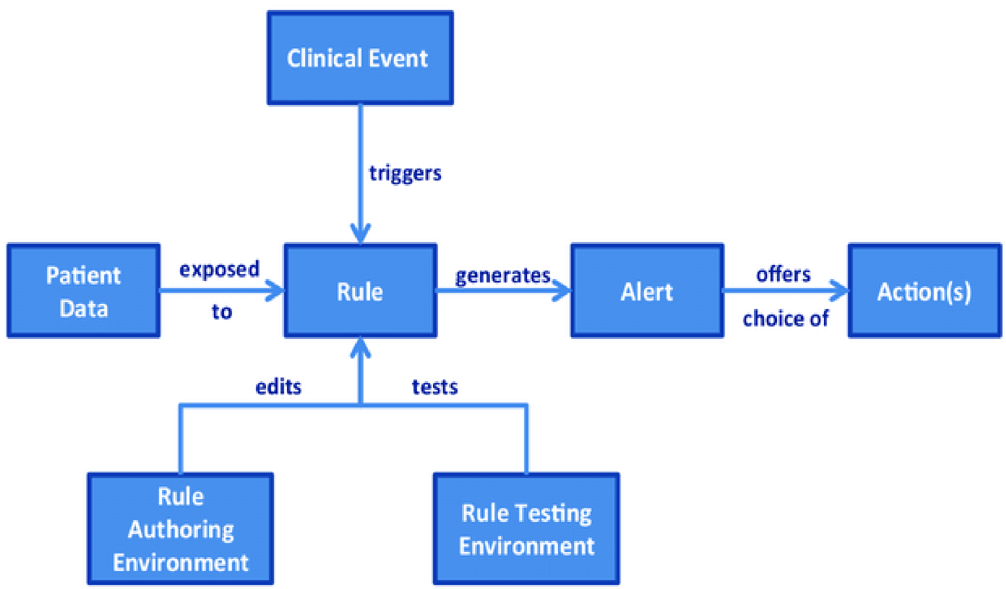

Figure 2 – A Clinical Workflow (McCoy et al., 2015)

2.4 CDSS Implementation Challenges

While a Clinical Decision Support System can seem only to be beneficial to a clinical environment, this is without counting into the equation the implementation challenges. When considering the implementation of a CDSS, some external and internal factors can either jeopardize the purposes of the decision support and create barriers to the delivery of care or preclude the implementation of the CDSS itself (Khairat et al., 2018).

A Clinical Decision Support System comes with a purchase and implementation cost. Financial considerations can definitely be a challenge for an organization considering a CDSS (Sutton et al., 2020). Depending on the technology, the characteristics, and the level of integration, CDSS costs vary. Moreover, while implementing a CDSS, unidentified matters can arise, driving the implementation costs up (Khairat et al., 2018).

Looking at organizational considerations, implementing a CDSS can indeed be challenging when focusing on the workflow. All the components of a medical workflow, given the complexity and sensitivity of medical care, interact in a rigid set of rules (Karsh, 2009). CDSS usually needs the existing workflows to adapt to the CDSS's workflow, and this is where the challenge resides.

Finally, behavioral considerations can also drive challenges in implementing CDSS. Often, to receive decision support or apply recommendations, clinicians need to adapt their ways of practicing and providing care (Catho et al., 2020). The reluctance of practitioners is common and a frequent challenge healthcare companies are reporting when implementing any form of clinical decision support.

2.5 Adoption of General Information Systems

2.5.1 Definition and History of Information Systems

Information Systems collect, process, store, analyze, and disseminate information for a specific purpose (Rainer & Prince, 2021). The purpose of an Information System varies depending on the intent of the organization hosting the system (de la Vara et al., 2008). From being simply informative to being fully embedded in a decision-making process, the Information System's role remains supportive of an organization (O'brien & Marakas, 2006). Information Systems are today crucial and unavoidable in supporting organizations' strategy, operations, and risk mitigation (Rainer & Prince, 2021).

The academic field of Information Systems started in the sixties when it was commonly referred to as Management Information Systems (Davis, 2000). According to Hirschheim and Klein, the history of Information Systems is defined by four eras (Hirschheim & Klein, 2012):

- The first era lasted from the mid-sixties to the mid-seventies. Considered the genesis of the Information Systems academic field, that era focused on studying the added value of Information Systems on organizations' general management and governance. Academic Research focused then on supporting decision-making, defining early frameworks, and assessing the value of Information Systems.

- The second era lasted from the mid-seventies to the mid-eighties. This era continued the focus on the management and governance of organizations with an extra emphasis related to Information Technology. Indeed, that era corresponded to the development of minicomputers and mid-range computers, which enabled Information Systems to a higher efficiency within organizations.
- The third era ranged from the mid-eighties to the mid/late nineties. The Internet was a game-changer in the Information Systems field. It allowed for a significant enhancement to Information Systems: Decentralization. The academia then focused on the questions of building economic performance along with IT productivity while considering the questions around Outsourcing.
- The fourth and last era started in the late nineties and is still the one academia is building on. Revolutionized by Internet democratization, the Information Systems field is now focused on ubiquitous computing. Leveraging the power of Artificial Intelligence or the Internet of Things, scientists are now adapting IS frameworks and challenging organizations to scale up to a knowledge-driven IS.

2.5.2 Adoption of Information Systems

The literature is unequivocal about the Information Systems' positive impact on organizations (de la Vara et al., 2008; O'brien & Marakas, 2006; Rainer & Prince, 2021). However, before enjoying the benefits of a fully efficient Information System, an organization needs to go through the path of adoption (Jackson, 2011). The adoption of Information Systems is not trivial (Rainer & Prince, 2021). There are a significant number of factors that intervene in the process of Information System adoption (Limayem et al., 2003).

Kerimoglu, Basogluy, and Daim suggest at least six impactful factors in the adoption of Information Systems (Kerimoglu et al., 2008). These factors are essential pinpoints that organizations face when addressing Information Systems related evolution.

The first factor is system quality. This point has a significant impact on the efficiency of the Information System. Indeed, the system quality is an assessment of the ability of the IS to connect, to integrate all necessary components for an organization to see an impactful use of the IS (Pitt et al., 1995).

Information Quality is another crucial factor. Also referred to as Data Quality in the literature, this feature assesses IS's ability to convey accurate information between the system's components (Timmerman & Bronselaer, 2019). Certainly, circulating inaccurate information is a scenario that can be detrimental to an organization.

The use and user satisfaction of the Information System also contribute to the general adoption of a given IS. These two are more trivial as, without usage, the Information System has no impact on the organization (Barišić et al., 2019). Therefore, an organization must consider the perceived usefulness, and perceived ease of use of the tentative IS so it can ensure its usage (Chirchir et al., 2019).

The individual impact of an Information System is another significant yet underrated contributor to IS adoption (Legner et al., 2017). An information system is expected to enable individual contributors and system users to grow within the organization in a structural setup (Rainer & Prince, 2021).

Finally, the organizational impact of Information Systems is arguably the essential factor in IS adoption. Indeed, the organization is the initiator and sponsor of the Information System integration; therefore, a clear impact on the organization must be drawn out from the IS project (Almazán et al., 2017). Organizational knowledge is a central measurement unit of the organizational impact of IS (Al-Emran et al., 2018).

2.6 Adoption of Health Information Technology

2.6.1 Definition and Types of Health Information Technology

According to Brailer and Thompson, Health Information Technology is "the application of information processing involving both computer hardware and software that deals with the storage, retrieval, sharing, and use of health care information, health data, and knowledge for communication and decision making" (Thompson & Brailer, 2004).

Health Information Technology comes in different types with different applications within the healthcare industry (Chaudhry et al., 2006). Indeed, three health information technologies stand out as the most flourished literature.

First is the electronic health record (EHR). Gunter and Terry define it as a "systematized collection of patient and population electronically-stored health information in a digital format" (Gunter & Terry, 2005). These records can be shared across different health care settings and providers (Jha et al., 2009). EHRs may include a range of data, including demographics, medical history, medication and allergies, immunization status, laboratory test results, radiology images, vital signs, personal statistics like age and weight, and billing information (Häyrinen et al., 2008).

The second type of HIT arising from the literature is Clinical Decision Support Systems (CDSS). According to Osheroff, CDSS is a “System that provides clinicians, staff, patients, or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and health care” (Osheroff et al., 2007). CDSS is intended to support Clinical Decision-Making.

Finally, the literature focuses on Computerized Physician Order Entry (CPOE). Also referred to as computerized provider order entry or computerized provider order management (CPOM), it is a computer-embedded process that allows physicians to enter medical orders directly (Ash et al., 2003). This HIT facilitates the implementation of the clinical protocol to provide healthcare (Koppel et al., 2005).

2.6.2 Adoption of Health Information Technology

When considering the adoption of Health Information Technology, some external and internal factors can jeopardize its purposes and create barriers to the delivery of care (Khairat et al., 2018).

Financial considerations can definitely be a factor for an organization considering the adoption of Health Information Technology (Sutton et al., 2020). Depending on the technology, the characteristics, and the level of integration, the HIT costs vary. Moreover, while implementing a HIT, unidentified matters can arise, driving the implementation costs up (Khairat et al., 2018).

Looking at organizational considerations, adopting Health Information Technology can be challenging when focusing on the workflow. All the components of a medical workflow, given the complexity and sensitivity of medical care, interact in a rigid set of rules (Karsh, 2009). HIT usually needs the existing workflows to adapt to the HIT's workflow.

Finally, behavioral considerations can also drive the adoption of Health Information Technology. Practitioners' reluctance is a common and frequent challenge that healthcare organizations report when implementing any form of clinical decision support (Catho et al., 2020).

2.7 Adoption of Health Information Technology Assessment

In light of the literature review on Information Systems Adoption and Health Information Technology adoption, we can first draw a relationship between the two fields. Indeed, Health Information Technology can be considered an Information System (Blumenthal, 2011). Therefore the adoption factors and challenges are shared, and all the factors involved in Information Systems are directly or indirectly involved in Health Information Technology adoption (Cresswell et al., 2013).

It is crucial that the assessment of Health Information Technology adoption addresses all the factors presented in the literature above.

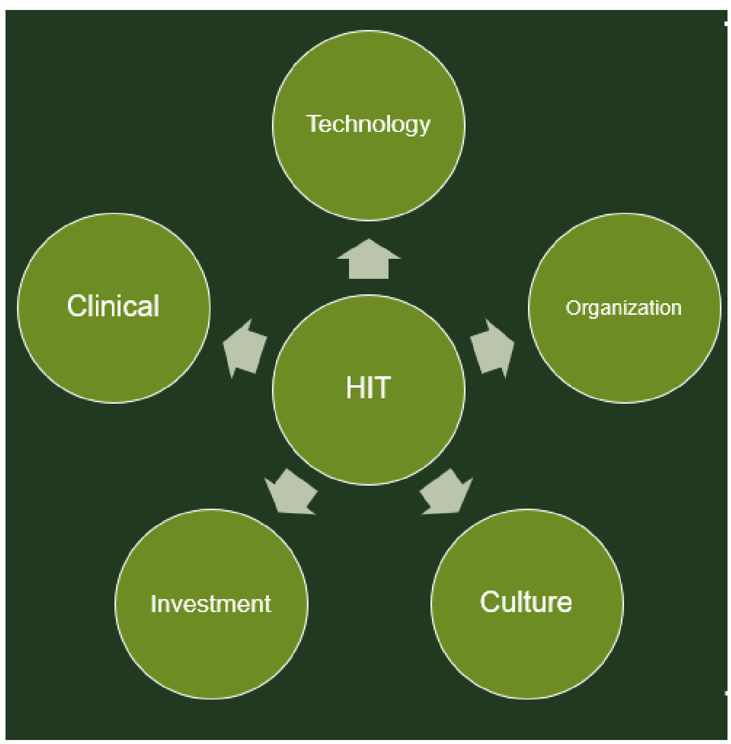

Figure 3 - HIT Adoption Factors

Assessing these factors to ultimately assess the adoption capabilities of a given organization is not trivial (Hogaboam & Daim, 2018). They need to be taken into consideration through a holistic approach (Shaygan, 2021). While the literature presents some models for such an assessment (Kerimoglu et al., 2008), they remain scarce (Shaygan, 2021), especially when it comes to the healthcare industry (Hogaboam & Daim, 2018).

Technology Acceptance Models can be used for that purpose. Davis introduced TAM in the eighties; it uses a mathematical model to extract levels of user acceptance of a system (Silva, 2015). Other theories that derive from TAM are related to behavioral science. It is the case of the Theory of Reasoned Action (Hale et al., 2002) and the Theory of Planned Behavior (Ajzen, 1991). Both focus on the user's behavior to assess the likelihood of technology adoption.

According to the literature, HDM remains a valid tool for the purpose of technology adoption (Shaygan, 2021). The use of desirability curves can help pinpoint the main barrier for a technology to be adopted in a particular environment (Daim & Kocaoglu, 2016). The rankings and scores extracted from the model's quantification can help practitioners assess their technology adoption potential.

However, HDM application for healthcare-related technology adoption matters is still picking up, and more research can be added in that sense (Hogaboam & Daim, 2018).

2.8 Action Research

2.8.1 History and Definition of Action Research

Action Research is seen as an interventionist approach to research (Eikeland, 2012). Rather than a research methodology, it is framed as a research philosophy or research approach (Coghlan, 2011). In Action Research, researchers are seen as full participants in the research setup and are expected to have a transformational impact on the research environment (Chevalier & Buckles, 2019).

The concept of Action Research has first been eluded to in the mid-forties by Kurt Lewin, an American psychologist. He described Action Research as "proceeding in a spiral of steps, each of which is composed of planning, action, and the evaluation of the result of action" (Burnes & Bargal, 2017). At the time, Lewin already had stressed the interventional aspect of Action Research, explaining that the approach "understand and change certain social practices" and that "social scientists have to include practitioners from the real social world in all phases of inquiry" (Burnes & Bargal, 2017).

As noted by Masters, Action Research found grounds mainly in social sciences and particularly in education (Masters, 1995). According to her work, the historical foundations on which Action Research was built are articulated around five schools of thought listed in table 1.

The research approach was used progressively through the 20th century to support these schools of thought. As early as 1904, *The Science of Education Movement*, with the work of RG Boone, introduced research approaches that would later inspire the formalization of Action Research (Boone, 1904; McKernan, 2013).

Later, *The Experimentalist and Progressive educational work* led by John Dewey relied on researchers' intervention and participatory approaches paving the way for Action Research (Miettinen, 2000).

In psychology, the movement of *Group Dynamics,* studying the system of behaviors and psychological processes occurring within a social group or between social groups, has been explicitly named Action Research through the work of Lewin (McKernan, 2013). Scientists related to that movement intended to positively impact the social group or groups which were studied (Lewin, 1947).

Building on Group Dynamics but grounded in education, the Post-war Reconstructionists used Action Research to design education curriculums tackling the complex issues of inter-group relations specifically (Corey, 1954).

The last movement that Masters includes is the *Teacher-Researcher movement*. This movement aimed at grounding teaching in research and believed that teachers should develop curriculums essentially based on research (Stenhouse, 1971). Action Research was critical and helped enable groups where teachers and research in a participatory fashion used research to intervene and impact curriculums (McKernan, 2013).

Research Field	**Research Movement**	**Link to Action Research**	**Period**	**References**
Education	The Science of Education Movement	Using science and research to impact education	Late 19th century, Early 20th century	(Boone, 1904)
Education	Experimentalist and Progressive educational work	Inductive scientific method	Mid 20th century	(Miettinen, 2000)
Psychology	Group Dynamics	The intervention of researchers in group studies	Mid 20th century	(Lewin, 1947)
Education/Psychology	Post-war Reconstructionist Curriculum Development	The intervention of researchers in curriculum development	Mid 20th century	(Corey, 1954)
Education	The teacher-researcher movement	Participation of teachers in the research to develop curriculums	The 70s	(Stenhouse, 1971)

Table 2 - Historical influences on Action Research

There are multiple definitions of Action Research in the literature with different focuses often related to the research field that contextualize the definition or associated with the particular goal of the action research that is intended in the study in question (Jefferson, 2014).

Bob Dick's simplified definition summarizes the aim of Action Research as its name suggests (Dick, 2019).

Action	to bring about change in some community or organization or program
Research	to increase understanding on the part of the researcher or the client, or both (and often some wider community)

Table 3 - Simplified Action Research split

On the one hand, some methodology-related definitions range from focusing on the participatory aspect of the approach to the aim of its related inquiry. On the other hand, some research field-related definitions range from focusing on the roles of participants to the specifics of the action that will resolve the main issues in the area in question is exposed to (Cohen et al., 2017).

Definition Focus	Definition	References
Academic Research	A form of research that generates knowledge claims for the express purpose of taking action to promote social change and social analysis	(Couch, 2004)
Action inquiry	A form of self-reflective inquiry undertaken by participants in social situations in order to improve the rationality, justice, coherence, and satisfactoriness of (a) their own social practices, (b) their understanding of these practices, and (c) the institutions, programs, and ultimately the society in which these practices are carried out	(McTaggart, 1994)
Methodology	A collaborative, transformative approach with a joint focus on rigorous data collection, knowledge generation, reflection, and distinctive action/change elements that pursue a practical solution	(Piggot-Irvine et al., 2015)
Methodology	A problem-solving strategy that encourages academic researchers and community members to work together to: (a) identify and analyze community problems, (b) find solutions to those problems through the best methods of research, and (c)test those solutions in the community	(Rajaram, 2007)
Field related/ Action inquiry	Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework	(Rapoport, 1970)

Table 4 - Action Research Definitions

2.8.2 Types and Characteristics of Action Research

The literature agrees on three types of Action Research (Dick, 2019; Laudonia et al., 2018; Masters, 1995).

First, the Technical Action Research's intent is to solve a problem from a scientific and technical lance. In this vision of Action Research, the scientists and collaborators agree to use a theoretical framework driven by existing and agreed-on science as a foundation for the collaboration and the intervention that the study aims to complete (Condori Fernandez & Lago, 2019). The theoretical framework is taken for granted, and no challenge is being brought against it by the participants (Adaba & Kebebew, 2018). This approach is suited for more technical studies where incontestable scientific truths are a basis for knowledge building (Wieringa & Moralı, 2012).

The second type of Action Research is Practical Action Research, also referred to as Interactive Action Research (Masters, 1995). More flexible than Technical Action Research, this type of Action Research is based on a collaborative approach where researchers and practitioners come together to discuss and interpret the research process of a given study (Prasetyo et al., 2020). The flexibility brings a greater involvement of all the participants in the action aimed by the study because of the active participation in identifying the root cause of the study's problem (Grundy, 1982).

The third and last type of Action Research is referred to as Emancipatory Action Research. This type of Action Research puts the practitioners at the center of the study by responsibilizing them entirely for the significant problems the study aims to address (Ledwith, 2017). That type of Action Research enables more transformative actions by turning participants into advocates for change (Worthen et al., 2019). This last Action Research type drives enhancements to processes and environments engaged in the study(Li & Gong, 2019).

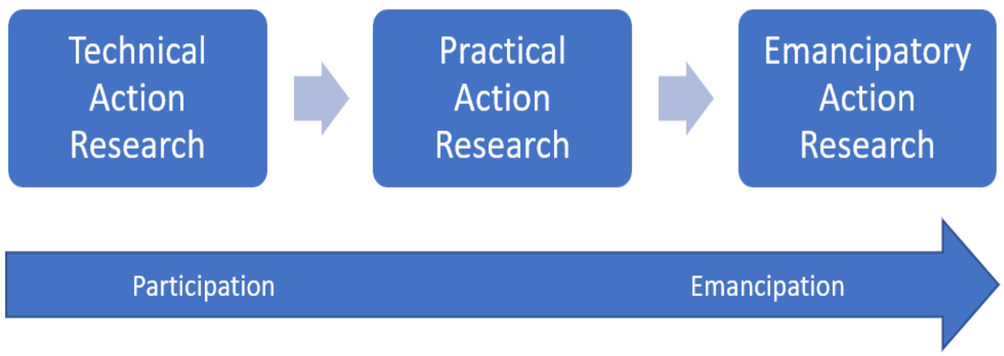

Figure 4 - Types of Action Research (Eilks et al., 2010)

Action research has numerous characteristics that distinguish it from traditional academic research. Through the work of Hult and Lennnung, McKernan, Ferrance, Kemmis, and Cohen, we are able to list the following (Cohen et al., 2017; Ferrance, 2000; Hult & Lennung, 1980; Kemmis et al., 2014; McKernan, 2013):

- Enables practical problem-solving at the same time as expanding scientific knowledge
- It helps participants grow their competencies in their respective fields
- Grants more collaboration time than traditional research
- Is fully participatory
- It takes place directly in the original site and context of the study
- Uses a cyclical data-driven feedback process
- It is undertaken within an agreed framework of ethics
- It aims to improve the quality of human intervention
- Prioritizes problems based on objective, practical, and immediate need
- It is an approach, a philosophy, and therefore it is methodologically diverse
- Strives to be emancipatory.

2.8.3 Incorporating Action Research

In light of this literature review on Action Research, I can see the added value of such a research approach to a Research Process. Indeed, the added value is grounded in the theoretical nature of Action Research and its practical contribution to the particular field and case study to which I aim to apply my model.

From a theoretical standpoint, as the literature review stresses above, Action Research aims to produce a change in the study's site, such as an organization. When putting my own research goal into perspective, which is *to develop a model that will help healthcare organizations identify the challenges of implementing Clinical Decision Support Systems and assess their readiness for such an implementation in a comprehensive and multi-dimensional manner*, Action Research could be a catalyst to help practitioners intervene within their organization to dig out the challenges they are facing and to build a greater understanding. Another theoretical aspect inherent to Action Research is the collaboration between researchers and practitioners in a participatory fashion. This collaboration could only be beneficial, as the literature suggests, thanks to the responsibilization of the practitioners, making them advocates for the cause of the study.

Practically, Action Research applied to my research goal can contribute significantly. Clinical Decision Support Systems (CDSS) remain a highly customizable decision support tool, and the more customized, the easier the adoption of the system (Khong et al., 2015). The emancipatory aspect of Action Research can be key here as the practitioners, while taking action on the finding of the challenge for a successful implementation of CDSS, can be proactive on the customization needs of their organization by defining or at least discussing CDSS customization potential.

Now Action Research has already been enabled within an HDM research process by Lavoie and Daim (Lavoie & Daim, 2020). Daim and Lavoi proposed an "Action Research enhanced HDM" approach in their research. Their framework added Action Research as an input to the construction of the HDM on top of the Literature Review:

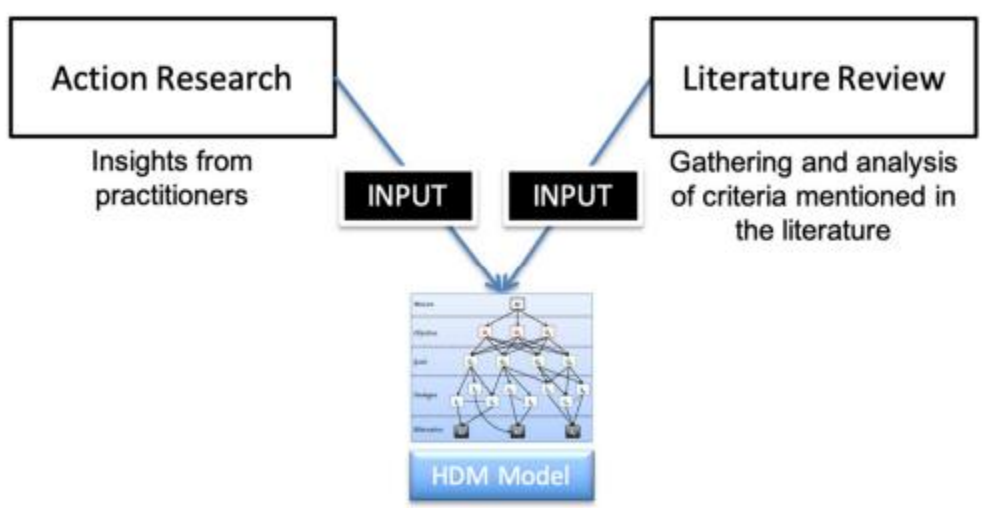

Figure 5 - Action Research input to HDM Model (Lavoie & Daim, 2020)

In light of my literature review on Action Research and the work of Lavoie Daim, I believe that my research could be adding to theirs by integrating Action Research as an input to my HDM model. However, I would attempt to adapt the approach of Lavoie and Daim to integrate an extra characteristic of Action Research, the cyclical feedback process, in the sense where data I could submit the initial Literature Review's findings to the Action Research participants and allow at least two rounds of participatory feedback before finalizing the input for the HDM model:

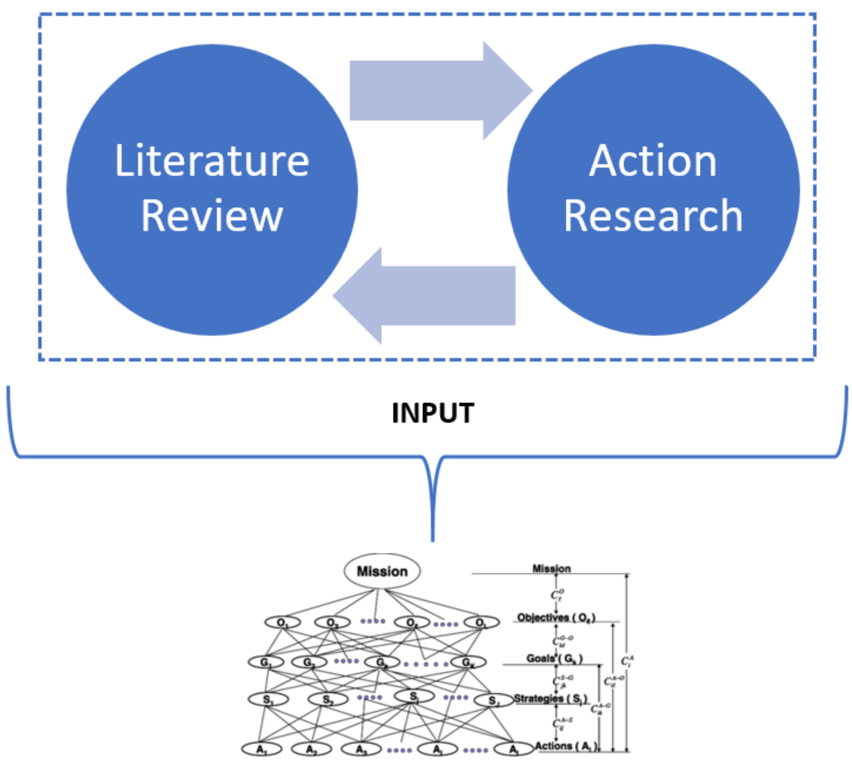

Figure 6 - Proposed incorporation of Action Research in my process

Participants will be given an initial literature review summary, especially regarding the challenges of implementing CDSS in healthcare organizations. They will be given the opportunity to appraise the literature review and its adequacy to their own organization with direction to potentially add an extra round of literature review more specific this time. I would propose allowing for at least one round of feedback, maybe two.

CHAPTER 3 – GAP ANALYSIS

While the literature remains consensual on the purposes of Clinical Decision Support Systems, the characteristics are driving multiple forms of Clinical Support Systems. Indeed, improving the healthcare outcome for patients, building a more efficient healthcare delivery, and reducing unwanted care variability and medical errors are absolute priorities making the purpose of CDSS.

However, when looking at the different characteristics of CDSS, the literature confirms their heterogeneity. All the possible combinations of technologies, integration levels, workflows, and clinical knowledge make clinical decision support a significant endeavor. It becomes apparent that any organization considering CDSS needs to thoroughly assess its clinical workflow needs and beyond.

Based on the literature review section findings, research gaps and questions can be raised focusing on the essential goal of assessing the readiness of organizations to implement CDSS. Indeed, the challenges brought by the implementation are critical, and if not considered the proper way, the CDSS's purposes can easily be jeopardized. A possible path for the assessment is to use a model that has the ability to consider all the dimensions where the challenges arise.

3.1 Research Gaps

- **RG1**: Research around Clinical Decision Support Systems implementation challenges is scarce. As framed in the literature review section, the focus of the literature is first on defining CDSS, their purpose, and their post-implementation impact. There is an apparent lack of studies focusing on the hurdles that healthcare organizations encounter during the implementation of CDSS.
- **RG2**: No multi-dimensional, comprehensive model has been used or developed for the specific assessment of organizations' readiness to implement CDSS. The systemization of clinical decision support requires a comprehensive review of the organization from multiple perspectives. As framed in the Characteristics section of the literature review, CDSS involves very diverse components of the organization, from the clinical context to the technological setups.
- **RG3**: No studies have focused on the impact of the organizations' readiness to implement CDSS on the success of the CDSS implementation. While the literature shows interest in the effect of CDSS on clinical outcomes and processes, very limited studies have looked at how readiness for implementation could actually impact the CDSS implementation process on patients, providers, and healthcare organizations.

3.2 Research Goal

During this research, I aim to develop a model that will help healthcare organizations identify the challenges of implementing Clinical Decision Support Systems and assess their readiness for such an implementation. Using a comprehensive and multi-dimensional approach, the model will focus on the relevant, challenge-generating perspectives and look for the organization's particular area that we need to evaluate to ensure a successful and beneficial implementation of Clinical Decision Support Systems.

3.3 Research Questions

- **RQ1**: What are the main challenges for implementing CDSS in healthcare organizations, and how do these challenges interact?
- **RQ2**: What are the different perspectives and criteria under which we can classify the challenges to build a comprehensive view for the successful implementation of CDSS?
- **RQ3**: What are the most impactful pinpoints an organization should address when considering the implementation of a CDSS?

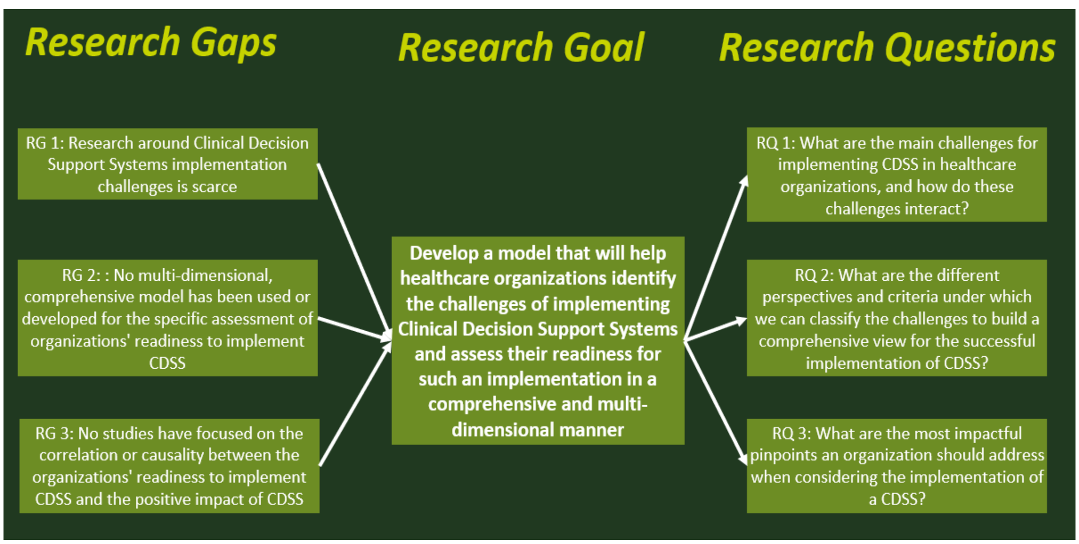

Figure 7 - Research Gaps, Goal and Questions

CHAPTER 4 - METHODOLOGY

4.1 The Hierarchical Decision Model (HDM)

4.1.1 Overview of HDM

The Hierarchical Decision Model is a derivative of the Analytic Hierarchy Process technique. It was first introduced to the literature in the early 80s by Kocaoglu (Kocaoglu, 1983). Analytic Hierarchy Processes bring us models and methods when decisions must be made in an uncertain environment harmonizing between several dimensions and perspectives (Daim & Kocaoglu, 2016). Applications of these tools to a non-exclusively technological issue could seem a bit misplaced. However, the literature suggests that organizational management has strong similarities with technology management. The uncertainty and the multi-dimension inputs and outputs are characteristics that both fields share. Decision-makers on both sides have been using similar methodologies to support their challenges. Moreover, Clinical Decisions Support System implementations carry a significant technological component.

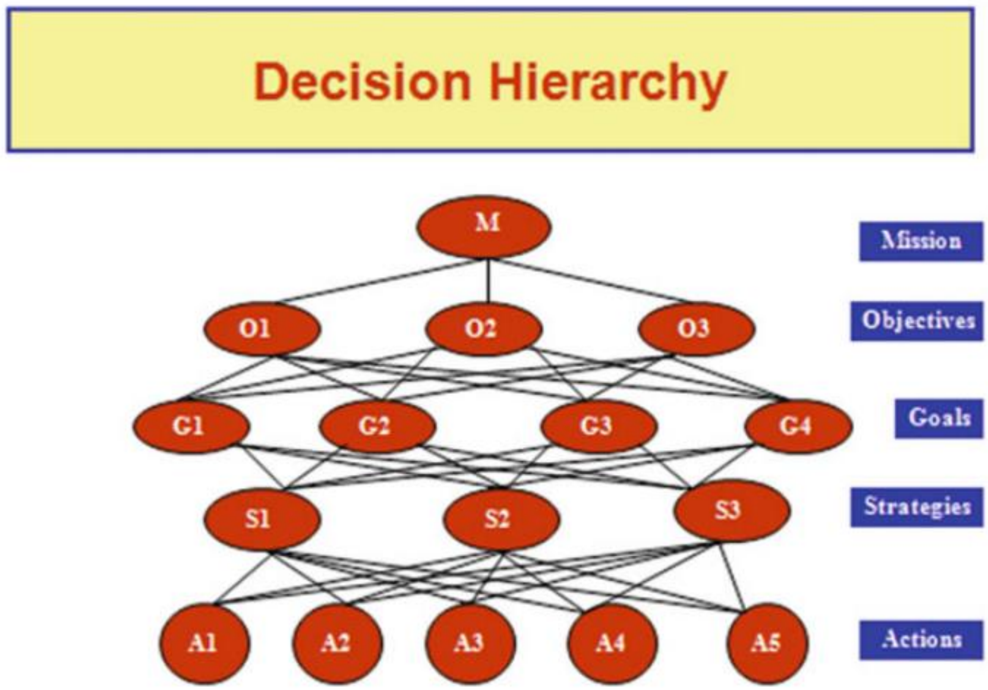

Figure 8 - An HDM example (Daim & Kocaoglu, 2016)

The Hierarchical Decision Model breaks a mission or decision into a multi-level set of components and decisions. Figure 4 presents an HDM where a mission is broken into objectives, goals, and strategies that will all influence the action that will be picked. The usual levels are Perspectives, Criteria, and Sub-Criteria (Daim & Kocaoglu, 2016).

Once the model is defined, it needs the input of subject matter experts who submit their subjective judgments on the different layers of the model's hierarchy using a pair-wise comparison approach. At each level, the SMEs are in charge of weighing the components of the model against each other. The model then computes the judgments following the mathematical logic (Kocaoglu, 1983):

$$\boldsymbol{M} = \sum_{k=1}^{K} \sum_{jk=1}^{JK} \boldsymbol{P}_k \times \boldsymbol{C}_{jk} \times \boldsymbol{D}_{jk}$$

Where M= Maturity Score, K=Number of Perspectives, J= Number of Criteria, Pk= Weight of Perspective, Cjk= Relative importance of criterion (jth) for Perspective (kth), and D(jk)= Desirability value of criterion (jth) for Perspective (kth)

We can note the presence of a Desirability value in the formula. When a model is intended for several usages, e.g., to answer a particular organizational question in multiple organizations, desirability curves can be added to the process. They quantify the desired levels for each criterion to serve the general mission of the model. In this approach, the subject matter experts are asked to evaluate the current standing of the criteria as they relate to the model's mission.

Tying back the methodology to the research goal, it is essential to note that the HDM approach has been successfully used in multiple healthcare-related contexts. Indeed, numerous research projects applied HDM to healthcare-related objectives, from healthcare devices identification to healthcare technologies assessments (Alanazi et al., 2015; Hogaboam et al., 2014; Sheikh et al., 2016).

4.1.2 Strengths of HDM

First, HDM being a Multi-Criteria Decision methodology, allows us to address an issue from a holistic standpoint (Kocaoglu, 1983). Indeed, when using HDM, researchers are able to consider all the perspectives factoring into the mission of the model (Daim & Kocaoglu, 2016). That way, organizations and research centers can be guaranteed performant decision support (Hogaboam et al., 2014).

While the experts' input to the HDM model remains qualitative, the model computes it quantitatively, allowing for a more robust analysis of the expertise (Alzahrani, 2021). That specificity of the methodology is a strong advocate of its applicability to industries and has been a significant strength raised by decision-makers (Shaygan, 2021).

Staying on the tool’s specificities, HDM allows for a solid mathematical analysis of the sources of the variation in the quantitative results (Lavoie & Daim, 2020). With the ability to quantify the inconsistencies and disagreement between experts, the methodology allows for its autocritique, a definite strength from a practitioner's standpoint (H. Chen & Kocaoglu, 2008).

From a human perspective, it is essential to note that HDM has the capability to bring together a diverse group of experts, a definite advantage when considering complex decision-making problems (Alzahrani, 2021).

HDM also has the benefit of being easy to use from the expert's point of view (Sheikh et al., 2016). The pairwise comparisons are easy to explain and generally don't get any resistance from the participants in the model quantification (Daim & Kocaoglu, 2016).

Category	**Strength**	**References**
Method/Tool	A holistic approach to address the research goals	(Daim & Kocaoglu, 2016; Kocaoglu, 1983)
Method/Tool	Transforming a qualitative judgment into quantitative scores	(Alzahrani, 2021; Shaygan, 2021)
Method/Tool	Robust source of variation assessment with inconsistencies and disagreement quantification	(H. Chen & Kocaoglu, 2008; Daim & Kocaoglu, 2016)
Human/Experts	Allows for adequate expertise to be brought together despite diversity	(Alzahrani, 2021)
Human/Experts	The pairwise comparison allows for ease of use that is appreciated by experts.	(Daim & Kocaoglu, 2016; Sheikh et al., 2016)

Table 5 - Strengths of the HDM Methodology

4.1.3 Weaknesses of HDM

HDM, like any methodology, presents its own weaknesses (Daim & Kocaoglu, 2016). First, from a tool standpoint, the same HDM model can produce diverse outcomes, and therefore, the consensus among researchers and practitioners can be challenged (Alzahrani, 2021).

Also, it is important to note that HDM does not help practitioners directly with complex decisions (Kocaoglu, 1983). It contributes to clarifying the decision-making system in which the practitioners need to evolve (Daim & Kocaoglu, 2016). That is why desirability curves are often used as the lowest level of the model (Shaygan, 2021).

Obviously, as the HDM model allows for the quantification of disagreement inconsistencies among experts, one of its weaknesses is that these variations can reach levels where the model result is challenging (H. Chen & Kocaoglu, 2008). Beyond a certain level, the HDM results are not accepted (Kocaoglu, 1983).

When building an HDM model, the researchers and practitioners can be tempted to multiply the number of perspectives, factors, and criteria (Hogaboam et al., 2014). However, complexifying the model goes against its purpose. It can drive difficulties in the quantification phase (Daim & Kocaoglu, 2016).

Finally, the experts' panel selection can be a complicated endeavor, from the identification of the experts to convincing them to participate in a study (Barham & Daim, 2020).

Category	Weaknesses	References
Method/Tool	Diverse outcomes are possible using the same model	(Alzahrani, 2021; Daim & Kocaoglu, 2016)
Method/Tool	No decision but a decision-making support	(Daim & Kocaoglu, 2016; Kocaoglu, 1983)
Method/Tool	Risk of high inconsistencies and disagreement	(H. Chen & Kocaoglu, 2008)
Method/Tool	A high number of factors and criteria can be counterproductive	(Hogaboam et al., 2014)
Human/Experts	Difficulties in expert panel selections	(Barham & Daim, 2020)

Table 6 - Weaknesses of the HDM Methodology

4.2 Other Multi-Criteria Decision Approaches

Multi-Criteria Decision Making (MCDM) or Multi-Criteria Decision Analysis (MCDA) belongs to the academic family of Operation Research. This approach allows for the holistic study of a given problem. Since the genesis of the approach in the seventies (Zionts, 1979), multiple tools have been developed to support it. HDM, as described above, is part of these tools. It is not the only one. Here is a list of other tools that can be used to implement a Multi-Criteria Decision Analysis:

- TOPSIS: Technique for Order of Preference by Similarity to Ideal Solution. Developed by Ching-Lai Hwang and Yoon in the early eighties (Lai et al., 1994), it belongs to the Goal Programming category of MCDM tools. In that sense, TOPSIS considers a preferred alternative that will allow the model to reach the expected levels of outcomes. Inclusion or exclusion of alternatives can happen by hard cut-offs.
- PROMETHEE: Preference Ranking Organization METHod for Enrichment of Evaluations. Initially developed by Brans in the eighties (Brans et al., 1986), this MCDM tool relies on the outranking approach where alternatives are compared to each other under the lance of a given criterion. After weighing the criteria, the outranking approach is applied, which allows for the PROMETHEE's quantification. A sensitivity analysis is performed before the final decision can be made.

- AHP: Analytic Hierarchy Process. Developed by Saaty in the seventies (Saaty, 1988), AHP belongs to the group of value measurement approaches. It is founded on the principle of averaging the weights of the criteria and consolidating these through mathematical normalization. The weights are introduced by pairwise comparison. The results of the normalization provide a hierarchy used in the decision-making process.
- ANP: Analytic Network Process. Also developed by Saaty (Saaty & Vargas, 2013), ANP is the result of an attempt to generalize AHP. It is also a value measurement approach and is a result of the challenging hierarchy that AHP introduced. Saaty argues that not all decision-making systems can be looked at from a linear standpoint, and therefore, ANP brings the ability to have a network of components that can be quantified.
- HDM: Hierarchical Decision Model. Introduced in the early 80s by Kocaoglu (Kocaoglu, 1983), it is also a value measurement approach. HDM breaks a mission or decision into a multi-level set of components and decisions. The quantification happens by pairwise comparison from the experts. HDM also provides a quantification of the variation sources like inconsistencies or disagreement.
- ELECTRE: ELimination Et Choix Traduisant la REalité. Initially developed by Roy in the mid-sixties (Figueira et al., 2016), the tool relies on the outranking approach and has gone through four incremental enhancements to reach the ELECTRE IV version. A performance level is set in advance; ELECTRE will then use its

computerized power to rank a set of actions and enable the practitioners to pick the closest action to the performance level.

- MAUT: Multi-Attribute Utility Theory. Developed by Keeney and Raiffa in the nineties (Dyer, 2005) and is also part of the value measurement approach. It enables participants to score each possible alternative. The alternative with the highest score is considered to be preferred. Once the preference is set, the lower levels of the mode; are quantified, and a ranking is proposed in that sense.

Category	Approach	Strengths	Weaknesses	References
Value Measurement	AHP	- Hierarchical structure easing the understanding - Pairwise comparison driving ease of use	-Inconsistencies threaten the results - The higher the number of model components, the more complex the quantification process	(Saaty, 1988; Saaty & Vargas, 2013)
Value Measurement	ANP	- The network structure allows for more flexibility within the model - Ability to address more complex decision-making systems	- The ease of use can be altered - No variation quantification is possible	(Saaty, 1988; Saaty & Vargas, 2013)
Value Measurement	HDM	- Similar strengths that AHP and ANP - Robust source of variation assessment with inconsistencies and disagreement quantification	- Similar weaknesses that AHP and ANP - Diverse outcomes are possible using the same model	(Daim & Kocaoglu, 2016; Kocaoglu, 1983)
Value Measurement	MAUT	- Preference can be given to an alternative - Ability to account for uncertainty	- does not scale up within complex decision-making systems	(Dyer, 2005)
Outranking	ELECTRE	- Alternatives are ranked pre quantification - Ability to account for uncertainty	- Incremental enhancement attests to the complexity	(Figueira et al., 2016)
Outranking	PROMETHEE	- Transforming a qualitative judgment into quantitative scores - Less time-consuming than other tools	- does not scale up within complex decision-making systems - Does not account for uncertainty	(Brans et al., 1986)
Goal programming	TOPSIS	- Easy to use - Actions are programmed in advance through goals	- Does not account for uncertainty	(Lai et al., 1994)

Table 7 - Strengths and Weaknesses of MCDM Methods

4.3 Other Methodologies

4.3.1 Fuzzy Cognitive Maps (FCM)

Developed during the eighties by Kosko, this methodology combines the property of fuzzy logic and neural networks. It brings a unique mixed-method between the qualitative side of capturing human logical thinking in mental model maps and the quantitative capabilities of running scenarios and studying the behaviors of the captured mental models (Jetter, 2006; Kosko, 1986).

Fuzzy cognitive maps are composed of concepts that are linked. The linkages are also weighted. The aggregate composes a Map that represents the logical thinking eco-system of a group or an individual. Hence, this methodology allows capturing such a logical thinking eco-system to understand the decision-making process.

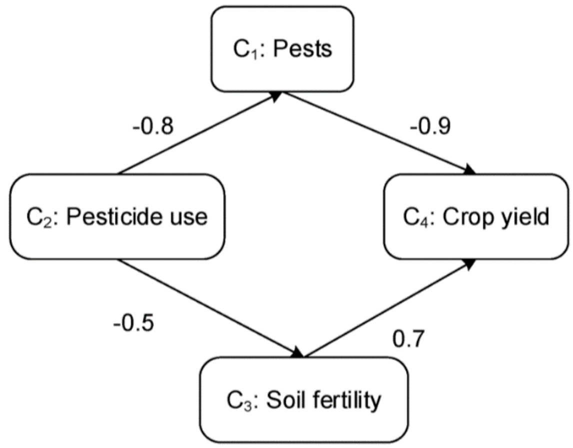

Figure 9 - A Fuzzy Cognitive Map (Mourhir et al., 2017)

The strength of this methodology resides in its ability to create comprehensive maps that will illustrate the dynamics within decision-making systems. These comprehensive maps are inherently generalizable; when a map is finalized, it could be used for other decisions within the same system.

The weaknesses of FCM are mainly related to the practicalities of implementation. A high level of involvement is requested from all the participants as a multitude of participatory sessions are required to finalize the mapping process.

4.3.2 Delphi

The Delphi method was developed at the beginning of the Cold War to forecast the impact of technology on warfare (Custer et al., 1999). It relies on the principle that decisions and forecasts are systematically more efficient if arising from a group. Often referred to as the Delphi Technique, it consists of two or more rounds of questionnaires that are submitted to participants. The experts confront their own choices between each round. The choices are then anonymously presented by a change agent.

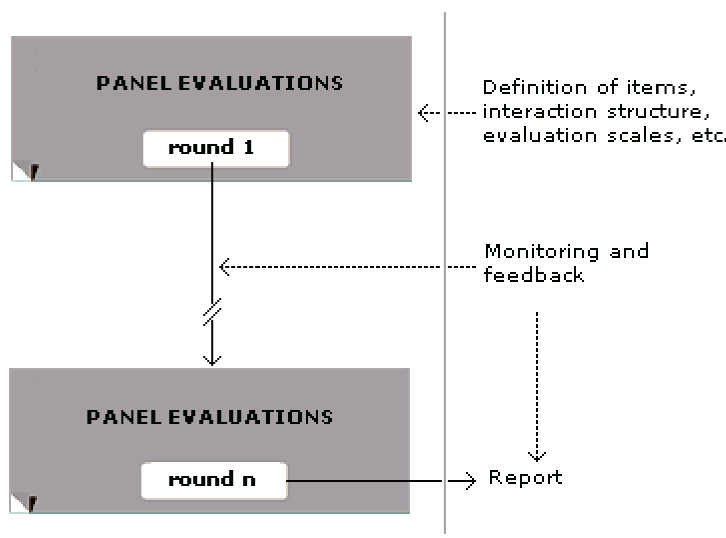

Figure 10 - The Delphi Technique Process (Goodman, 1987)

Thanks to its strong validity in management fields, the Delphi technique seems to be widely adopted in many studies (Tran & Daim, 2008). It is often combined with a quantitative methodology to compute the technique’s feedback.

A recognized strength of this methodology is the ability to bring together a large number of experts to create a strong collaboration around problem-solving. It allows decision-makers to gather despite their diversity and productively confront the point of view. Another strength is the undeniable ease of implementation. Questionnaires are easy to submit, and a multitude of tools are available to facilitate this part.

The weaknesses of this methodology are initially related to the qualitative grounds of the results it can produce. Indeed, Delphi has no quantitative abilities. Also, the technique often introduces a bias as top experts tend to give the most positive assessments to the problems (Tichy, 2004).

4.4 Methodology Justification

In light of the methodology-related literature review, the Hierarchical Decision Model is comforted as a preferred method to complete this research. The justification advanced in that sense will be split into three parts. The first one is related to the particular research topic I am proposing to pursue. The second is driven by the HDM methodology a how it compares to the others. That last one will be related to more of a personal aspect and ease of implementation.

As eluded to in my topic-specific literature review, Clinical Decision Support Systems are at the intersection of Information Systems and Information Technology. That fact on its own requires any attempt to address CDSS within a complex decision-making system to do so in a holistic way. Indeed, IS and IT adoption implicates very diverse factors and encounters significant challenges that we can only overcome when applying a multi-perspective approach to the decision-making system we involve in.

Furthermore, the healthcare industry brings additional points to this argument. Indeed, Clinical Decision Support Systems are complex to implement within healthcare organizations and rely on stakeholders' ability to step back and look at their environments in a holistic manner.

So far, HDM being an MCDM tool, allows for this comprehensive vision that will allow me to propose a model to assess the readiness for CDSS implementation.

From a methodology standpoint, HDM, compared to other MCDM tools, stands out as sharing most of the strengths except the ability to introduce preferences like other outranking or goal programming tools. However, considering the particularities of my proposed topic and its complexity, I believe these approaches would not be appropriate. Healthcare organizations are home to a very diverse stakeholder population; achieving a consensus on a preferred alternative before the quantification is challenging and maybe impossible. Therefore, HDM remains an appropriate tool in light of the analysis complete above.

Finally, to address the personal aspect of my decision, which I believe to be a valid justification, I would like to stress my own experience and competence as a Ph.D. student as well as the resources I have access to. Indeed, I have been exposed to HDM since my enrollment in the ETM department of Portland State University in 2016. I have used HDM in multiple fashions through the years and have learned how to perform research with this methodology adequately. Moreover, as a student of the ETM department, I have access to an open-source HDM web interface tool. That same tool happens to be very robust and easy to access. Also, between my advising faculty and fellow students, I have access to a sufficient set of resources to help me through the journey of HDM implementation. This is a very pragmatical yet substantial justification of my methodology.

4.5 Forming an expert panel

Experts are crucial participants in an HDM model implementation. Their role is to provide the initial input that will allow the model computation and output data production. Therefore, HDM is still a qualitative-based model, and that characteristic raises the utmost importance of experts and expert panels in this approach. Forming expert panels should not be looked at lightly and should be conducted very thoroughly. Hence, the researcher should be aware of all the critical issues in forming an expert panel and selecting the experts.

First comes the expertise definition. Experts are identified by having, involving, or displaying special skills or knowledge derived from training or experience (Merriam-Webster definition). Building on this dictionary definition, the researcher needs to define the particular set of skills or knowledge related to the research questions. This is the first critical issue in selecting and forming expert panels (Shaygan, 2021). Certainly, the literature review will help narrow down the topic and, therefore, the knowledge that will best serve the purpose of the research.

Then comes the identification and selection of the experts. Once the knowledge is thoroughly framed, the research can use different methodologies to identify and select experts. One of the methods is Social Network Analysis (SNA). Combined with bibliometrics, SNA can leverage the academic literature to link different research through topic matching or citation matching. Another method is the use of personal connections. Between the two methods, there is obviously a difference in the complexity of implementation, but also the difference in efficiency. Ultimately, identifying experts remains a critical challenge in forming expert panels.

Another challenge in forming expert panels is the panel size. The literature counts extensive contributions toward the question of the optimal size of an expert panel (Daim & Kocaoglu, 2016; Shaygan, 2021). An expert panel with only a few experts can be challenged on its reliability, while an expert panel with a large number of experts can increase the source of variations of an HDM model (Alzahrani, 2021). Ultimately, a size of 6 to 12 experts panels has arisen as the ideal for technology management studies (Shaygan, 2021).

Finally, bias can be a challenging issue in forming an expert panel. Indeed, when evolving in a panel, experts can express cognitive biases that can impact the reliability of their quantification of the model. Some of the well-documented biases are related to overconfidence (Shaygan, 2021) which results in “loud voice” experts as well as “silent bystander” experts. That can compromise the efficiency of the panel in completing the research tasks (Alzahrani, 2021). Also, HDM has embedded mitigation of biases by its anonymous judgments. However, that is not preventing all kinds of biases, as personal interests can potentially harm the objectivity of an expert assessment.

4.6 Inconsistencies in Expert Judgments

When weighing an HDM model, experts can express a judgment that contradicts their own previous judgment. This inconsistency is driven by the expert's behavior variance when quantifying the HDM model. HDM accounts for this inconsistency to validate the robustness of the model's results.

The inconsistency in HDM is calculated using the sum of standard deviations. For n elements of pairwise comparison, n! vectors are created using the constant sum calculation (s1, s2…, sn). It is mathematically represented by the standard deviation between the values calculated in the n! combinations (Daim & Kocaoglu, 2016; Hogaboam & Daim, 2018; Kocaoglu, 1983):

$$\text{Inconsistency} = \frac{1}{\mathrm{n}}\sum_{i=1}^{n}\sqrt{\frac{1}{\mathrm{n!}}\sum_{j=1}^{n!}\left(\mathrm{C}_{\bar{\mathrm{I}}} - \mathrm{C}_{\mathrm{ij}}\right)^{2}\alpha}$$

The acceptable threshold for inconsistency in HDM has been identified as 10% (Kocaoglu, 1983). In case the inconsistency of an expert goes beyond the threshold, actions can be taken to correct it. The researcher could ask the expert to re-quantify the model after having a conversation about the importance of consistency.

Another measure that can be taken is to delete the expert's judgment from the model. That way, this inconsistent judgment will not corrupt the overall quantification of the model. A mathematical way of mitigating the inconsistencies was introduced by Abbas and Kocaoglu, with the idea that inconsistency should be based on the criticality of the decision (Abbas & Kocaoglu, 2016). This method uses the root sum of variances by considering the number of pairwise comparisons made by the expert.

4.7 Disagreement among Expert Judgments

Another crucial aspect of HDM validation is the quantification of the disagreement between the experts. A disagreement happens when no consensual judgment is found between experts for a given question (Daim & Kocaoglu, 2016). Disagreement is expected among experts. It is completely natural in a panel to have conflicting points of view. However, the validity of the model relies on a general agreement about the problem studied. That is why, similarly to inconsistencies, a threshold should be introduced.

They are multiple mathematical methods to calculate the disagreement. First, the Hierarchical Agglomerative Clustering (HAC), developed by Kocaoglu, introduced the disagreement index for the m experts can be obtained by calculating the average of the standard deviations of "n" decision variables (Kocaoglu, 1983).

$$\text{Disagreement Index} = \frac{1}{\text{m}}\sum_{i=1}^{n} Stdv_i$$

The Intraclass Correlation Coefficient (ICC) and the F-Test are two other mathematical methods that can be used to calculate the disagreement. ICC calculates the degree of disagreement among experts for a relative number of elements, while the F-test is used to compare the ratio of two variances and tests that there is no correlation between the values through a null hypothesis.

The threshold of disagreement has been set in the literature at 10%, similar to the inconsistencies threshold (H. Chen & Kocaoglu, 2008; Daim & Kocaoglu, 2016; Kocaoglu, 1983).

When the disagreement spikes above the 10% threshold, several mitigation approaches can be used. When the disagreement is grounded in valid experts' concerns, and when a re-quantification is possible, the idea is to share the disagreement within the panel using a methodology similar to the Delphi Technique. The expectation is that disagreement can be reduced through the second quantification. The Hierarchical Clustering Method (HCM) can also be used as a mathematical mitigation method to obtain homogeneous clusters of cases based on measured characteristics (Daim & Kocaoglu, 2016).

4.8 Sensitivity Analysis of HDM

Sensitivity Analysis is a mathematical method used to analyze the impacts of potential changes in the values of HDM quantifications at any level. In a world where technology changes rapidly, it is imperative to assess our models' robustness over time and, therefore, over changes. This allows us to sense how much our model depends on its inputs (Shaygan, 2021).

In my application, Sensitivity Analysis will be crucial. Indeed, the readiness to implement Clinical Decision Support Systems is an organizational challenge, and the ability to do SA allows the organization to adapt to the changes. This would have tremendous value in generalizing my research model.

Mathematical models are available to assess a model's potential for sensitivity, the operating point sensitivity coefficient (OPSC), and the total sensitivity coefficient (TSC) (H. Chen & Kocaoglu, 2008). These methods determine the allowance of perturbation induced on each element without any impact on the original ranking based on the readiness score, meaning that the rankings from the readiness score will not change as long as the values of the perturbations remain within the allowable range of values (Alzahrani, 2021).

4.9 Generalization of my Research Model

Generalizing my model is a core objective of my research. Indeed, the successful application of an HDM model to assess the readiness of healthcare organizations to implement Clinical Decision Support Systems is particularly reliant on its ability to be generalized. Considering my intent to propose a hybrid application of my model to both CDSS vendors and CDSS implementation candidates, generalization is my only way to succeed.

The questions in the section have been particularly helpful in addressing the generalization question and how to increase the ability to generalize my proposed model.

First, let's consider the experts-related generalization potential. In addressing the issue related to selecting experts for my model, we went through the crucial part of identifying the proper knowledge and suitable level of knowledge needed for my research goals. Assuring a panel with renowned experts globally respected for their proficiency in their domains guarantees the ability to generalize the model. Therefore, the selection of experts becomes more crucial.

Then comes the model validation. After going through the inconsistencies and disagreement analysis, it is important to note that the lack of or low validity of a model automatically means the end of the generalization possibilities. Mitigating these variations is, therefore, really important as a generalizable model is a highly validated one.

Finally, we consider the sensitivity of a model in its ability to be generalized. As analyzed earlier, the sensitivity analysis allows us to see how the model handles changes in input values. Change is precisely what can be expected when generalizing a model. Applying a model from one organization to the other will implicate changes to some value. Therefore, to be generalizable, our model needs to handle the changes within the acceptable sensitivity threshold.

CHAPTER 5 – RESEARCH FRAMEWORK AND INITIAL MODEL

5.1 Research Framework

Through the previous sections and the efforts made during the research journey, the following a priori theoretical framework has been developed. The framework in question will guide and structure the research.

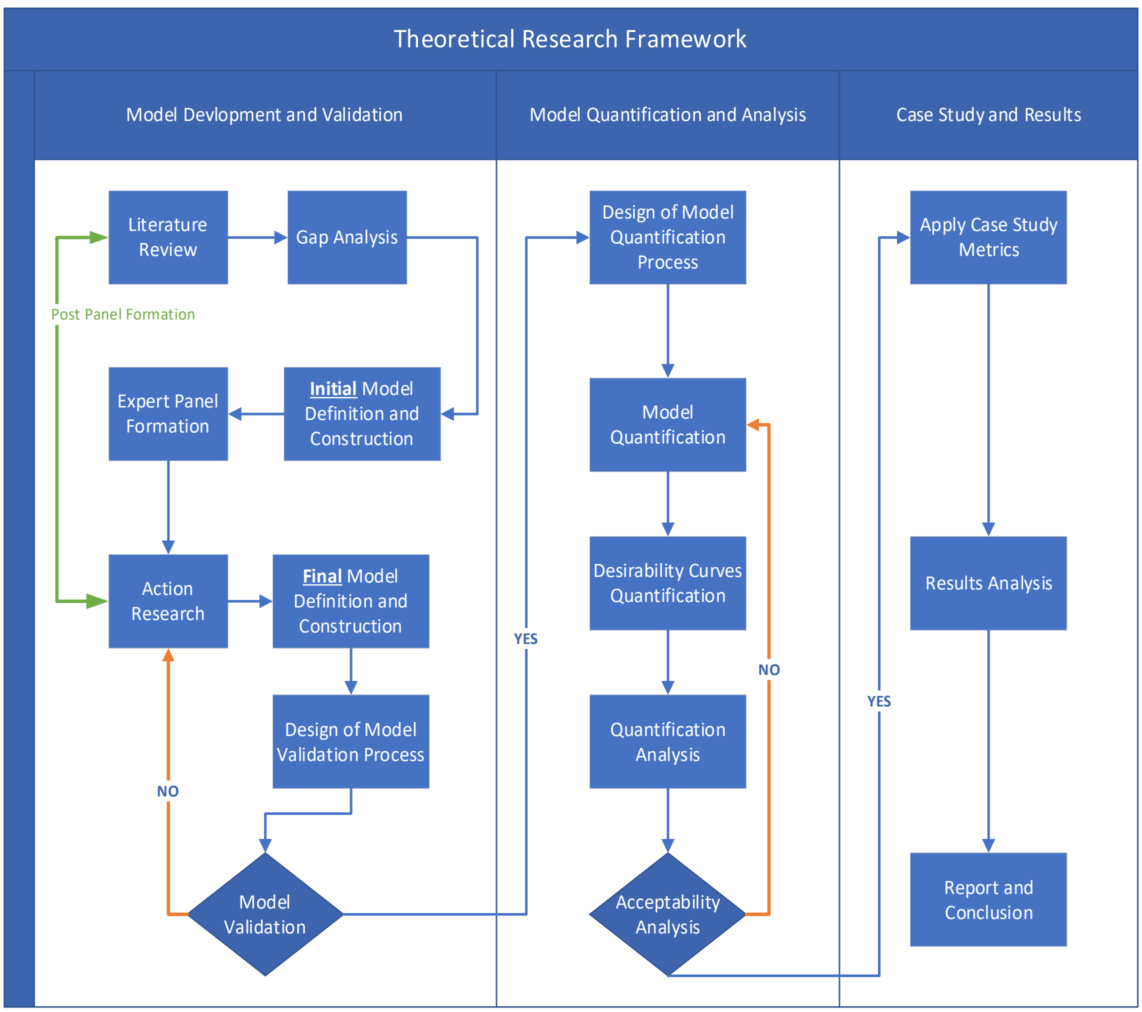

Figure 11 - Theoretical Research Framework

The literature supports the three phases of this framework. The precedent questions have mostly covered these phases, but it is essential to tie back the academic grounding of this model.

The first phase of Model Development and Validation starts with the literature review, which constitutes a solid and indispensable basis for any Multi-Criteria Decision-Making model (Daim & Kocaoglu, 2016; Hogaboam et al., 2014). This framework also introduces Action Research as an additional input to the model development. As exposed in the literature review, Lavoie and Daim have noticed the positive impact of Action Research in HDM modeling (Lavoie & Daim, 2020). According to their work, the experts' participation in the model development gives the latter a more substantial legitimacy. To complete this phase, the model validation by the experts remains a critical step to validate that the model will serve the purpose of its research goal (Alzahrani, 2021; Daim & Kocaoglu, 2016; Shaygan, 2021).

The second phase of the framework ties to the model quantification and the acceptability of the resulting data. The literature agrees on the importance of the analysis of the results (Daim & Kocaoglu, 2016). Indeed, the inconsistencies and disagreements need to remain at a certain level for the model to be acceptable (H. Chen & Kocaoglu, 2008).

Once the first and second phases are cleared, the third phase is where the application of the model happens. This phase is where the Case Study is confronted with the model and where the real added value of the research can be framed (Alzahrani, 2021; Hogaboam & Daim, 2018). The application allows the researcher to report back to the practitioners and potentially support the studied decision-making process.

5.2 Initial HDM Model

This initial model is built based on the literature review section. It focuses on the main perspectives healthcare organizations should consider when implementing Clinical Decision Support Systems. Within these perspectives, the model illustrates some of the critical pinpoints that can create challenges when the implementation occurs. The model's underlying mission is to assess the readiness of a given healthcare organization to implement a Clinical Decision Support System.

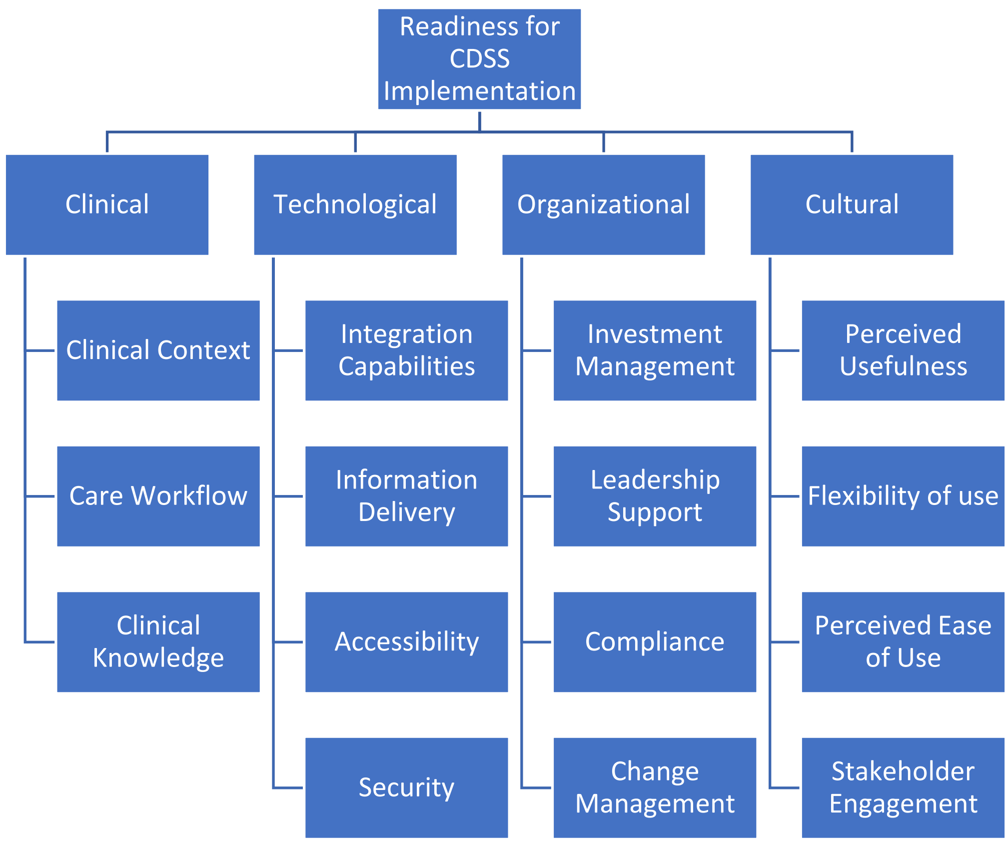

Figure 12 - Initial HDM Model

5.2.1 Perspectives

Perspective	Description
Clinical	The clinical perspective encompasses all the clinical components of a given healthcare organization that are crucial to the clinical decision process.
Technological	The Technological perspective covers all technical skills and capabilities to acquire to ensure a smooth Clinical Decision Support System implementation.
Organizational	The organizational perspective covers the operational readiness of the healthcare provider to take on a CDSS implementation.
Cultural	The Cultural perspective focuses on the cultural aspects that will make influence the implementation of a CDSS and eventually make it successful or not.

Table 8 - Initial HDM Model's Perspectives

5.2.2 Clinical Criteria and Desirability Curves

Criterion	Description	References
Clinical Context	The clinical context criterion assesses the knowledge needed for a Clinical Decision Support System. A CDSS is a contextual system. The nature of clinical care provided is the initial step in defining the context of a CDSS. It is critical and needs to be thoroughly described and mapped out.	(Greenes, 2007c)
Care Workflow	The care workflow criterion evaluates the framework in which clinical decision support is offered to clinicians. It is a step-by-step events sequence that results in the CDSS generating decision support and applying it to deliver care.	(McCoy et al., 2015)
Clinical Knowledge	This criterion evaluates clinical knowledge that is intended to be used by the system to provide support to clinicians. Driven by the context, the clinical expertise needed can take several forms.	(Jiang et al., 2017) (Jenders, 2017)

Table 9 - Initial HDM Model's Clinical Criteria

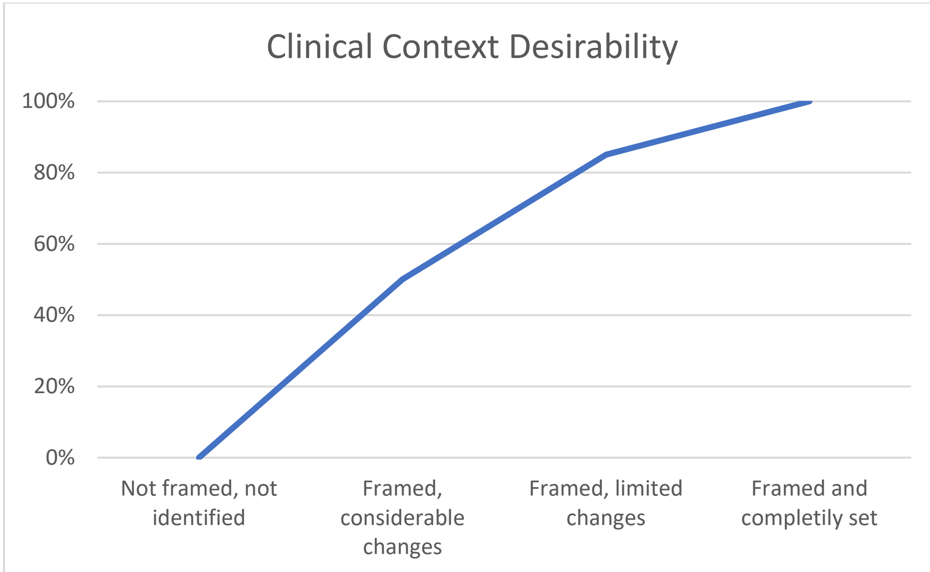

Figure 13 - Clinical Context Desirability Curve

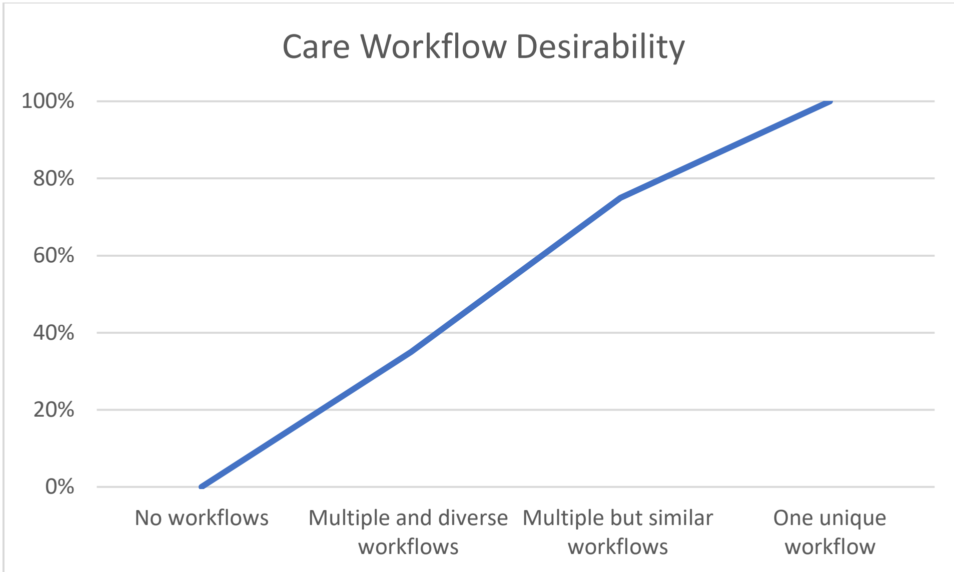

Figure 14 - Care Workflow Desirability Curve

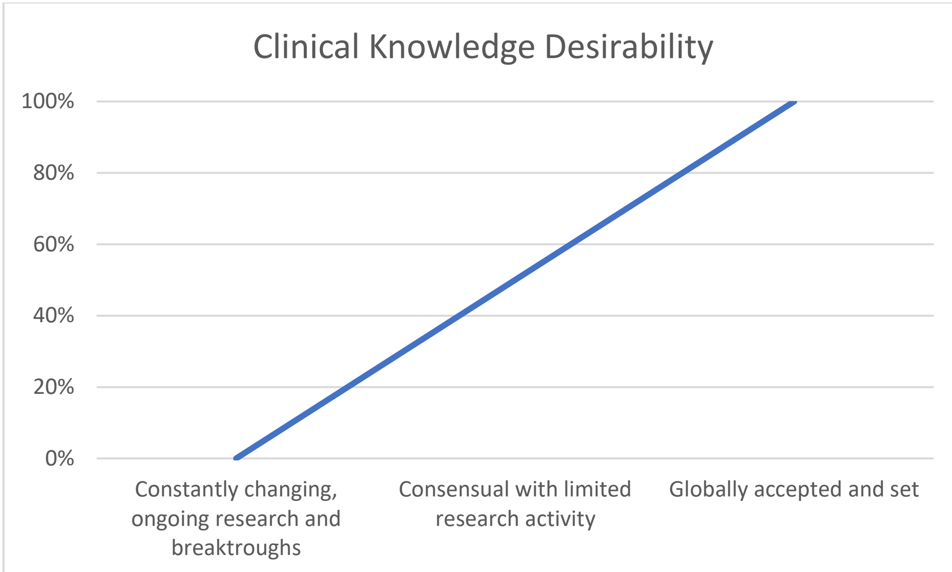

Figure 15 - Clinical Knowledge Desirability Curve

5.2.3 Technological Criteria and Desirability Curves

Criterion	**Description**	**References**
Integration Capabilities	The Integration Capabilities criterion evaluates the ability of a healthcare organization to integrate decision support solutions into their existing information system environments.	(Kaplan, 2001) (Wasylewicz & Scheepers-Hoeks, 2019)
Information Delivery	The information delivery evaluates the capabilities of a healthcare organization to deliver accurate information at the right time.	(Beeler et al., 2014)
Accessibility	The accessibility criterion assesses the technological accessibility of information systems within the healthcare organization and its accessibility towards healthcare providers.	(Berlin et al., 2006)
Security	The security here assesses the ability to use information systems in a safe and secure technology setting to ensure the patient's data and health is not jeopardized.	(Vinks et al., 2020)

Table 10 – Initial HDM Model's Technological Criteria

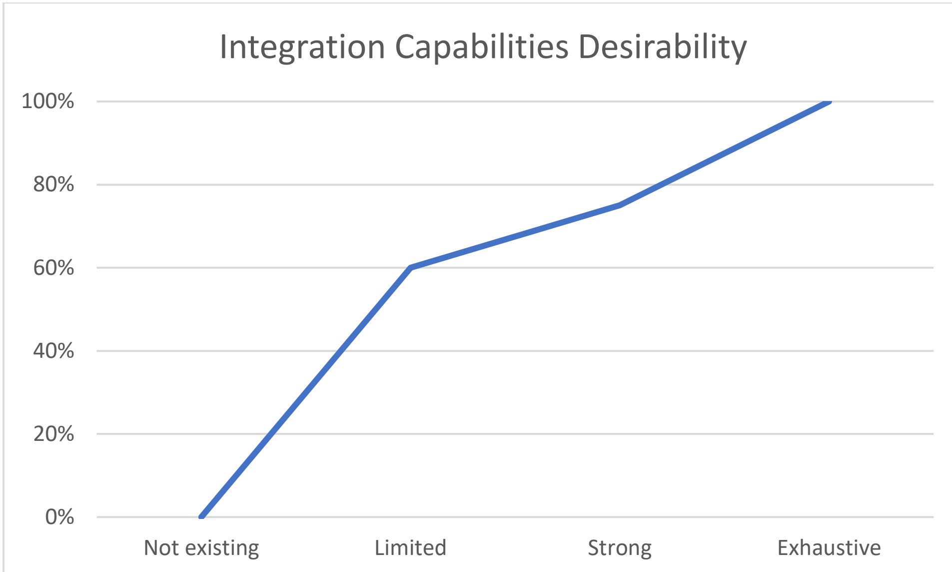

Figure 16 - Integration Capabilities Desirability Curve

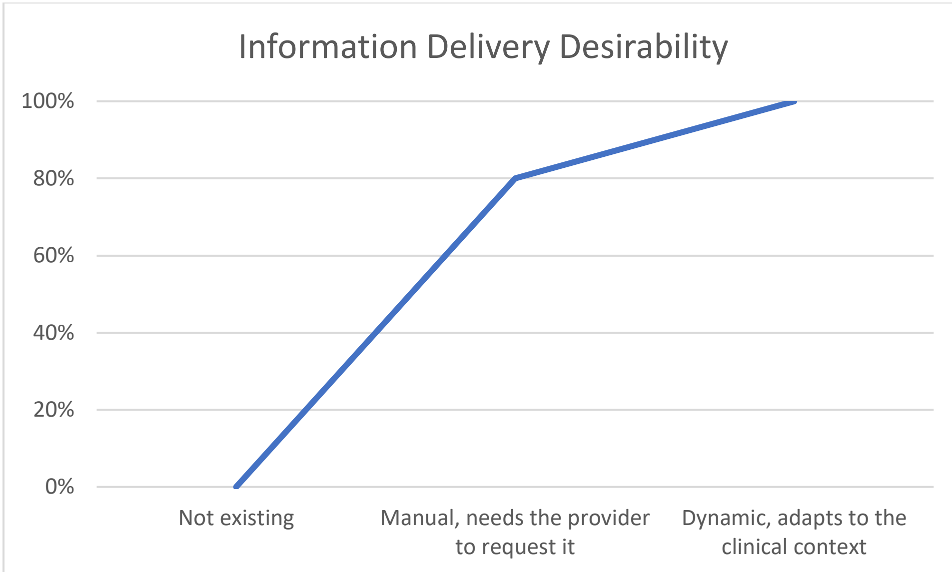

Figure 17 - Information Delivery Desirability Curve

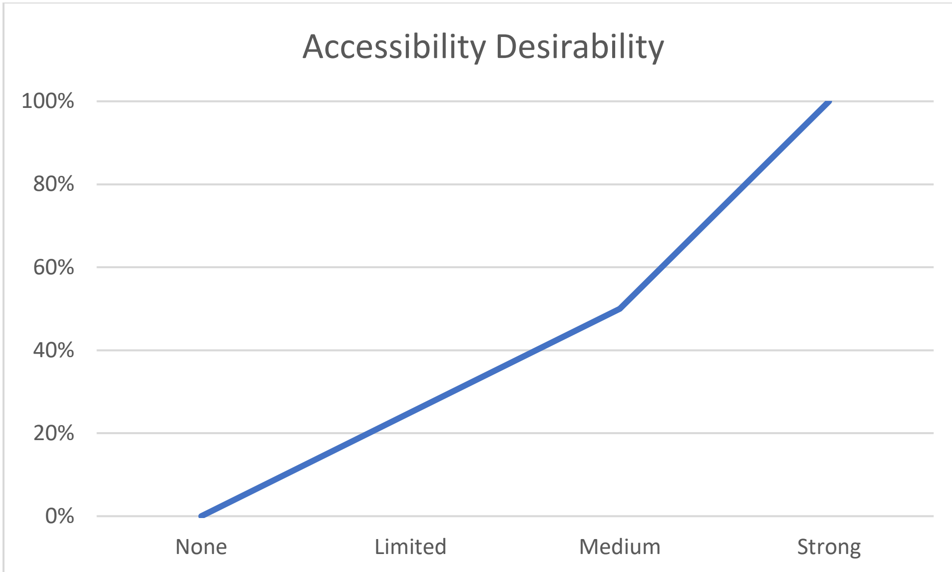

Figure 18 - Accessibility Desirability Curve

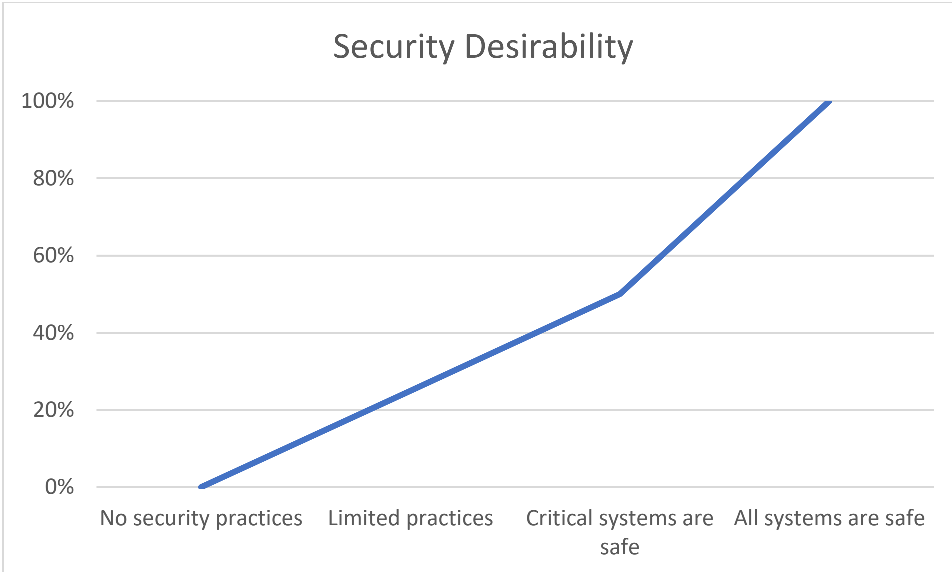

Figure 19 - Security Desirability Curve

5.2.4 Organizational Criteria and Desirability Curves

Criterion	Description	References
Investment Management	This criterion evaluates the investment management skills of organizational leaders. They are critical in the implementation of a CDSS. Leaders need to understand the investment level that will fit the organization's goals.	(Sutton et al., 2020)
Leadership Support	It evaluates the leadership support for a CDSS implementation is also crucial. C-level executives need to engage in and sponsor the implementation efforts to ensure its success.	(Sutton et al., 2020)
Compliance	The compliance criterion is to assess the level of legal and regulatory compliance of the organization aiming to implement the CDSS.	(Bonczek et al., 2014)
Change Management	Change management is critical when implementing a CDSS. This criterion assesses the level of change management existence in a given organization.	(Aljarboa & Miah, 2020)

Table 11 - Initial HDM Model's Organizational Criteria

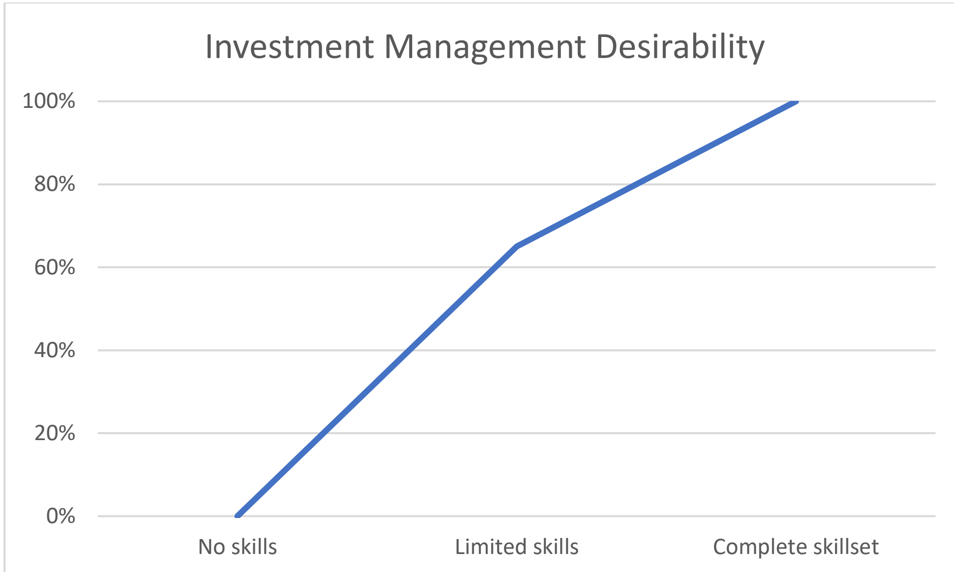

Figure 20 - Investment Management Desirability Curve

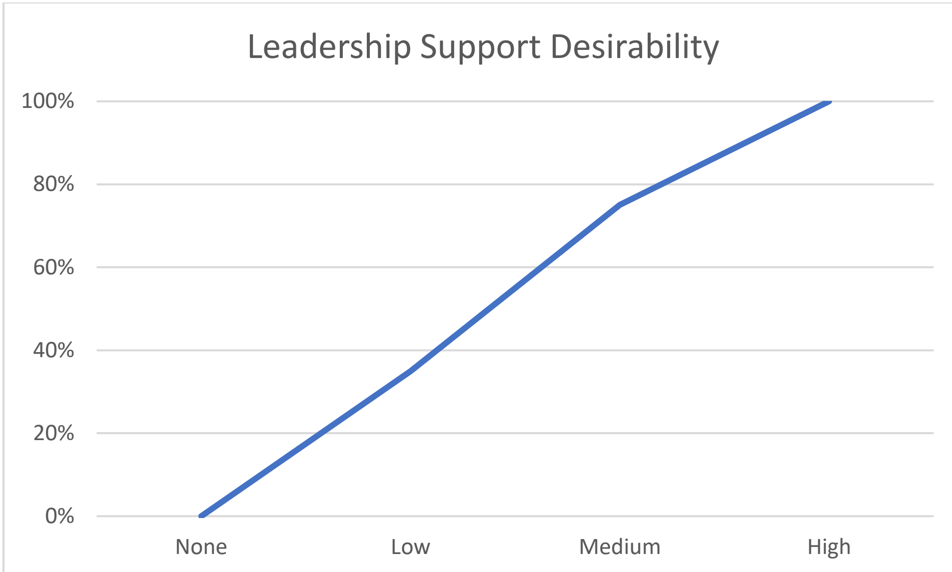

Figure 21 - Leadership Support Desirability Curve

Figure 22 - Compliance Desirability Curve

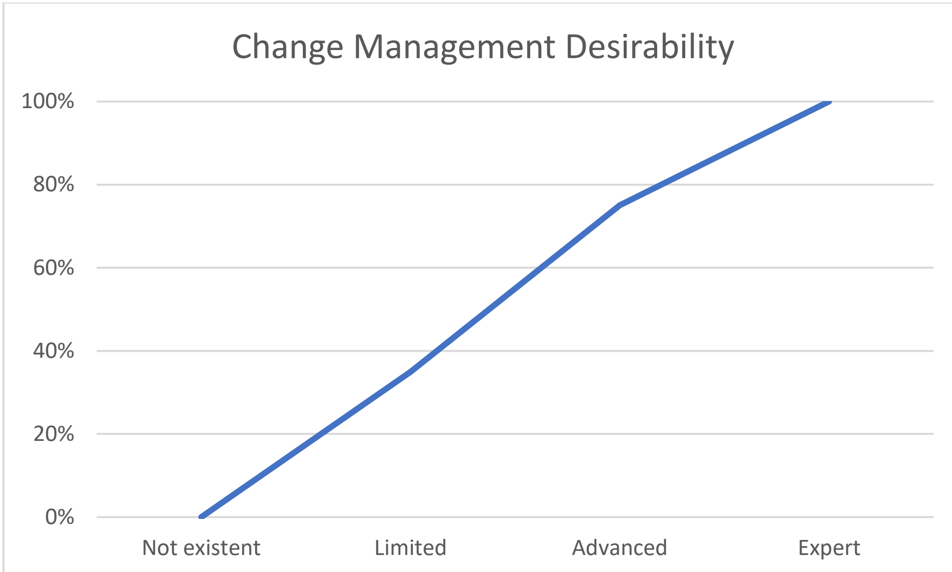

Figure 23 - Change Management Desirability Curve

5.2.5 Cultural Criteria and Desirability Curves

Criterion	Description	References
Perceived Usefulness	This criterion assesses the level of trust healthcare providers has for the CDSS through their perception of its usefulness in supporting their decision-making. The higher this perception, the better adoption we have.	(Sutton et al., 2020)
Flexibility of Use	This criterion evaluates the flexibility given to providers as far as using or not using the CDSS. The flexibility helps get the buy-in of late adopters of CDSS and initially reluctant providers.	(Aljarboa & Miah, 2020)
Perceived Ease of Use	This criterion assesses the level of perception healthcare providers has for the ease of using CDSS to support their decision-making. The higher this perception, the better adoption we have.	(Sutton et al., 2020)
Stakeholder Engagement	Here we evaluate the presence of engagement practices during the implementation period. All stakeholders need to be associated with the CDSS project continuously and as early as possible.	(Wasylewicz & Scheepers-Hoeks, 2019)

Table 12 - Initial HDM Model's Cultural Criteria

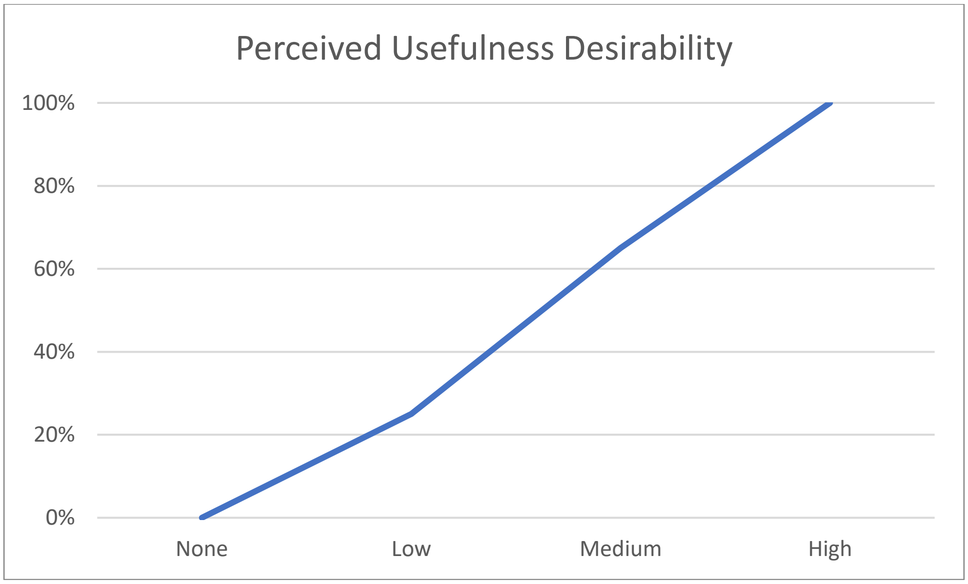

Figure 24 - Perceived Usefulness Desirability Curve

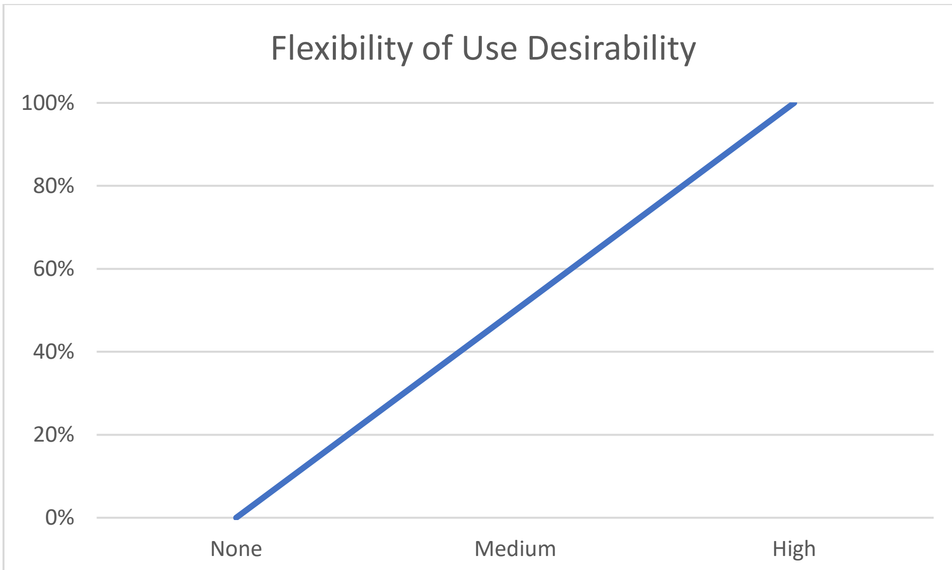

Figure 25 - Flexibility of Use Desirability Curve

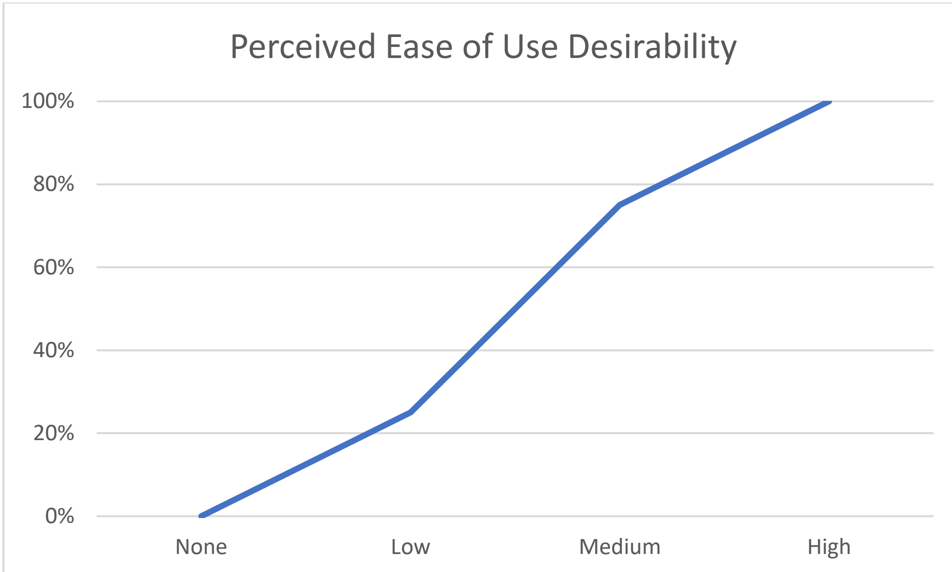

Figure 26 - Perceived Ease of Use Desirability Curve

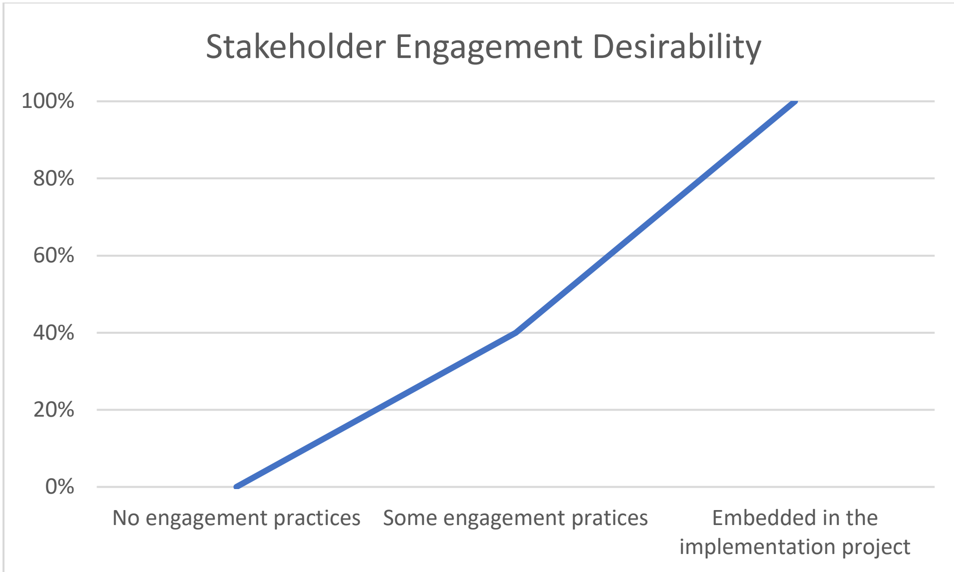

Figure 27 - Stakeholder Engagement Desirability

5.3 Expert Panel Formation

5.3.1 Background on the value of Expertise in Academic Research

As presented in section 4.5, in the field of Technology Management, expertise in academic research is crucial for ensuring the effective utilization of technology in organizations. Recent research has highlighted the importance of expertise in technology management in academic research. That expertise in technology management is essential for developing effective decision-making strategies. Lee et al. (2021) suggest that expertise in technology management is particularly important for research on artificial intelligence. Liu et al. (2021) found that research expertise is critical for predicting academic performance in technology-related fields. Williams and Brown (2020) emphasize the importance of interdisciplinary expertise in academic research, particularly in the field of technology management. These recent studies suggest that expertise in technology management is essential for conducting high-quality research, developing effective interventions, and predicting academic performance in technology-related fields.

5.3.2 Identifying Experts

Both personal and professional networks were key to identifying the experts participating in this research. Experts identified through these consisted of individuals I know personally or have worked with and who possessed the necessary expertise to contribute to your panels. Different backgrounds are represented, from Healthcare to Information Systems or Organizational Management.

Social Network Analysis (SNA) was also used to identify academic research experts. SNA enables the analysis of large and inter-related databases. When using SNA and Bibliometrics together, we can leverage the relation keys of academic literature, like citations or authors, to map a network.

To identify a list of experts using this approach, I relied on citations and author bibliometric data. The start point was a literature search on Google Scholar, using the keywords "Clinical Decision Support Systems Adoption". The next step was to identify the top 3 papers ranked by citation numbers and select their lead authors as potential experts. Then for each of these three papers, select the top two papers that cited them, again ranked by citation numbers, and select their authors as experts.

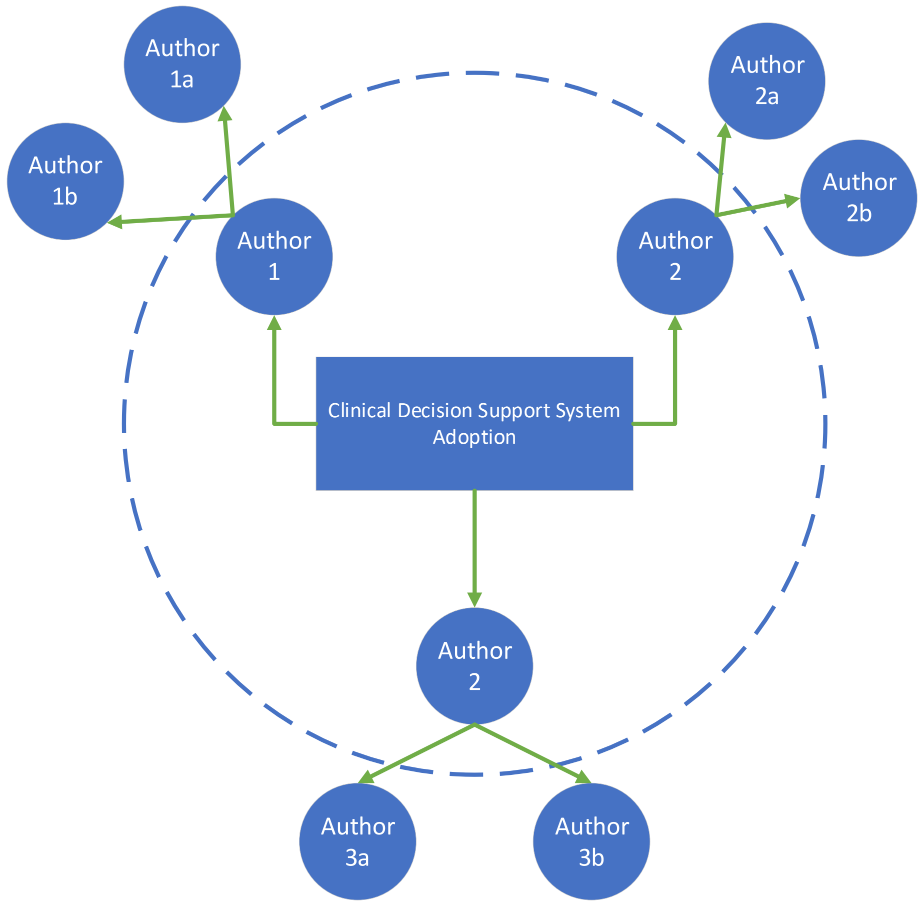

Figure 28 - SNA & Bibliometrics Selection of Experts

5.3.3 Identified Experts

Based on the methodologies of identification, 32 experts participated in this research. Table 13 lists their titles, line of work, expertise, the type of organization they belong to, and the method by which they were identified.

Alias	Line of Work	Expertise	Organization Type	Identification Method
Expert 1	Medical Doctor	Healthcare	Healthcare System	Personal Network
Expert 2	Medical Doctor	Healthcare	Healthcare System	Personal Network
Expert 3	Medical Doctor	Healthcare	Healthcare System	Personal Network
Expert 4	Medical Doctor	Healthcare	Healthcare System	Professional Network
Expert 5	Doctor of Pharmacology	Healthcare	Academia	Professional Network
Expert 6	Medical Doctor	Healthcare	Healthcare Service Provider	Professional Network
Expert 7	Medical Doctor	Healthcare	Healthcare System	Personal Network
Expert 8	Medical Doctor	Healthcare	Healthcare System	Personal Network
Expert 9	CDSS Sales	Health IT	CDSS Developer	Professional Network
Expert 10	CDSS Development	Health IT	CDSS Developer	Professional Network
Expert 11	CDSS Development	Health IT	CDSS Developer	Professional Network
Expert 12	CDSS Development	Health IT	CDSS Developer	Professional Network
Expert 13	CDSS Sales	Health IT	CDSS Developer	Personal Network
Expert 14	CDSS Consulting Services	Health IT	Consulting	Personal Network
Expert 15	Decision-Making Research	Academia/Research	Academia	SNA
Expert 16	Medical Research	Academia/Research	Research Lab	SNA
Expert 17	Community Health Research	Academia/Research	Academia	SNA

Expert 18	Medical Research	Academia/Research	Research Lab	SNA
Expert 19	Medical Research	Academia/Research	Research Lab	SNA
Expert 20	Medical Research	Academia/Research	Research Lab	SNA
Expert 21	Community Health Research	Academia/Research	Academia	SNA
Expert 22	Information Systems Management	Information Systems	Information Systems Services	Professional Network
Expert 23	Information Systems Development	Information Systems	Information Systems Services	Professional Network
Expert 24	Information Systems Development	Information Systems	Information Systems Services	Professional Network
Expert 25	Information Systems Management	Information Systems	Information Systems Services	Personal Network
Expert 26	Information Systems Management	Information Systems	Information Systems Services	Personal Network
Expert 27	Information Systems Development	Information Systems	Information Systems Services	Professional Network
Expert 28	Executive Leadership	Organizational Management	Research Lab	Professional Network
Expert 29	Executive Leadership	Organizational Management	Financial Services	Personal Network
Expert 30	International Expansion	Organizational Management	Information Systems Services	Professional Network
Expert 31	Change Management	Organizational Management	Consulting	Personal Network
Expert 32	Global Alignment	Organizational Management	Consulting	Personal Network

Table 13 - Experts List

As presented in Figure 29, five expertise fields are represented. They align with the knowledge intersection that applies to Clinical Decision Support Systems. Healthcare experts are the primary user and consumers of CDSS, while Health IT experts are the developers of CDSS.

Information Systems experts bring to this study the technical validation when Organizational Management experts help us contextualize the application of CDSS within a business model. Finally, Academia is also an expertise that allows for the applied academic research perspective to be integrated into this research model.

Across the board, these five expertise fields are evenly disturbed in terms of representativity in this global experts list.

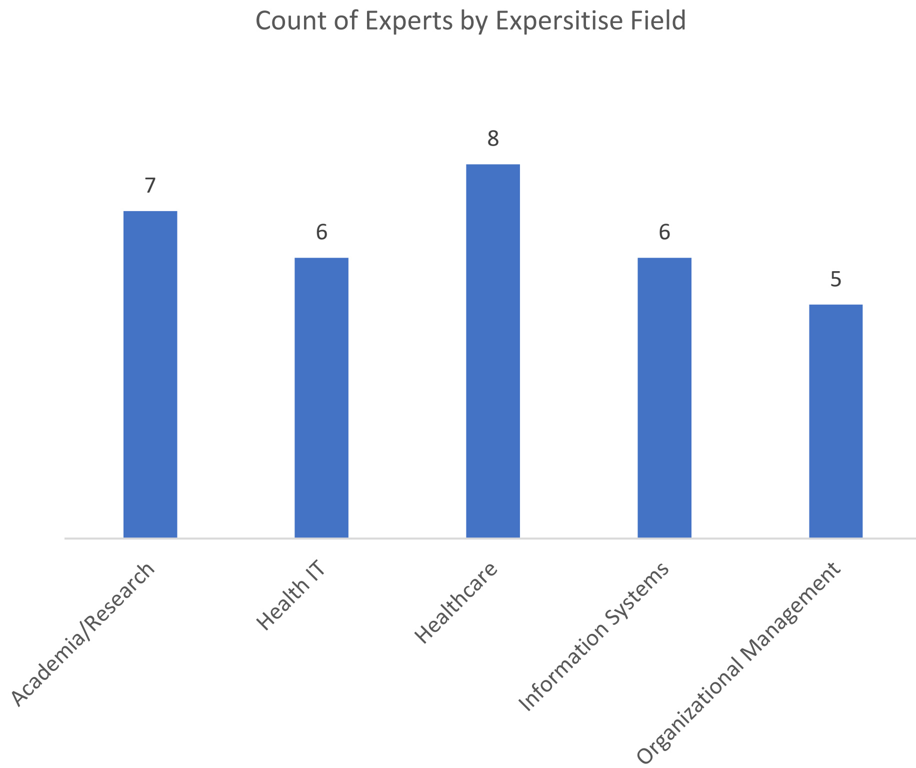

Figure 29 - Expertise Fields Distribution

The experts are also distributed across eight Organizational Types and fourteen Lines of Work. Presented respectively in Figure 30 and Figure 31, these distributions have been designed to account for the Expert Panels design detailed in the next section. Organization Types and Lines of Work reflect the diversity of expertise in the different expert panels.

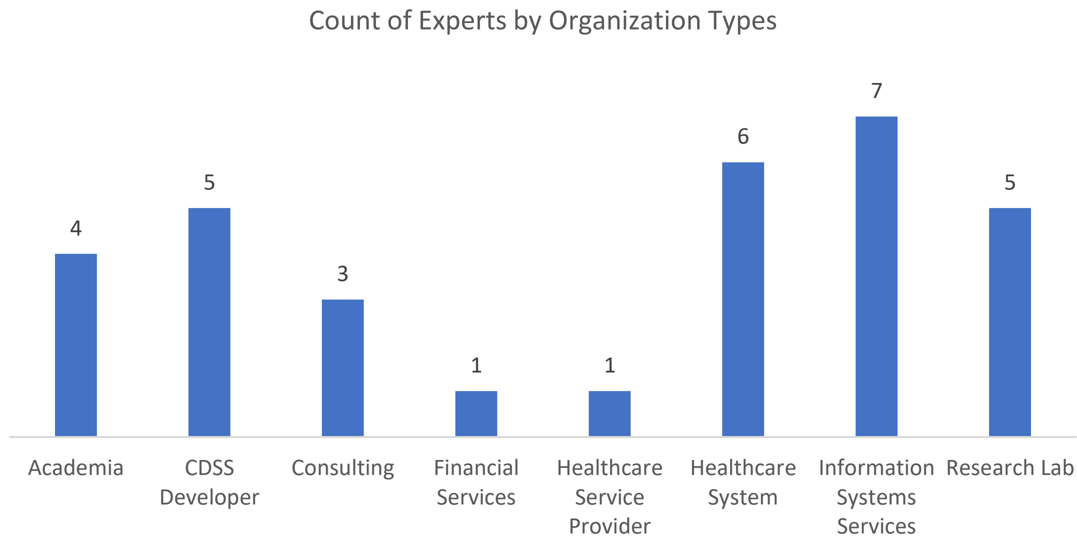

Figure 30 - Distribution of Expters by Organization Types

Figure 31 - Distribution of Expters by Lines of Work

5.3.4 Expert Panels Design

Designing Experts Panels is a crucial step in this research framework. Experts are therefore assigned to the steps and sub-steps of the model validation and quantification. The assignments follow a logic base on the expertise of each participant in the panels, where experts will validate or quantify parts of the model that are the closest to their expertise.

The first panel **P0** is dedicated to the Action Research step of this framework. As detailed in section 2.8, Action Research is a collaborative process that involves researchers working closely with practitioners to identify, investigate, and address problems in a real-world setting. That panel is composed of 8 healthcare experts that are also practitioners using Clinical Decision Support Systems. Through their expertise and their status as practitioners, they were included as Action Research stakeholders enabling this participatory approach that emphasizes collaboration between researchers and practitioners. Table 14 lists the experts participating in panel P0 and their titles.

Alias	Line of Work
Expert 1	Medical Doctor
Expert 2	Medical Doctor
Expert 3	Medical Doctor
Expert 4	Medical Doctor
Expert 5	Doctor of Pharmacology
Expert 6	Medical Doctor
Expert 7	Medical Doctor
Expert 8	Medical Doctor

Table 14 – Panel P0: Action Research

The next five panels are dedicated to the validation of the HDM model. At every level of the model presented in section 5.2, these panels are consulted to validate the components. Panel **P1** is in charge of validating the first layer of the HDM model, the perspectives. That layer represents the multi-dimensional approach that is fundamental to the Analytic Hierarchy Process. In this panel, the experts' assignment should be as diverse as possible to account for the diversity of perspectives. The following seven experts, listed in table 15, have been identified for this panel.

Alias	Line of Work
Expert 3	Medical Doctor
Expert 5	Doctor of Pharmacology
Expert 7	Medical Doctor
Expert 10	CDSS Development
Expert 12	CDSS Development
Expert 15	Decision-Making Research
Expert 17	Community Health Research
Expert 20	Medical Research
Expert 22	Information Systems Management
Expert 24	Information Systems Development
Expert 26	Information Systems Management
Expert 30	International Expansion

Table 15 - Panel P1: Perspectives Validation

Panel **P2** will be in charge of validating the criteria under the Clinical perspective and therefore is composed of experts having evolved a clinical environment. Panel **P3** is responsible for the validation of the criteria under the Technological perspective of the model. It comprises experts with a track record of technology development and technological strategy. Similarly, Panel P4 validates the criteria under the Organizational perspectives and groups individuals with subject matter expertise in organizational management. Finally, the last validation panel, P5, focuses on the Cultural perspective, and because of the broad impact of the Cultural perspective, a diverse panel has been composed to account for that specificity.

Tables 16 to 19 detail the experts' participation in the validation panels.

Alias	**Line of Work**
Expert 2	Medical Doctor
Expert 3	Medical Doctor
Expert 5	Doctor of Pharmacology
Expert 6	Medical Doctor
Expert 8	Medical Doctor
Expert 10	CDSS Development
Expert 14	CDSS Consulting Services
Expert 16	Medical Research
Expert 18	Medical Research
Expert 19	Medical Research
Expert 20	Medical Research

Table 16 - Panel P2: Clinical Criteria Validation

Alias	Line of Work
Expert 10	CDSS Development
Expert 11	CDSS Development
Expert 12	CDSS Development
Expert 13	CDSS Sales
Expert 15	Decision-Making Research
Expert 22	Information Systems Management
Expert 23	Information Systems Development
Expert 24	Information Systems Development
Expert 26	Information Systems Management
Expert 27	Information Systems Development

Table 17 - Panel P3:Technological Criteria Validation

Alias	Line of Work
Expert 9	CDSS Sales
Expert 14	CDSS Consulting Services
Expert 16	Medical Research
Expert 23	Information Systems Development
Expert 25	Information Systems Management
Expert 28	Executive Leadership
Expert 29	Executive Leadership
Expert 30	International Expansion
Expert 31	Change Management
Expert 32	Global Alignment

Table 18 - Panel P4: Organizational Criteria Validation

Alias	Line of Work
Expert 2	Medical Doctor
Expert 5	Doctor of Pharmacology
Expert 8	Medical Doctor
Expert 15	Decision-Making Research
Expert 17	Community Health Research
Expert 19	Medical Research
Expert 22	Information Systems Management
Expert 28	Executive Leadership
Expert 30	International Expansion
Expert 31	Change Management
Expert 32	Global Alignment

Table 19 - Panel P5: Cultural Criteria Validation

Following through the research framework, the next experts' panels are responsible for the model quantification. The quantification happens at all model levels, starting with the perspectives level and followed by the criteria level under each perspective.

Similarly to the validation step, these panels' designs follow the logic of adequate expertise matching. Panels P6, P10, and P11 will be composed of diverse experts as per the necessity of the level they are in charge of, while panels P7, P8, and P9 will gather a homogeneous experts' group related to the perspectives in question. It is important to note that on the one hand, panels P6 through P10 will be quantifying the HDM model through pairwise comparison as explained in Chapter 4, while on the other hand, panel P11 will be in charge of quantifying the desirability curves presented in section 5.2.

Tables 20 to 25 detail the experts' participation in the quantification panels.

Alias	Line of Work
Expert 1	Medical Doctor
Expert 4	Medical Doctor
Expert 7	Medical Doctor
Expert 9	CDSS Sales
Expert 11	CDSS Development
Expert 15	Decision-Making Research
Expert 17	Community Health Research
Expert 19	Medical Research
Expert 21	Community Health Research
Expert 23	Information Systems Development
Expert 27	Information Systems Development
Expert 31	Change Management

Table 20 - Panel P6: Perspectives Quantification

Alias	Line of Work
Expert 1	Medical Doctor
Expert 3	Medical Doctor
Expert 4	Medical Doctor
Expert 6	Medical Doctor
Expert 7	Medical Doctor
Expert 8	Medical Doctor
Expert 11	CDSS Development
Expert 12	CDSS Development
Expert 13	CDSS Sales
Expert 18	Medical Research
Expert 19	Medical Research
Expert 20	Medical Research

Table 21 - Panel P7: Clinical Criteria Quantification

Alias	Line of Work
Expert 11	CDSS Development
Expert 12	CDSS Development
Expert 13	CDSS Sales
Expert 15	Decision-Making Research
Expert 22	Information Systems Management
Expert 24	Information Systems Development
Expert 25	Information Systems Management
Expert 26	Information Systems Management
Expert 27	Information Systems Development
Expert 28	Executive Leadership

Table 22 - Panel P8: Technological Criteria Quantification

Alias	Line of Work
Expert 9	CDSS Sales
Expert 13	CDSS Sales
Expert 16	Medical Research
Expert 21	Community Health Research
Expert 23	Information Systems Development
Expert 25	Information Systems Management
Expert 28	Executive Leadership
Expert 29	Executive Leadership
Expert 30	International Expansion
Expert 31	Change Management
Expert 32	Global Alignment

Table 23 - Panel P9: Organizational Criteria Quantification

Alias	Line of Work
Expert 3	Medical Doctor
Expert 4	Medical Doctor
Expert 8	Medical Doctor
Expert 13	CDSS Sales
Expert 14	CDSS Consulting Services
Expert 19	Medical Research
Expert 28	Executive Leadership
Expert 29	Executive Leadership
Expert 30	International Expansion
Expert 31	Change Management
Expert 32	Global Alignment

Table 24 - Panel P10: Cultural Criteria Quantification

Alias	Line of Work
Expert 2	Medical Doctor
Expert 4	Medical Doctor
Expert 7	Medical Doctor
Expert 8	Medical Doctor
Expert 13	CDSS Sales
Expert 20	Medical Research
Expert 22	Information Systems Management
Expert 25	Information Systems Management
Expert 26	Information Systems Management
Expert 29	Executive Leadership
Expert 32	Global Alignment

Table 25 - Panel P11: Desirability Curves Quantification

Eleven expert panels have therefore been formed. Table 26 summarizes the breakout of the panels and the number of experts assigned to them. In the next chapter, moving further into the research framework presented in section 5.1, the expert panels will be leveraged to run the Action Research insight, the HDM model validation, and the model quantification.

Panel	**Responsibility**	**Number of Experts**
P0	Action Research	8
P1	Perspectives Validation	12
P2	Clinical Criteria Validation	11
P3	Technological Criteria Validation	10
P4	Organizational Criteria Validation	10
P5	Cultural Criteria Validation	11
P6	Perspectives Quantification	12
P7	Clinical Criteria Quantification	12
P8	Technological Criteria Quantification	10
P9	Organizational Criteria Quantification	11
P10	Cultural Criteria Quantification	11
P11	Desirability Curves Quantification	11

Table 26 - Expert Panels Summary

CHAPTER 6 – RESEARCH MODEL REFINEMENT, VALIDATION, AND QUANTIFICATION

In this chapter, the initial HDM model presented in section 5.2 will be submitted for revision and refinement through an Action Research approach, then the revised version will be forwarded to the expert panels for validation and quantification.

6.1 Action Research applied to the Clinical Perspective

6.1.1 Action Research Setup and Gap Identification

As explained in section 2.8, Action research is a powerful methodology that involves conducting research within a real-world setting to solve practical problems and improve organizational processes. The added value of action research lies in its ability to facilitate continuous improvement and knowledge creation through collaboration between researchers and stakeholders.

By involving stakeholders in the research process, action research helps to build trust and foster a sense of ownership in the solutions developed. Ultimately, the added value of action research lies in its ability to produce actionable insights that can lead to positive change and increased organizational effectiveness.

Panel P0 was formed with the intent to refine the HDM model by applying expert-driven inputs and suggestions inspired by Action Research. The focus is put on the Clinical perspective; therefore, experts with clinical backgrounds were directly involved in conducting research related to this perspective. As per the research framework present in the sections above, this hand-on expert participation in the research was focused on the literature review part. The experts were asked to contribute to the literature review to validate and potentially point out gaps, specifically in the Clinical perspective of Clinical Decision Support Tools.

The following step-by-step process was implemented:

1. Presentation of the Literature Review as initially conducted, with a focus on the Clinical perspective.
2. Presentation of the Clinical perspective in the model and its underlying criteria
3. Brainstorming on the potential gaps
4. Request each expert to provide three (3) keywords to research in order to expand the literature review to bridge the gaps identified.
5. Analyze the results of this process and amend the HDM model if necessary.

Table 27 presents the keywords that were identified by the experts.

Alias	Keyword 1	Keyword 2	Keyword 3
Expert 1	Results	Patient	Care
Expert 2	Patient	Procedure	Outcome
Expert 3	Efficiency	Outcome	Health
Expert 4	Wellness	Results	Patient
Expert 5	Patient	Outcome	Fitness
Expert 6	Diligence	Vigor	Protection
Expert 7	Patient	Effect	Repercussion
Expert 8	Protection	Patient	Consequences

Table 27 - Keywords by Experts

A trend was identified by listing all the keywords that were mentioned more than once.

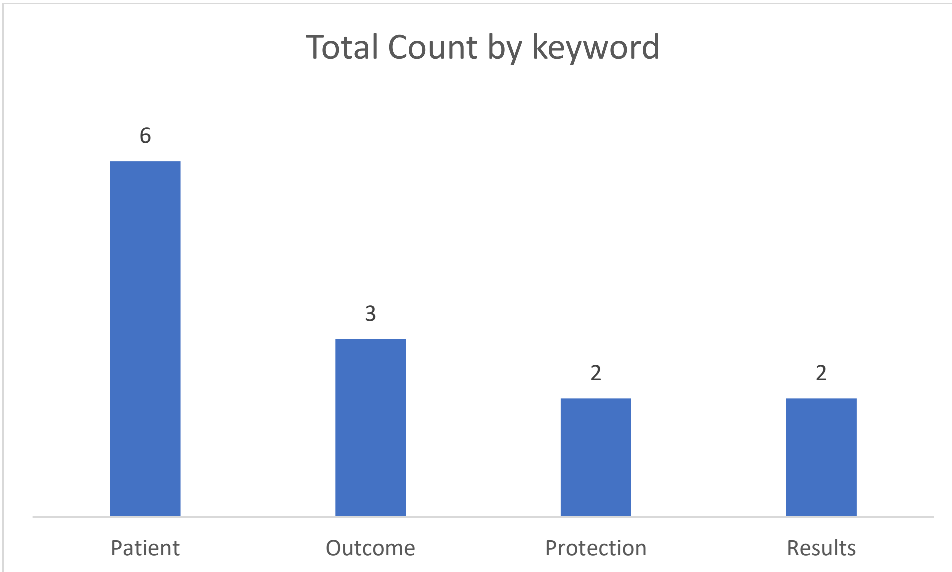

Figure 32 - Keywords mentioned more than once

The trend identified is related to the outcome or the results of the CDSS-aided care on the patient. Therefore the identified gap and additional literature review to be conducted were to be focused on the impact of CDSS on Clinical Outcomes.

6.1.2 Clinical Outcome and CDSS implementation readiness

It is important to note that this additional research is conducted under the lens of this study's primary goal, which remains the development of a model to assess the readiness of healthcare organizations to implement Clinical Decision Support Systems.
Indeed in section 2.2, we already identified Healthcare Improvement as one of the main purposes of CDSS. Now the question is, how does it extend to Clinical Outcome, and from the perspective of a Healthcare Organization, how does it come into play regarding the readiness for adopting CDSS tools?

Clinical Outcomes refer to the results or effects of healthcare interventions on patients' health status, functioning, and quality of life (DeNicola et al., 2020; Van Spall et al., 2019). They are a critical component of healthcare evaluation and are used to measure the effectiveness of healthcare interventions (Buljac-Samardzic et al., 2020). The term "outcomes" refers to the results or effects of healthcare interventions on patients' health status, functioning, and quality of life. Clinical outcomes can be classified into three main categories: clinical outcomes, functional outcomes, and quality of life outcomes (Giannakoulis et al., 2020; Pan et al., 2020).

As a healthcare organization, clearly identifying your target healthcare outcome is crucial for several reasons (Kwan et al., 2020; Lee et al., 2019). First, having a clear understanding of the desired clinical outcome enables providers to develop a tailored treatment plan that aligns with the patient's goals and expectations. This approach can help improve patient satisfaction and adherence to treatment, leading to better outcomes (Castiglione et al., 2019). Also, knowing the target clinical outcome can help providers monitor and evaluate the effectiveness of treatment interventions. This enables providers to adjust treatment plans as needed to ensure that patients are making progress toward their clinical goals (Xie et al., 2022). Understanding the target clinical outcome can also help providers identify patients who are at risk of adverse events and provide targeted interventions to mitigate these risks. This approach can help improve patient safety and reduce the incidence of medical errors (Burgener, 2020; Royce et al., 2019). Finally, knowledge of the target clinical outcome can help providers communicate more effectively with patients and their families, improving patient education and understanding of their condition and treatment options (Mohile et al., 2020).

Overall, identifying the target clinical outcome is essential for providing high-quality, patient-centered care. It enables providers to develop tailored treatment plans, monitor treatment effectiveness, mitigate risks, and communicate more effectively with patients and their families. By focusing on the desired clinical outcome, providers can optimize patient outcomes and improve the overall quality of care (Kwan et al., 2020).

6.1.3 Action Research Impact on the initial HDM model

The Action Research process, with the help of experts in panel P0, clearly identified a gap in our initial HDM model. Thanks to the Action Research process and the literature review in the previous section, we can now include with confidence the fourth criterion under the Clinical Perspective: the Clinical Outcome.

This criterion stresses the importance for a healthcare organization to identify its intended Clinical Outcomes clearly. By doing so, the organization steps ahead in the journey to implement Clinical Decision Support Systems and construct a better intent for the CDSS implementation, which translates into a higher readiness to implement and adopt these decision support tools.

While table 28 lists the updated criteria of the Clinical perspective, figure 33 shows the related desirability curve for the newly added criterion.

Criterion	Description	References
Clinical Context	The clinical context criterion assesses the knowledge needed for a Clinical Decision Support System. A CDSS is a contextual system. The nature of clinical care provided is the initial step in defining the context of a CDSS. It is critical and needs to be thoroughly described and mapped out.	(Greenes, 2007c)
Care Workflow	The care workflow criterion evaluates the framework in which clinical decision support is offered to clinicians. It is a step-by-step events sequence that results in the CDSS generating decision support and applying it to deliver care.	(McCoy et al., 2015)
Clinical Knowledge	This criterion evaluates clinical knowledge that is intended to be used by the system to provide support to clinicians. Driven by the context, the clinical expertise needed can take several forms.	(Jiang et al., 2017) (Jenders, 2017)
Clinical Outcome	This criterion assesses the maturity level of identifying the desired Clinical Outcome for patients while using Clinical Decision Support tools.	(Kwan et al., 2020) (Castiglione et al., 2019) (Xie et al., 2022)

Table 28 - Updated Clinical Perspective Criteria

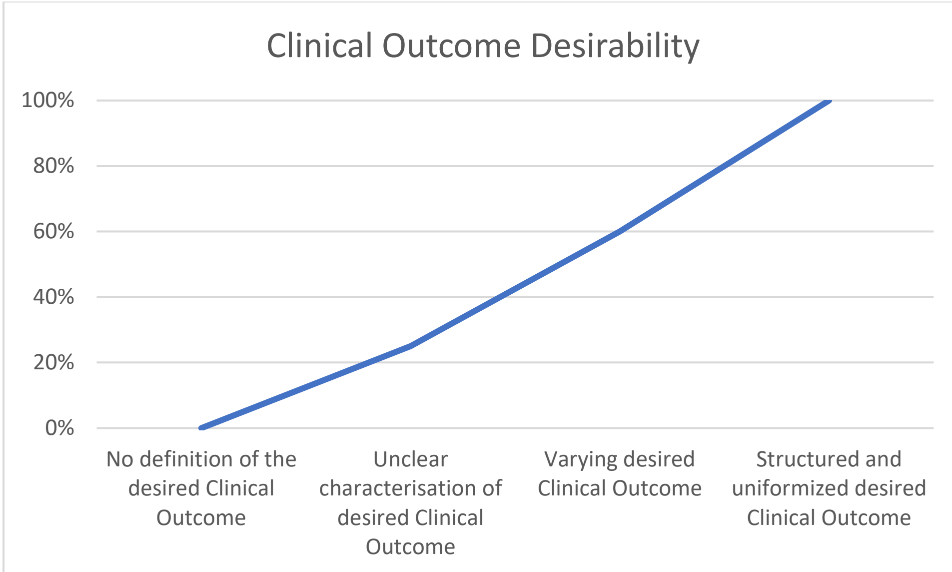

Figure 33 - Clinical Outcome Desirability

To wrap up this Action Research section, figure 34 presents the revised HDM model that will be submitted for validation and quantification in the following sections.

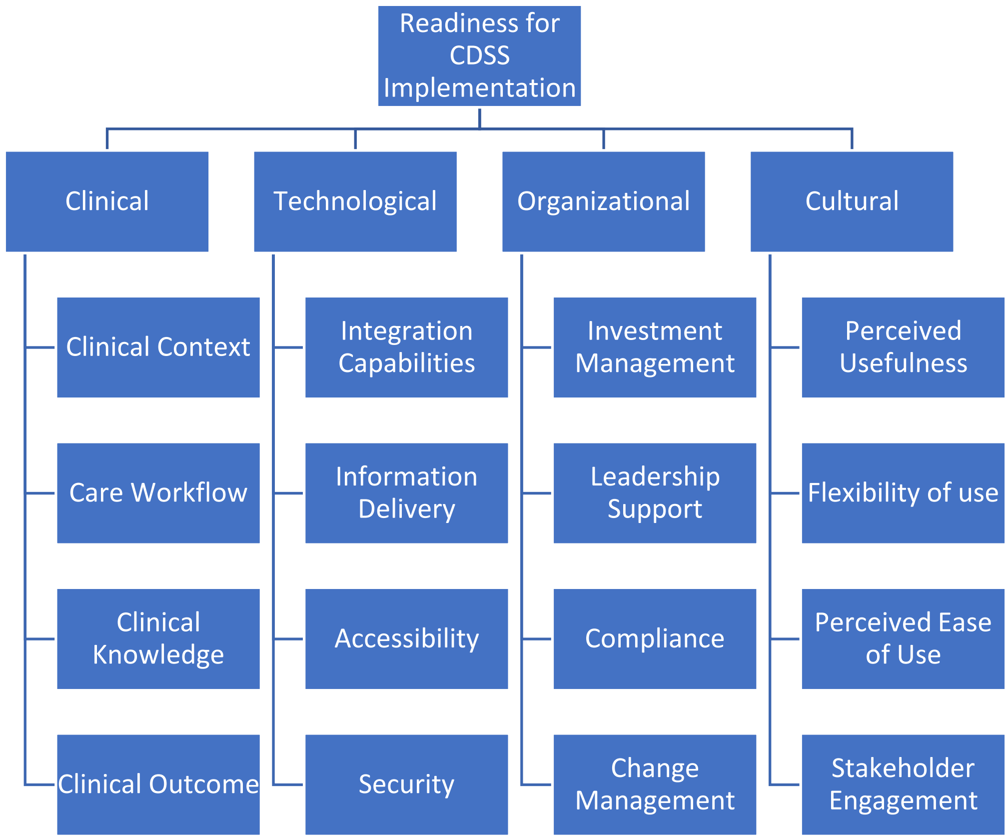

Figure 34 - Revised HDM model post Action Research

6.2 Validation of the HDM model

In this section, experts in panels P1 through P5, as described in section 5.3.4, are invited to validate the revised HDM model presented in figure 34. The validation process consists of collecting experts' feedback for each HDM component about its importance in the global intent of this research project. At every level of the model and for each component, the experts are asked if the element is:

- Important
- Not Important
- Not Applicable

Only one answer is possible, and a Qualtrics survey is the preferred tool to gather the panels' feedback on the model validation. Screenshots of the Qualtrics survey are displayed in Appendix B.

6.2.1 Validation of the model's Perspectives

Panel P1 and its 12 experts presented the first layer of the model, the Perspectives, for validation. All 12 experts validated the four perspectives unanimously by confirming their importance is the global intent of this research. Figure 35 and Table 29 detail the results of this validation.

	Perspectives			
Panel P1	**Clinical**	**Technological**	**Organizational**	**Cultural**
Expert 3	Important	Important	Important	Important
Expert 5	Important	Important	Important	Important
Expert 7	Important	Important	Important	Important
Expert 10	Important	Important	Important	Important
Expert 12	Important	Important	Important	Important
Expert 15	Important	Important	Important	Important
Expert 17	Important	Important	Important	Important
Expert 20	Important	Important	Important	Important
Expert 22	Important	Important	Important	Important
Expert 24	Important	Important	Important	Important
Expert 26	Important	Important	Important	Important
Expert 30	Important	Important	Important	Important

Table 29 - Perspectives Validation Results (Panel P1)

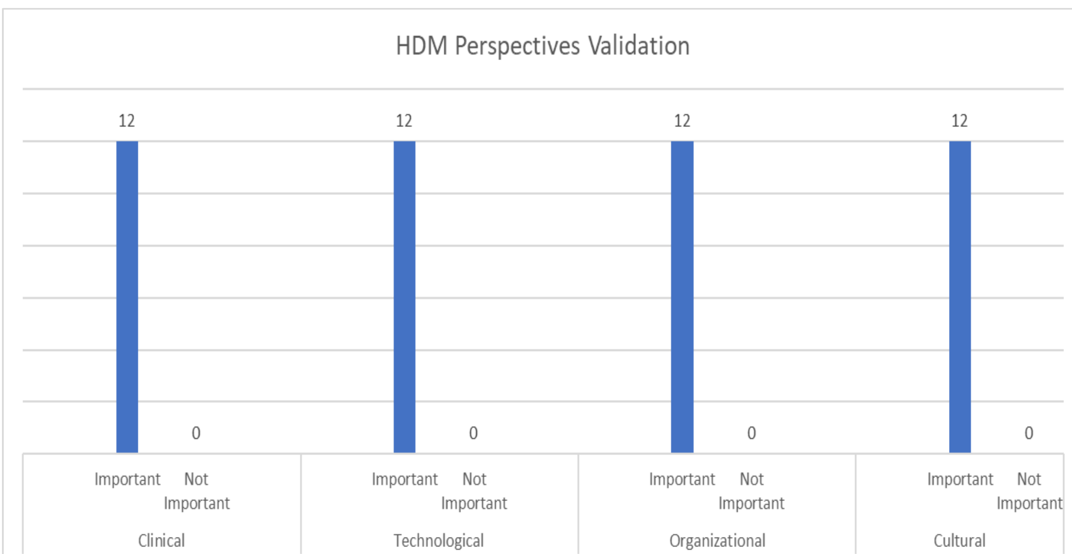

Figure 35 - Model Perspectives Validation

6.2.2 Validation of the Clinical Perspective Criteria

Panel P2 and its eleven experts were asked to validate the criteria from the Clinical Perspective. Here as well, the results were unanimous. All experts validate all four criteria of this perspective by judging it as necessary for the model and the overall research framework. This unanimous result might also be linked to the specific effort of the Action Research panel, which took the time to participate actively in the refinement of this perspective. The validation results of the experts' assessment of the model's Clinical perspective are presented in Figure 36 and Table 30.

	Clinical Perspective			
Panel P2	**Clinical Context**	**Care Workflow**	**Clinical Knowledge**	**Clinical Outcome**
Expert 2	Important	Important	Important	Important
Expert 3	Important	Important	Important	Important
Expert 5	Important	Important	Important	Important
Expert 6	Important	Important	Important	Important
Expert 8	Important	Important	Important	Important
Expert 10	Important	Important	Important	Important
Expert 14	Important	Important	Important	Important
Expert 16	Important	Important	Important	Important
Expert 18	Important	Important	Important	Important
Expert 19	Important	Important	Important	Important
Expert 20	Important	Important	Important	Important

Table 30 - Clinical Perspective Validation Results (Panel P2)

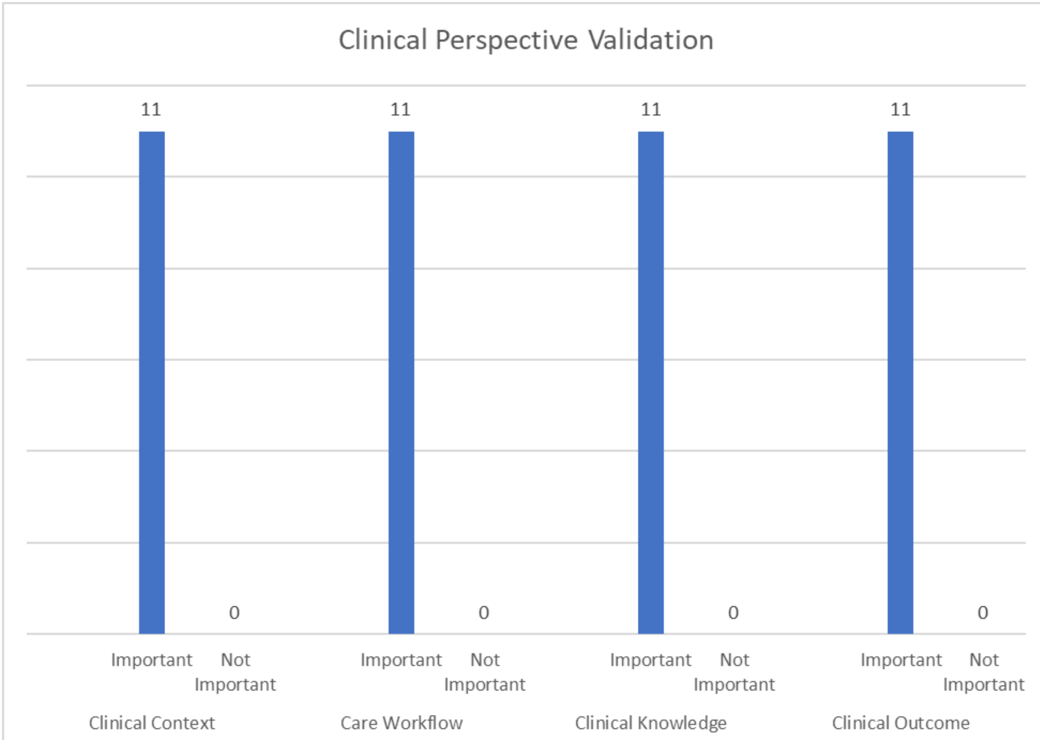

Figure 36 – Clinical Perspective Validation

6.2.3 Validation of the Technological Perspective Criteria

Panel P3 and its ten experts were in charge of validating the criteria from the Technological perspective. While three out of four criteria were unanimously validated, the Integration Capabilities criterion was deemed as not necessary by one expert out of the then participating in the panel. Despite that, this criterion remains validated with a 90% validation result. Therefore all the criteria for the Technological perspective are validated. The results of the experts' assessment of the model's Technological perspective are presented in Figure 37 and Table 31.

	Technological Perspective			
Panel P3	**Integration Capability**	**Information Delivery**	**Accessibility**	**Security**
Expert 10	Important	Important	Important	Important
Expert 11	Important	Important	Important	Important
Expert 12	Important	Important	Important	Important
Expert 13	*Not Important*	Important	Important	Important
Expert 15	Important	Important	Important	Important
Expert 22	Important	Important	Important	Important
Expert 23	Important	Important	Important	Important
Expert 24	Important	Important	Important	Important
Expert 26	Important	Important	Important	Important
Expert 27	Important	Important	Important	Important

Table 31 - Technological Perspective Validation Results (Panel P3)

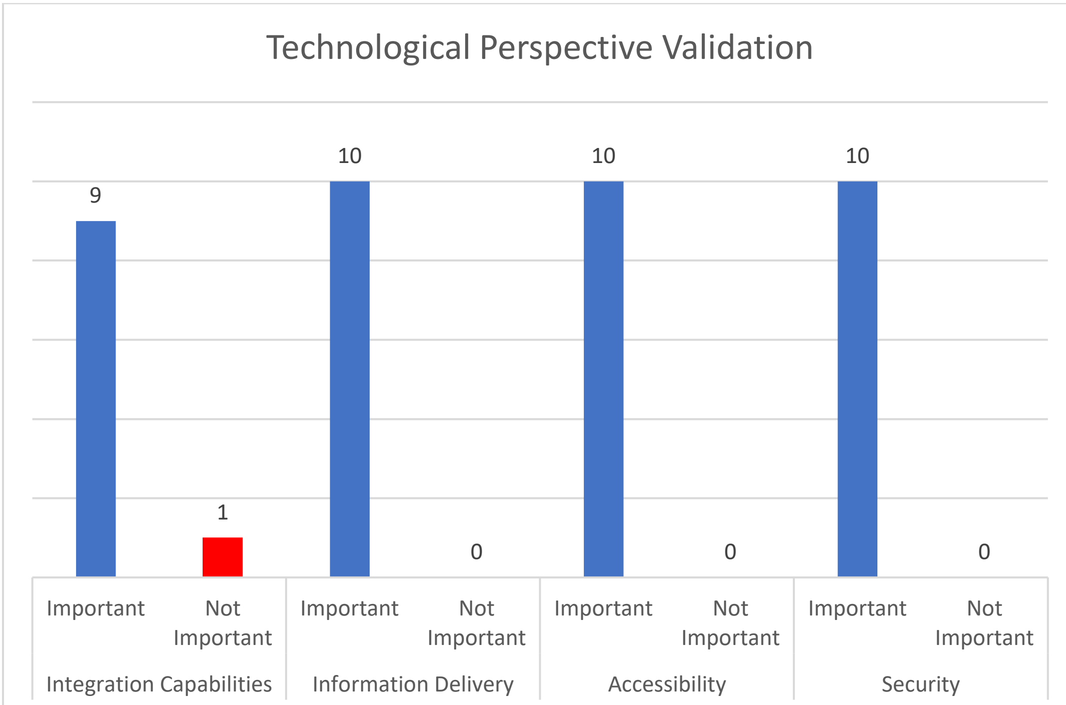

Figure 37 - Technological Perspective Validation

6.2.4 Validation of the Organizational Perspective Criteria

Panel P4 and its ten experts were presented the criteria of the Organizational perspective for validation. All ten experts validated the four criteria unanimously by confirming their importance is the global intent of this research. Figure 38 and Table 32 detail the results of this validation.

	Organizational Perspective			
Panel P4	**Investment Management**	**Leadership Support**	**Compliance**	**Change Management**
Expert 9	Important	Important	Important	Important
Expert 14	Important	Important	Important	Important
Expert 16	Important	Important	Important	Important
Expert 23	Important	Important	Important	Important
Expert 25	Important	Important	Important	Important
Expert 28	Important	Important	Important	Important
Expert 29	Important	Important	Important	Important
Expert 30	Important	Important	Important	Important
Expert 31	Important	Important	Important	Important
Expert 32	Important	Important	Important	Important

Table 32 - Organizational Perspective Validation Results (Panel P4)

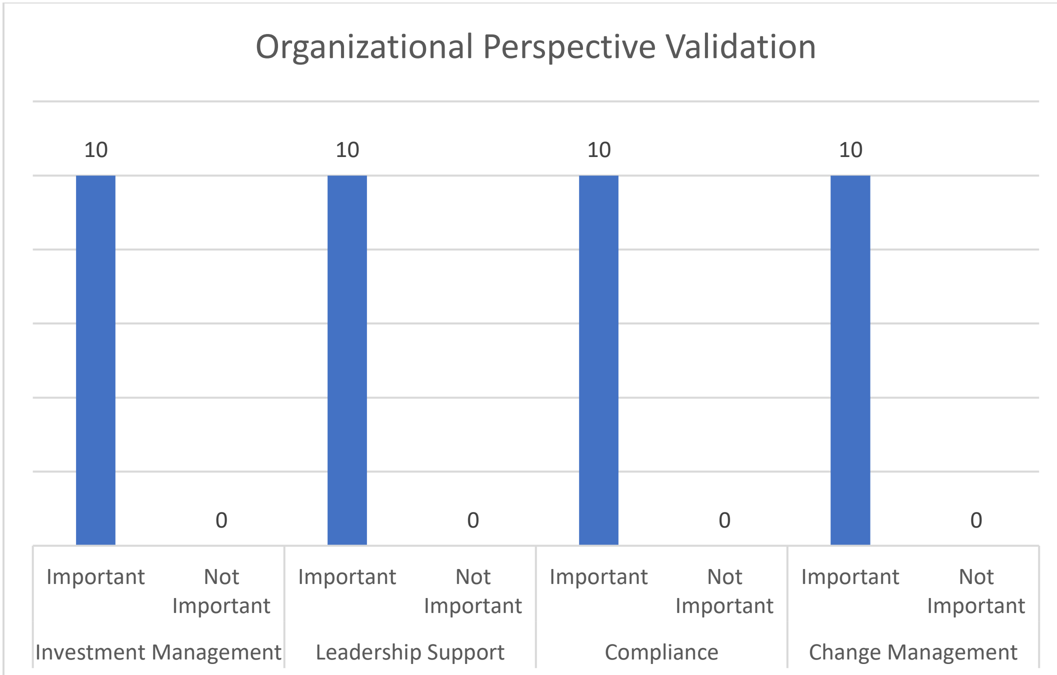

Figure 38 - Organizational Perspective Validation

6.2.5 Validation of the Cultural Perspective Criteria

The final validation step relies on Panel P5. Its eleven experts were in charge of validating the criteria from the Cultural perspective. All eleven experts validated the four criteria unanimously by confirming their importance is the global intent of this research. Figure 39 and Table 33 detail the results of this validation.

	Cultural Perspective			
Panel P5	**Perceived Usefulness**	**Flexibility of Use**	**Perceived Ease of Use**	**Stakeholder Engagement**
Expert 2	Important	Important	Important	Important
Expert 5	Important	Important	Important	Important
Expert 8	Important	Important	Important	Important
Expert 15	Important	Important	Important	Important
Expert 17	Important	Important	Important	Important
Expert 19	Important	Important	Important	Important
Expert 22	Important	Important	Important	Important
Expert 28	Important	Important	Important	Important
Expert 30	Important	Important	Important	Important
Expert 31	Important	Important	Important	Important
Expert 32	Important	Important	Important	Important

Table 33 - Cultural Perspective Validation Results (Panel P5)

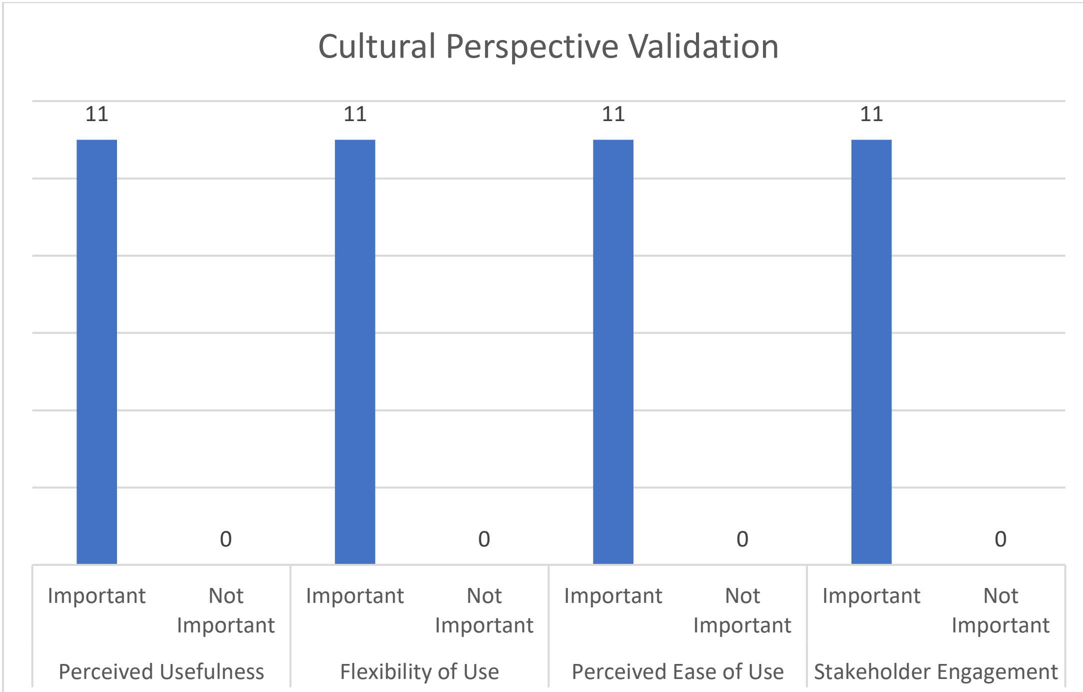

Figure 39 - Cultural Perspective Validation

6.2.6 Final HDM Model

The Validation process of the research framework concluded with complete validation of the HDM model that was refined by the Action Research process. Therefore the only change to the initial model was driven by the Action Research work on the Clinical perspective with the introduction of the Clinical Outcome criterion. The final model comprises four perspectives; four criteria are present under each perspective. Figure 40 shows the final HDM model that with which we will enter the next step of the Research Framework, the quantification.

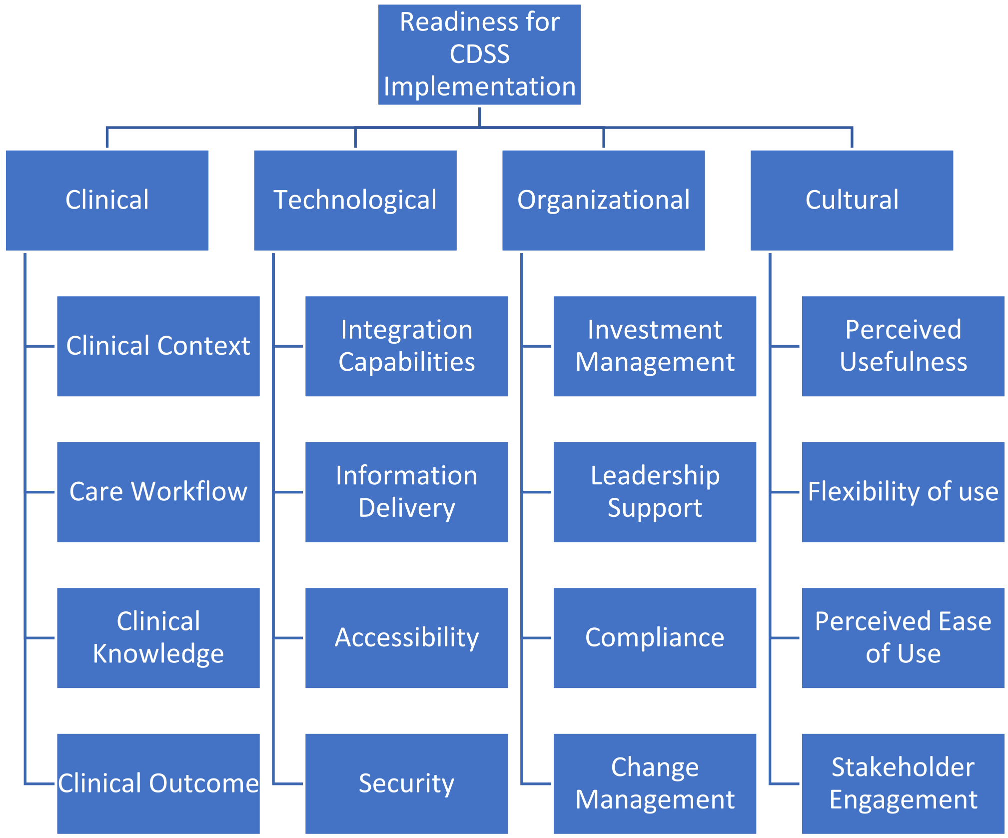

Figure 40 - Final HDM Model

6.3 Quantification of the HDM model

Now that a final and validated model is built, we enter the model quantification phase of the Research Framework. In this phase, expert panels P6 through P11 will provide inputs to quantify the different levels of the HDM model, as explained in Chapter 4.

As a reminder, the Hierarchical Decision Model is a derivative of the Analytic Hierarchy Process technique. It was first introduced to the literature in the early 80s by Kocaoglu (Kocaoglu, 1983). Analytic Hierarchy Processes bring us models and methods when decisions must be made in an uncertain environment harmonizing between several dimensions and perspectives (Daim & Kocaoglu, 2016).

Once the model is defined, it needs the input of subject matter experts who submit their subjective judgments on the different layers of the model's hierarchy using a pairwise comparison approach. At each level, the experts are in charge of weighing the components of the model against each other. The model then computes the judgments following the mathematical logic (Kocaoglu, 1983):

$$\boldsymbol{M} = \sum_{k=1}^{K} \sum_{jk=1}^{JK} \boldsymbol{P}_k \times \boldsymbol{C}_{jk} \times \boldsymbol{D}_{jk}$$

Where M= Maturity Score, K=Number of Perspectives, J= Number of Criteria, Pk= Weight of Perspective, Cjk= Relative importance of criterion (jth) for Perspective (kth), and D(jk)= Desirability value of criterion (jth) for Perspective (kth)

Using the HDM open-source tool developed by the Engineering and Technology Management department of Portland State University, the quantification of the model was slipt into five separate phases. One to quantify the perspectives against each other, and four others to quantify the criteria for each perspective of the HDM model. Screenshots of the tool's interface are provided in Appendix C.

6.3.1 Quantification of the HDM model Perspectives

Panel P6 groups twelve experts in charge of quantifying the first layer of the HDM model. Through this process, the experts will weigh each of the four perspectives against each other. The results have been collected in the HDM tool and are displayed in the tables and the figure below.

Panel P6	**Clinical**	**Technological**	**Organizational**	**Cultural**	**Inconsistency**
Expert 11	0.36	0.23	0.22	0.19	**0**
Expert 15	0.36	0.24	0.22	0.18	**0.01**
Expert 17	0.34	0.28	0.21	0.18	**0.01**
Expert 19	0.33	0.26	0.2	0.21	**0**
Expert 1	0.36	0.29	0.18	0.18	**0.01**
Expert 21	0.34	0.25	0.22	0.19	**0.01**
Expert 23	0.35	0.27	0.21	0.18	**0**
Expert 27	0.34	0.26	0.22	0.18	**0.01**
Expert 31	0.37	0.23	0.22	0.18	**0**
Expert 4	0.34	0.27	0.22	0.18	**0**
Expert 7	0.31	0.26	0.23	0.2	**0**
Expert 9	0.34	0.24	0.23	0.18	**0**
Mean	**0.35**	**0.26**	**0.22**	**0.19**	
Minimum	**0.31**	**0.23**	**0.18**	**0.18**	
Maximum	**0.37**	**0.29**	**0.23**	**0.21**	
Std. Deviation	**0.02**	**0.02**	**0.01**	**0.01**	
Disagreement					**0.013**

Table 34 - Perspective Quantification Results (Panel P6)

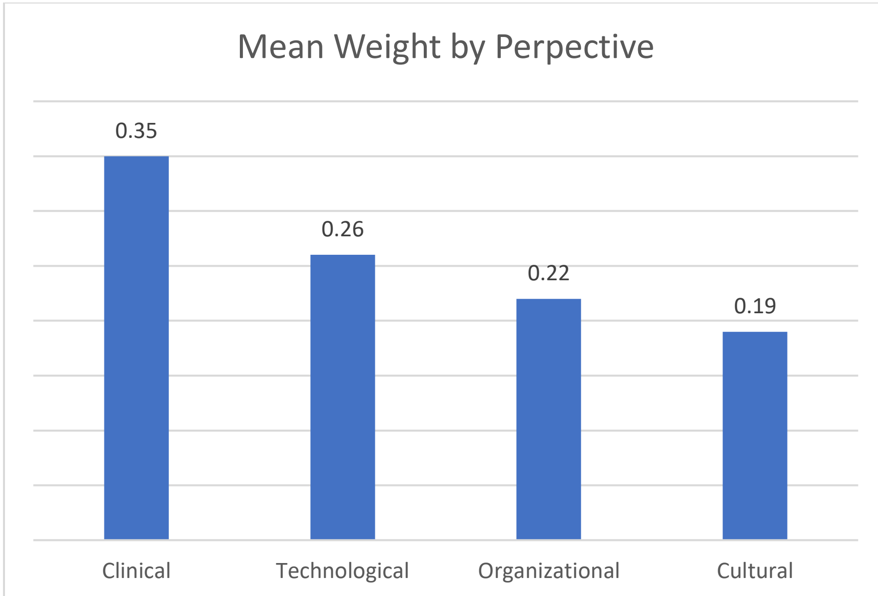

Figure 41 - Mean Weights by Perspective

Rank	Perspective	Mean Weight
1	Clinical	0.35
2	Technological	0.26
3	Organizational	0.22
4	Cultural	0.19

Table 35 - Model's Perspectives Ranking

This quantification concluded with a clear ranking. The Clinical perspective ranked first with a mean weight of 0.35, followed by the Technological perspective, weighted at 0.26; then comes the Organizational perspective at 0.22, and finally, the Cultural perspective at 0.19.

The inconstancies and disagreement values remain at an acceptable level based on the HDM literature (Alzahrani, 2021; Daim & Kocaoglu, 2016; Hogaboam et al., 2014; Kocaoglu, 1983; Shaygan, 2021).

6.3.2 Quantification of the Clinical perspective's criteria

Panel P7 groups twelve experts in charge of quantifying the criteria from the Clinical perspective. Through this process, the experts will weigh each of the four criteria against each other. The results have been collected in the HDM tool and are displayed in the tables and the figure below.

Panel P7	**Clinical Context**	**Care Workflow**	**Clinical Knowledge**	**Clinical Outcome**	**Inconsistency**
Expert 11	0.2	0.17	0.34	0.29	**0.02**
Expert 12	0.22	0.2	0.32	0.26	**0.01**
Expert 13	0.22	0.16	0.34	0.27	**0.01**
Expert 18	0.2	0.18	0.36	0.26	**0.01**
Expert 19	0.23	0.19	0.33	0.25	**0.03**
Expert 1	0.22	0.18	0.34	0.26	**0**
Expert 20	0.22	0.2	0.3	0.28	**0**
Expert 3	0.22	0.2	0.33	0.25	**0**
Expert 4	0.21	0.18	0.35	0.26	**0**
Expert 6	0.2	0.18	0.36	0.26	**0.01**
Expert 7	0.22	0.18	0.34	0.26	**0.01**
Expert 8	0.24	0.21	0.3	0.26	**0.02**
Mean	**0.22**	**0.19**	**0.33**	**0.26**	
Minimum	**0.2**	**0.16**	**0.3**	**0.25**	
Maximum	**0.24**	**0.21**	**0.36**	**0.29**	
Std. Deviation	**0.01**	**0.01**	**0.02**	**0.01**	
Disagreement					**0.013**

Table 36 - Clinical Perspective Quantification Results (Panel P7)

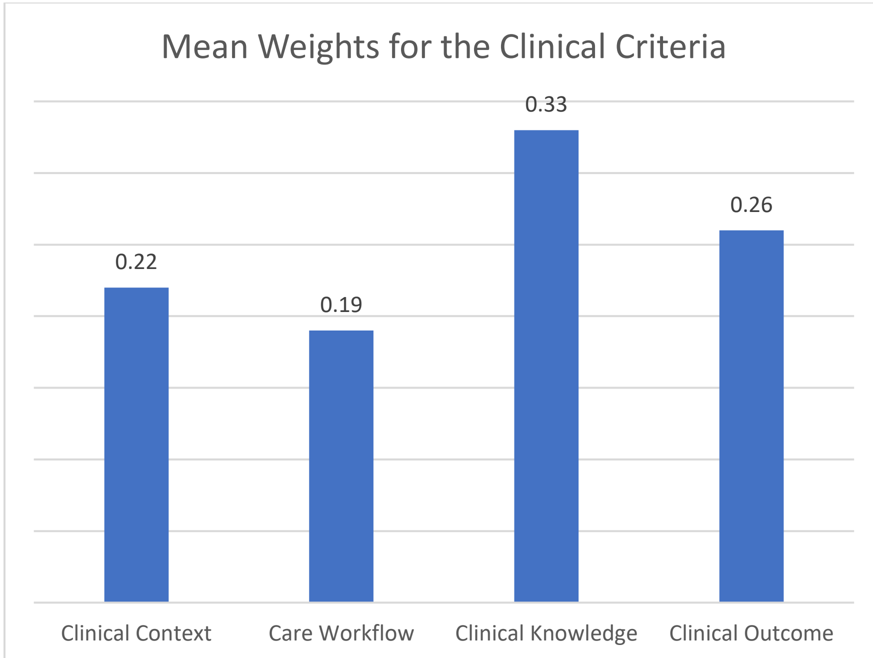

Figure 42 - Mean Weights by Clinical Criterion

Rank	Clinical Criteria	Mean Weight
1	Clinical Knowledge	0.33
2	Clinical Outcome	0.26
3	Clinical Context	0.22
4	Care Workflow	0.19

Table 37 - Clinical Criteria Ranking

This quantification concluded with a clear ranking. The Clinical Knowledge ranked first with a mean weight of 0.33, followed by the Clinical Outcome, weighted at 0.26; then comes the Clinical Context at 0.22, and finally, the Care Workflow at 0.19.

The inconstancies and disagreement values remain at an acceptable level based on the HDM literature (Alzahrani, 2021; Daim & Kocaoglu, 2016; Hogaboam et al., 2014; Kocaoglu, 1983; Shaygan, 2021).

6.3.3 Quantification of the Technological perspective's criteria

Panel P8 groups ten experts in charge of quantifying the criteria from the Technological perspective. Through this process, the experts will weigh each of the four criteria against each other. The results have been collected in the HDM tool and are displayed in the tables and the figure below.

Panel P8	**Integration Capabilities**	**Information Delivery**	**Accessibility**	**Security**	**Inconsistency**
Expert 11	0.22	0.37	0.15	0.26	**0.01**
Expert 12	0.19	0.4	0.14	0.27	**0.01**
Expert 13	0.21	0.32	0.2	0.27	**0**
Expert 15	0.21	0.35	0.17	0.27	**0**
Expert 22	0.22	0.34	0.2	0.24	**0.01**
Expert 24	0.19	0.37	0.19	0.25	**0.01**
Expert 25	0.23	0.3	0.2	0.27	**0**
Expert 26	0.24	0.31	0.19	0.26	**0.01**
Expert 27	0.24	0.3	0.21	0.25	**0**
Expert 28	0.23	0.31	0.2	0.26	**0**
Mean	**0.22**	**0.34**	**0.19**	**0.26**	
Minimum	**0.19**	**0.3**	**0.14**	**0.24**	
Maximum	**0.24**	**0.4**	**0.21**	**0.27**	
Std. Deviation	**0.02**	**0.03**	**0.02**	**0.01**	
Disagreement					**0.021**

Table 38 - Technological Criteria Quantification Results (Panel P8)

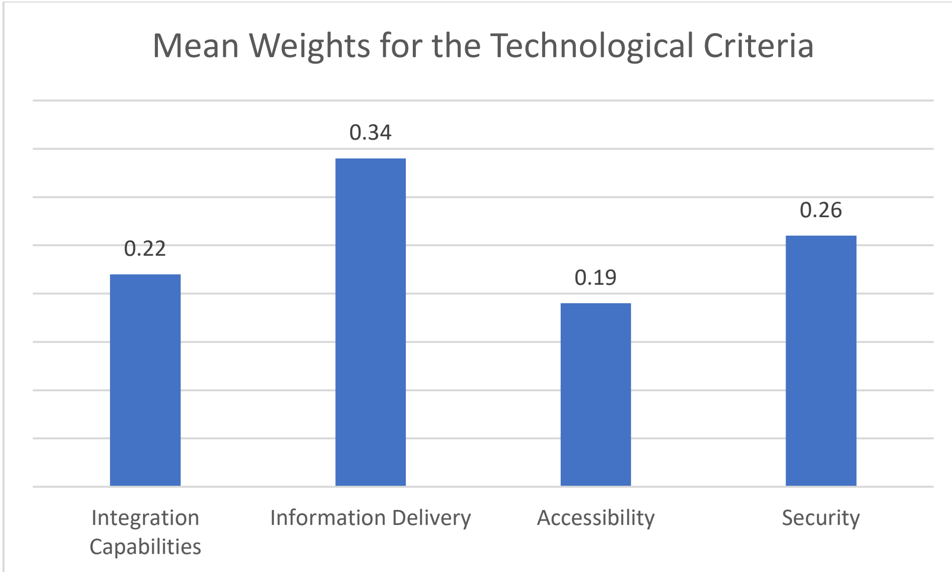

Figure 43 - Mean Weights by Technological Criterion

Rank	Technological Criteria	Mean Weight
1	Information Delivery	0.34
2	Security	0.26
3	Integration Capabilities	0.22
4	Accessibility	0.19

Table 39 - Technological Criteria Ranking

This quantification concluded with a clear ranking. The Information Delivery ranked first with a mean weight of 0.34, followed by the Security, weighted at 0.26; then comes the Integration Capabilities at 0.22, and finally, the Accessibility at 0.19.

The inconstancies and disagreement values remain at an acceptable level based on the HDM literature (Alzahrani, 2021; Daim & Kocaoglu, 2016; Hogaboam et al., 2014; Kocaoglu, 1983; Shaygan, 2021).

6.3.4 Quantification of the Organizational perspective's criteria

Panel P9 groups eleven experts in charge of quantifying the criteria from the Organizational perspective. Through this process, the experts will weigh each of the four criteria against each other. The results have been collected in the HDM tool and are displayed in the tables and the figure below.

Organizational	**Investment Management**	**Leadership Support**	**Compliance**	**Change Management**	**Inconsistency**
Expert 13	0.33	0.38	0.16	0.12	**0.01**
Expert 16	0.26	0.38	0.2	0.16	**0.04**
Expert 21	0.28	0.3	0.24	0.18	**0.01**
Expert 23	0.26	0.35	0.21	0.18	**0.01**
Expert 25	0.23	0.43	0.21	0.13	**0.02**
Expert 28	0.26	0.36	0.22	0.17	**0.01**
Expert 29	0.28	0.39	0.17	0.16	**0.02**
Expert 30	0.31	0.36	0.19	0.15	**0.01**
Expert 31	0.28	0.34	0.21	0.17	**0.02**
Expert 32	0.27	0.38	0.2	0.15	**0.01**
Expert 9	0.27	0.34	0.21	0.18	**0.02**
Mean	**0.28**	**0.36**	**0.2**	**0.16**	
Minimum	**0.23**	**0.3**	**0.16**	**0.12**	
Maximum	**0.33**	**0.43**	**0.24**	**0.18**	
Std. Deviation	**0.03**	**0.03**	**0.02**	**0.02**	
Disagreement					**0.022**

Table 40 - Organizational Criteria Quantification Results (Panel P9)

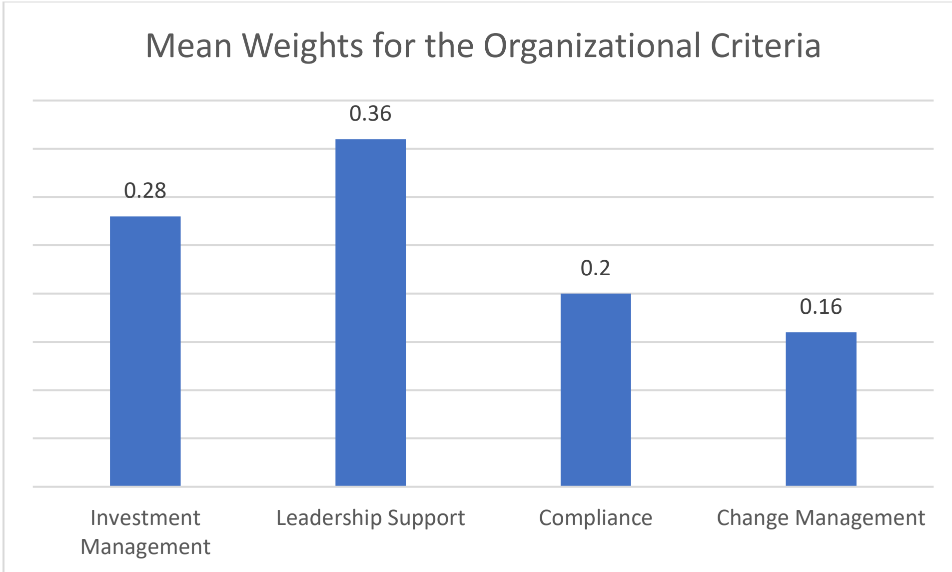

Figure 44 - Mean Weights by Organizational Criterion

Rank	Technological Criteria	Mean Weight
1	Leadership Support	0.36
2	Investment Management	0.28
3	Compliance	0.20
4	Change Management	0.16

Table 41 - Organizational Criteria Ranking

This quantification concluded with a clear ranking. Leadership Support ranked first with a mean weight of 0.36, followed by Investment Management, weighted at 0.28; then comes Compliance at 0.20, and finally, Change Management at 0.16.

The inconstancies and disagreement values remain at an acceptable level based on the HDM literature (Alzahrani, 2021; Daim & Kocaoglu, 2016; Hogaboam et al., 2014; Kocaoglu, 1983; Shaygan, 2021).

6.3.5 Quantification of the Cultural perspective's criteria

Panel P10 groups eleven experts in charge of quantifying the criteria from the Cultural perspective. Through this process, the experts will weigh each of the four criteria against each other. The results have been collected in the HDM tool and are displayed in the tables and the figure below.

Cultural	**Perceived Usefulness**	**Flexibility of Use**	**Perceived Ease of Use**	**Stakeholder Engagement**	**Inconsistency**
Expert 13	0.17	0.16	0.07	0.6	**0.04**
Expert 14	0.15	0.17	0.13	0.55	**0.08**
Expert 19	0.21	0.19	0.13	0.47	**0.03**
Expert 28	0.27	0.21	0.15	0.37	**0.02**
Expert 29	0.23	0.19	0.15	0.42	**0.02**
Expert 30	0.27	0.2	0.13	0.4	**0.01**
Expert 31	0.26	0.15	0.12	0.47	**0.04**
Expert 32	0.31	0.17	0.13	0.38	**0.03**
Expert 3	0.28	0.23	0.16	0.33	**0.01**
Expert 4	0.24	0.2	0.14	0.42	**0.02**
Expert 8	0.2	0.16	0.11	0.53	**0.02**
Mean	**0.24**	**0.18**	**0.13**	**0.45**	
Minimum	**0.15**	**0.15**	**0.07**	**0.33**	
Maximum	**0.31**	**0.23**	**0.16**	**0.6**	
Std. Deviation	**0.05**	**0.02**	**0.02**	**0.08**	
Disagreement					**0.043**

Table 42 - Cultural Criteria Quantification Results (Panel P10)

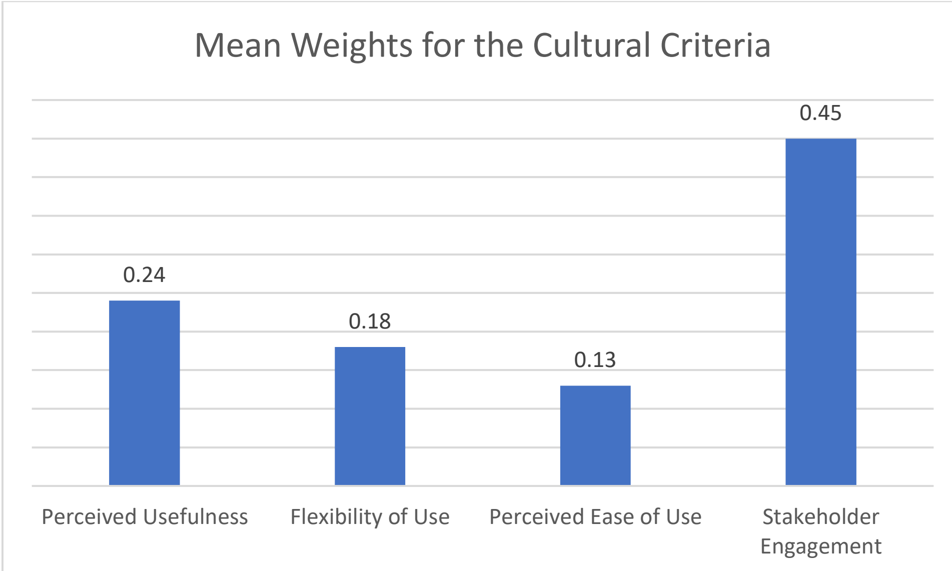

Figure 45 - Mean Weights by Cultural Criterion

Rank	Technological Criteria	Mean Weight
1	Stakeholder Engagement	0.45
2	Perceived Usefulness	0.24
3	Flexibility of Use	0.18
4	Perceived Ease of Use	0.13

Table 43 - Cultural Criteria Ranking

This quantification concluded with a clear ranking. Leadership Support ranked first with a mean weight of 0.45, followed by Perceived Usefulness, weighted at 0.24; then comes Flexibility of Use at 0.18, and finally, Perceived Ease of Use at 0.13.

The inconstancies and disagreement values remain at an acceptable level based on the HDM literature (Alzahrani, 2021; Daim & Kocaoglu, 2016; Hogaboam et al., 2014; Kocaoglu, 1983; Shaygan, 2021).

6.3.6 Global Model Quantification

Now that the HDM model has been fully validated and quantified, we can build the global quantification view that summarizes all the perspectives and underlying criteria. Table 44 and Figure 46 display this global view. As the Clinical perspective stands with the highest weight, its criteria reflect the perspective's importance by ranking top globally in the model. Indeed, the Clinical Knowledge criterion stands out as the top-ranked criterion in the model, followed by the Clinical Outcome criterion. In the three other perspectives, Information Delivery, Leadership Support, and Stakeholder Engagement lead the weights ranking for the Technological, Organizational, and Cultural perspectives, respectively.

Perspectives	Perspective Weight	Criteria	Criteria Local Weight	Criteria Global Weight
Clinical	0.345	Clinical Context	22%	7.6%
		Care Workflow	19%	6.5%
		Clinical Knowledge	33%	11.4%
		Clinical Outcome	26%	9.0%
Technological	0.256	Integration Capabilities	22%	5.6%
		Information Delivery	34%	8.7%
		Accessibility	19%	4.9%
		Security	26%	6.7%
Organizational	0.215	Investment Management	28%	6.0%
		Leadership Support	36%	7.7%
		Compliance	20%	4.3%
		Change Management	16%	3.4%
Cultural	0.186	Perceived Usefulness	24%	4.5%
		Flexibility of Use	18%	3.3%
		Perceived Ease of Use	13%	2.4%
		Stakeholder Engagement	45%	8.4%

Table 44 - Global HDM Model Quantification

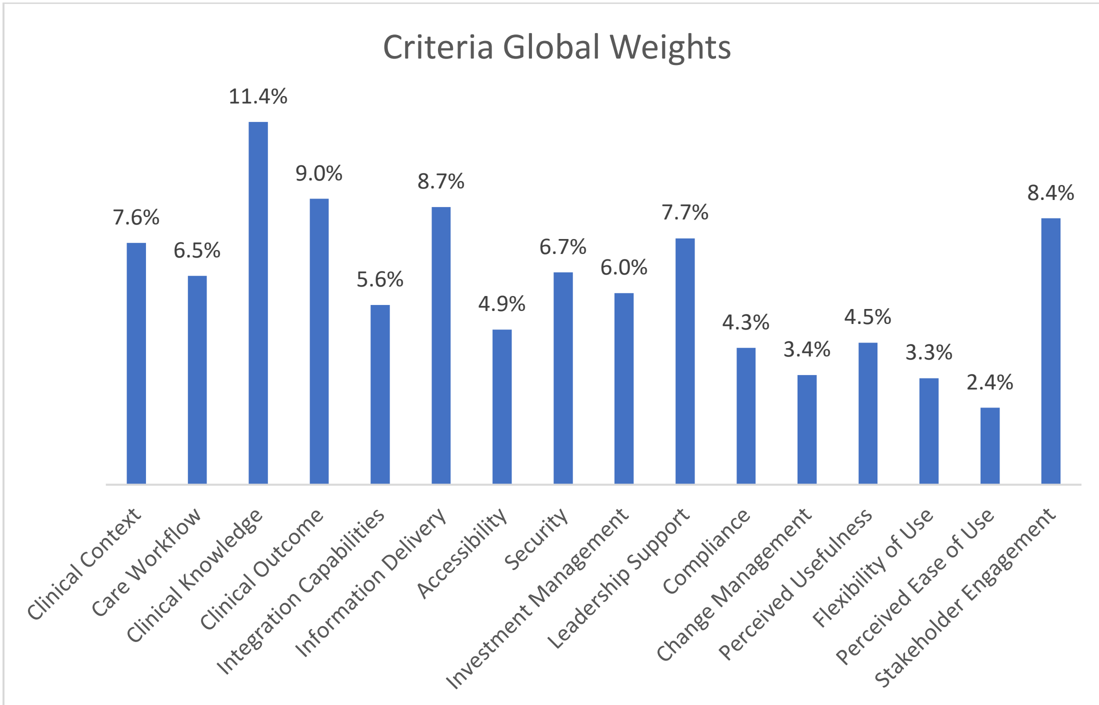

Figure 46 - Model Criteria Global Weights

6.3.7 Inconsistency and Disagreement Analysis

As explained in section 4.6, when weighing an HDM model, experts can express a judgment that contradicts their own previous judgment. This inconsistency is driven by the expert's behavior variance when quantifying the HDM model. HDM accounts for this inconsistency to validate the robustness of the model's results. The acceptable threshold for inconsistency in HDM has been identified as 10% (Kocaoglu, 1983).

Similarly, as pointed out in section 4.7, a disagreement happens when no consensual judgment is found between experts for a given question (Daim & Kocaoglu, 2016). Disagreement is expected among experts. It is completely natural in a panel to have conflicting points of view. However, the validity of the model relies on a general agreement about the problem studied. That is why, similarly to inconsistencies, a threshold should be introduced. The threshold of disagreement has been set in the literature at 10%, similar to the inconsistencies threshold (H. Chen & Kocaoglu, 2008; Daim & Kocaoglu, 2016; Kocaoglu, 1983).

In the quantification of our HDM model, all the inconsistency levels and disagreement levels were under the threshold of 10%. Based on this analysis, the model can be taken to the next step of the Research Framework so that desirabilities can be applied and application cases can be studied.

6.4 Desirability Levels

Building upon the initial model work presented in Chapter 5, the intent of this section is to quantify the desirability levels for each criterion of the HDM model. The desirability levels identified through the Literature Review and Action Research are presented to the experts of Panel P11 to quantify the levels based on their desirabilities.

A Qualtrix survey was used as a quantification tool for this section.

The following tables and figures present the desirability levels gathered from the experts.

6.4.1 Desirability Levels for the Clinical Perspective Criteria

Clinical Context

Clinical Context Levels	**Desirability**
Not framed, not identified	5%
Framed, considerable changes	52%
Framed, limited changes	90%
Framed and completely set	100%

Table 45 - Clinical Context Desirability Levels and Quantification

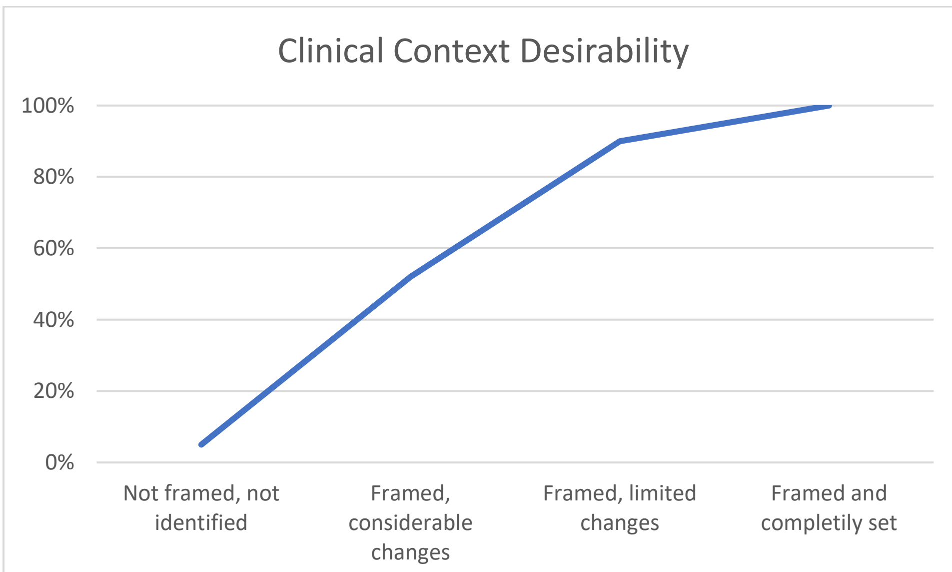

Figure 47 - Clinical Context Desirability Curve

Clinical Workflow

Clinical Workflow Levels	Desirability
No workflows	2%
Multiple and diverse workflows	36%
Multiple but similar workflows	80%
One unique workflow	100%

Table 46 - Clinical Workflow Desirability Levels and Quantification

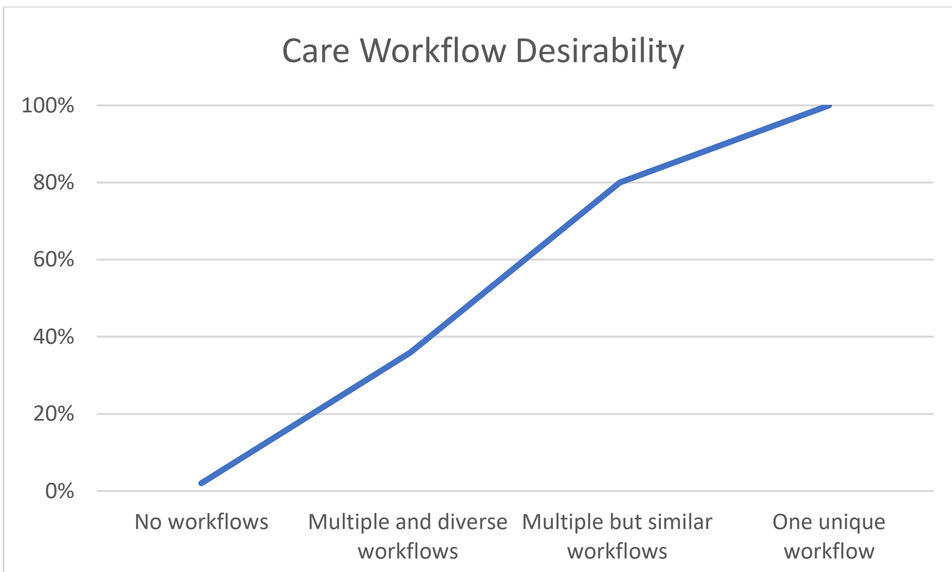

Figure 48 - Clinical Workflow Desirability Curve

Clinical Knowledge

Clinical Knowledge Levels	**Desirability**
Constantly changing, ongoing research and breakthroughs	0%
Consensual with limited research activity	60%
Globally accepted and set	100%

Table 47 - Clinical Knowledge Desirability Levels and Quantification

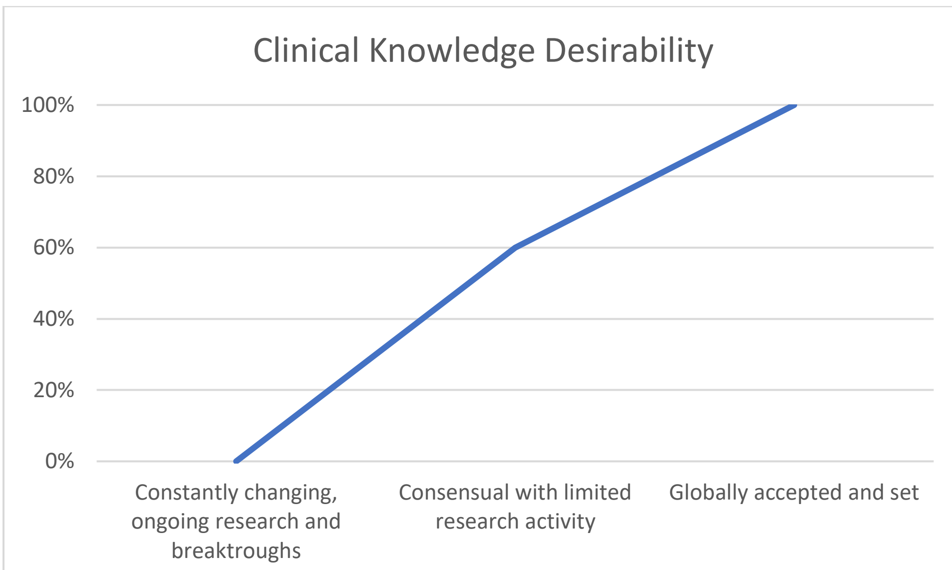

Figure 49 - Clinical Knowledge Desirability Curve

Clinical Outcome

Clinical Outcome Levels	Desirability
No definition of the desired Clinical Outcome	2%
Unclear characterization of desired Clinical Outcome	32%
Varying desired Clinical Outcome	72%
Structured and uniformized desired Clinical Outcome	100%

Table 48 - Clinical Outcome Desirability Levels and Quantification

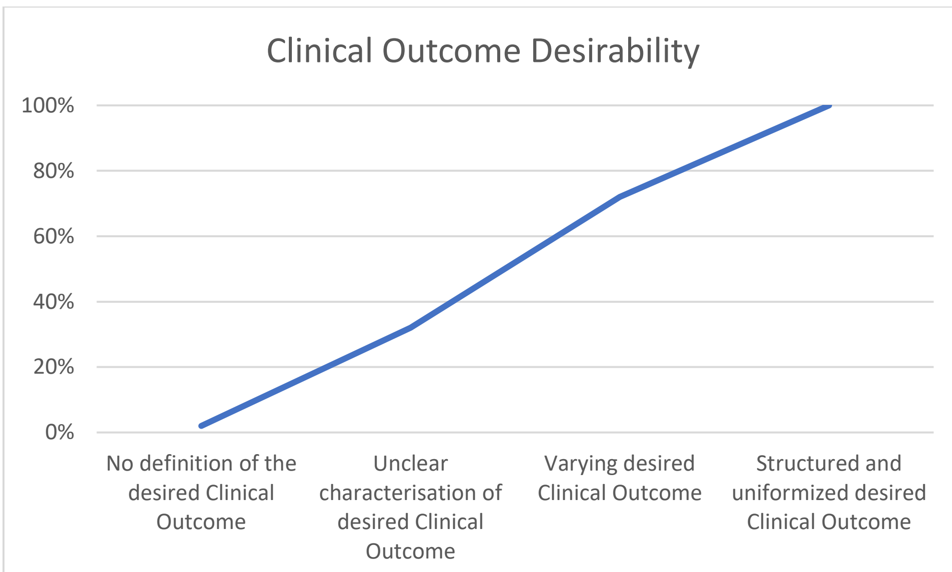

Figure 50 - Clinical Outcome Desirability Curve

6.4.2 Desirability Levels for the Technological Perspective Criteria

Integration Capabilities

Integration Capabilities Levels	Desirability
Not existing	7%
Limited	58%
Strong	80%
Exhaustive	100%

Table 49 – Integration Capabilities Desirability Levels and Quantification

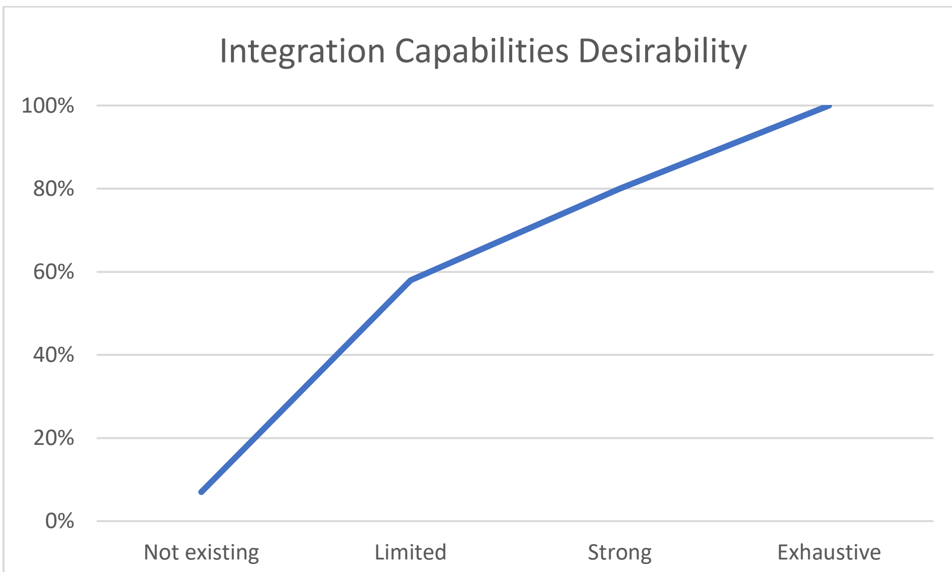

Figure 51 - Integration Capabilities Desirability Curve

Information Delivery

Information Delivery Levels	**Desirability**
Not existing	0%
Manual: needs the provider to request it	80%
Dynamic: adapts to the clinical context	100%

Table 50 - Information Delivery Desirability Levels and Quantification

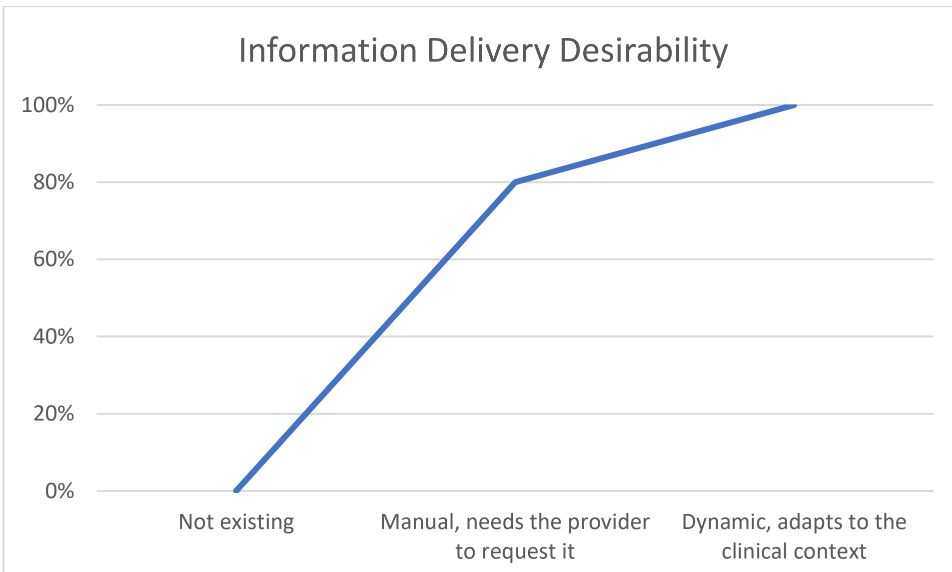

Figure 52 - Information Delivery Desirability Curve

Accessibility

Accessibility Levels	Desirability
None	7%
Limited	45%
Medium	90%
Strong	100%

Table 51 - Accessibility Levels Desirability Levels and Quantification

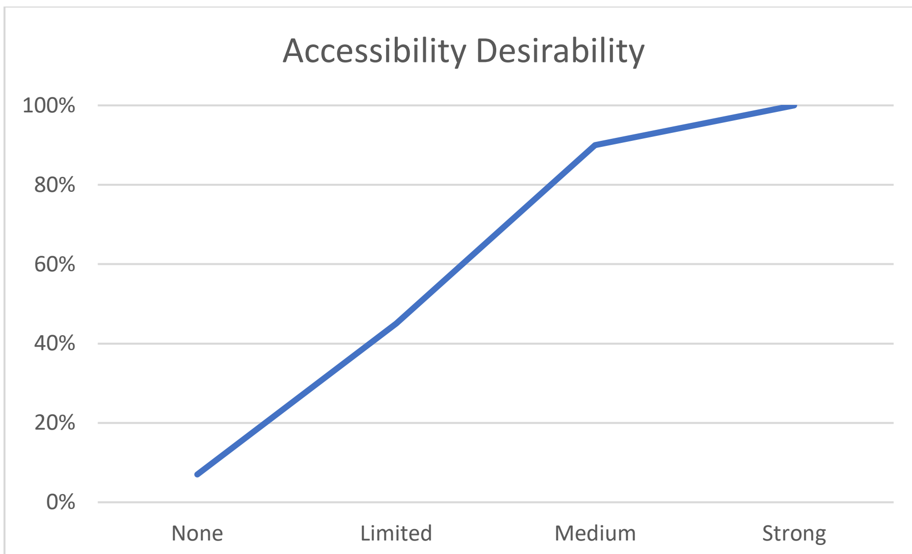

Figure 53 - Accessibility Desirability Curve

Security

Security Levels	**Desirability**
No security practices	0%
Limited practices	10%
Critical systems are safe	60%
All systems are safe	100%

Table 52 – Security Desirability Levels and Quantification

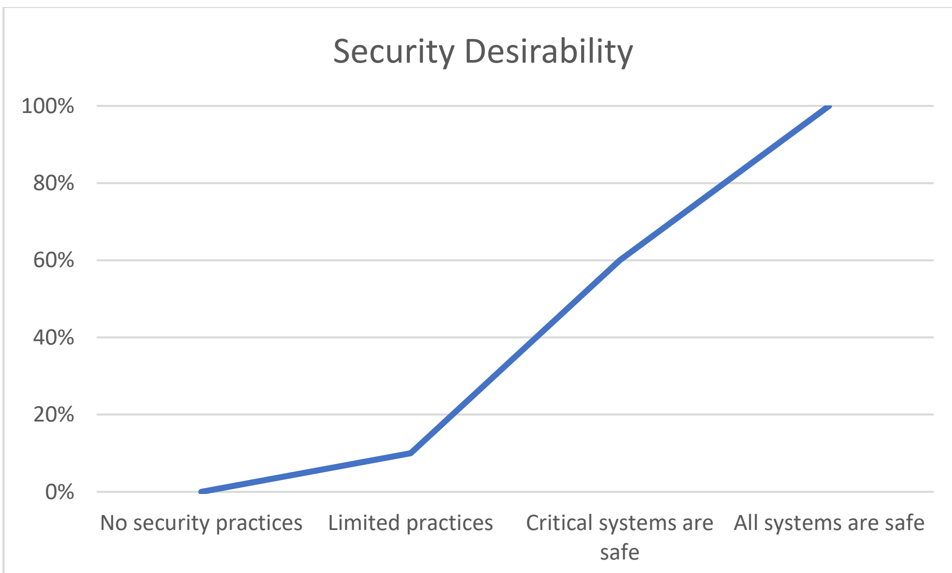

Figure 54 - Security Desirability Curve

6.4.3 Desirability Levels for the Organizational Perspective Criteria

Investment Management

Investment Management Levels	Desirability
No skills	10%
Limited skills	40%
Complete skillset	100%

Table 53 – Investment Management Levels and Quantification

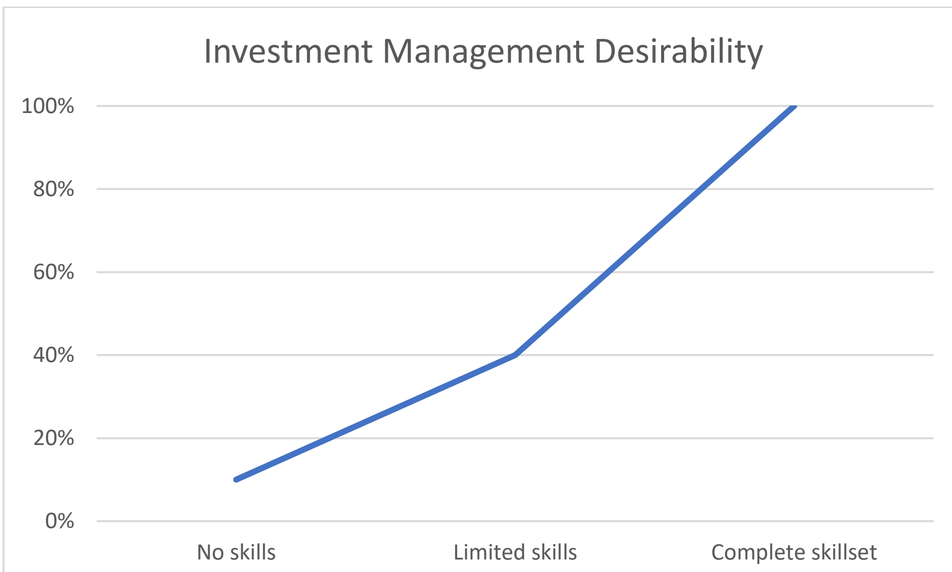

Figure 55 - Investment Management Desirability Curve

Leadership Support

Leadership Support Levels	Desirability
None	0%
Low	10%
Medium	63%
High	100%

Table 54 - Leadership Support Levels and Quantification

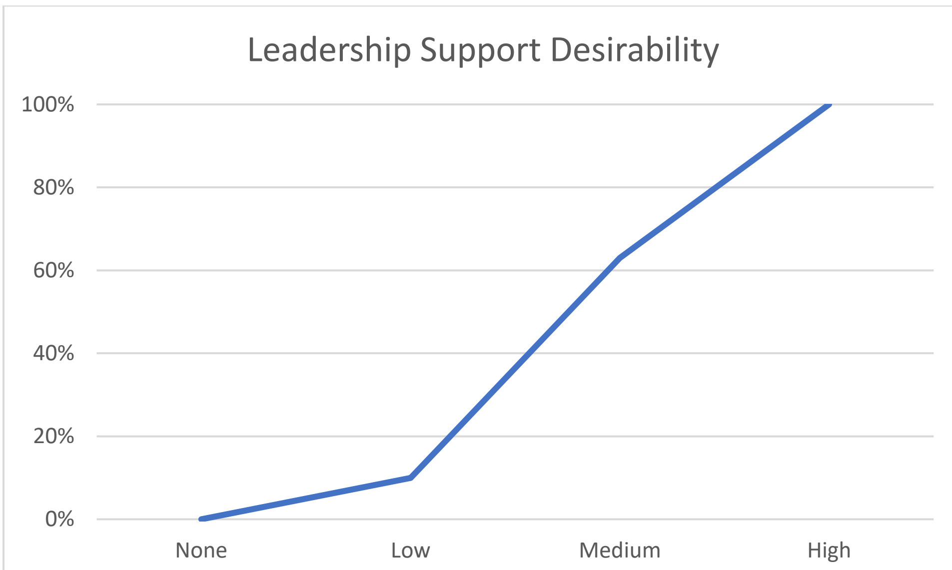

Figure 56 - Leadership Support Desirability Curve

Compliance

Compliance Levels	Desirability
Not compliant	0%
Compliant	100%

Table 55 - Compliance Levels and Quantification

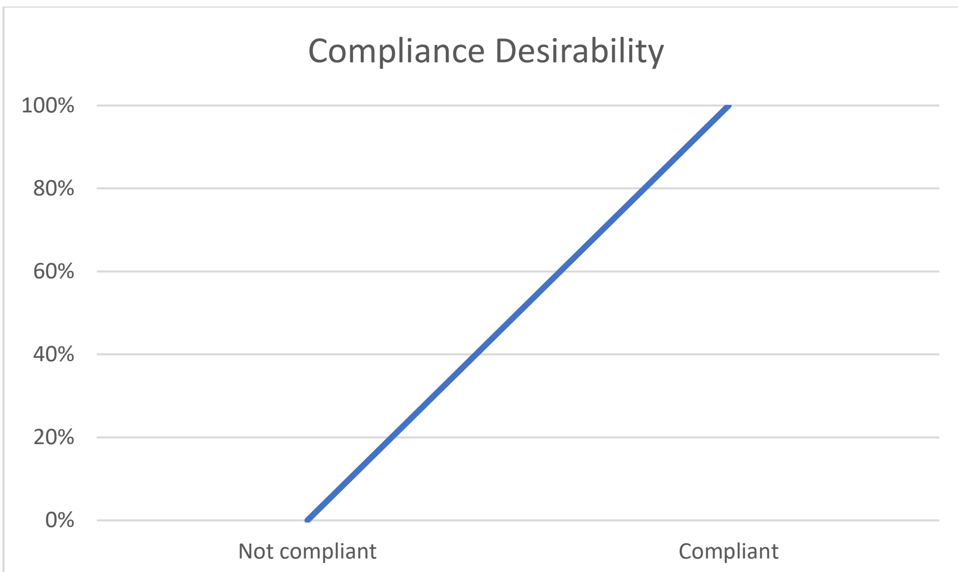

Figure 57 - Compliance Desirability Curve

Change Management

Change Management Levels	Desirability
Not existent	15%
Limited	50%
Advanced	90%
Expert	100%

Table 56 - Change Management Levels and Quantification

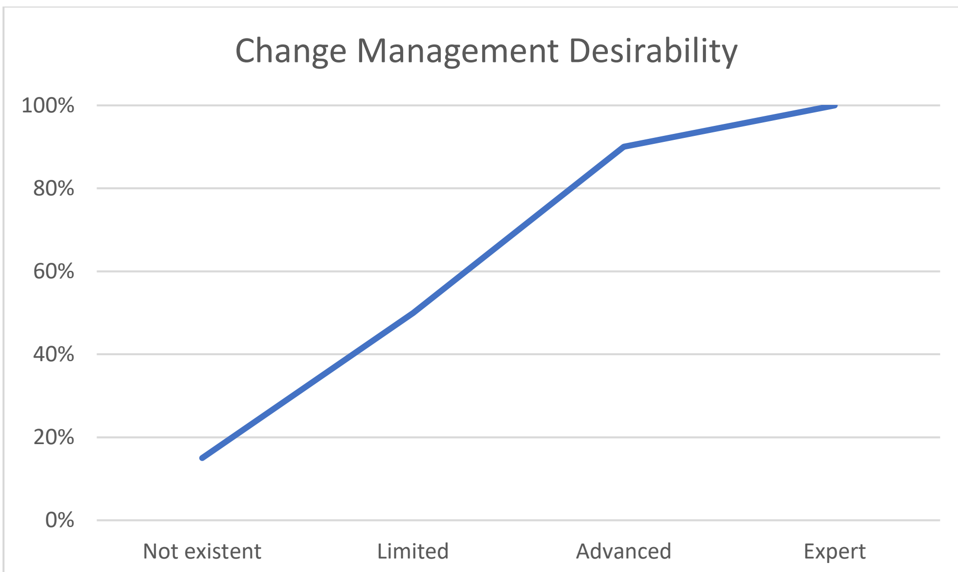

Figure 58 - Change Management Desirability Curve

6.4.4 Desirability Levels for the Cultural Perspective Criteria

Perceived Usefulness

Perceived Usefulness Levels	**Desirability**
None	0%
Low	25%
Medium	75%
High	100%

Table 57 - Perceived Usefulness Levels and Quantification

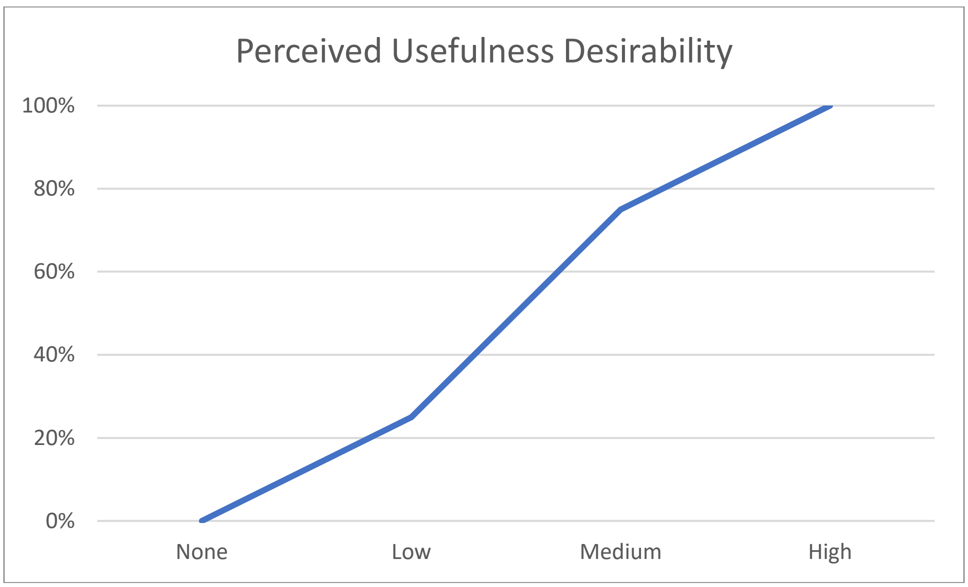

Figure 59 - Perceived Usefulness Desirability Curve

Flexibility of Use

Flexibility of Use Levels	Desirability
None	7%
Medium	72%
High	100%

Table 58 - Flexibility of Use Levels and Quantification

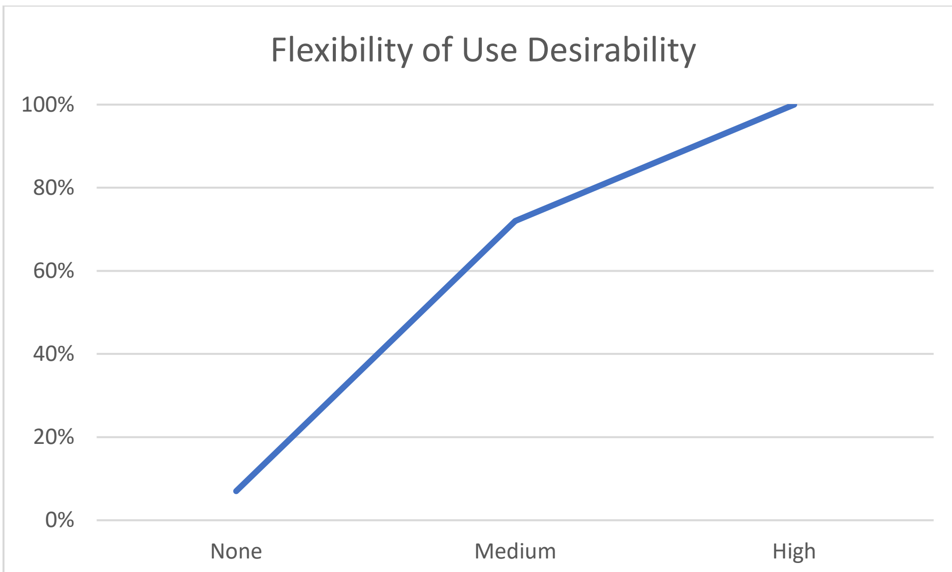

Figure 60 - Flexibility of Use Desirability Curve

Stakeholder Engagement

Stakeholder Engagement Levels	Desirability
No engagement practices	0%
Some engagement pratices	23%
Embedded in the implementation project	100%

Table 59 - Stakeholder Engagement Levels and Quantification

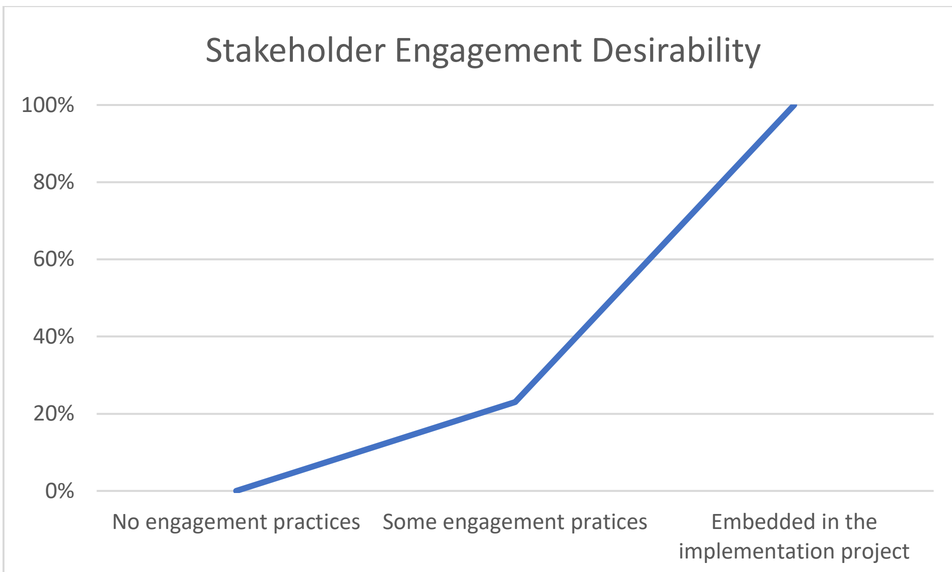

Figure 61 - Stakeholder Engagement Desirability Curve

Perceived Ease of Use

Perceived Ease of Use Levels	Desirability
None	0%
Low	25%
Medium	75%
High	100%

Table 60 - Perceived Ease of Use Levels and Quantification

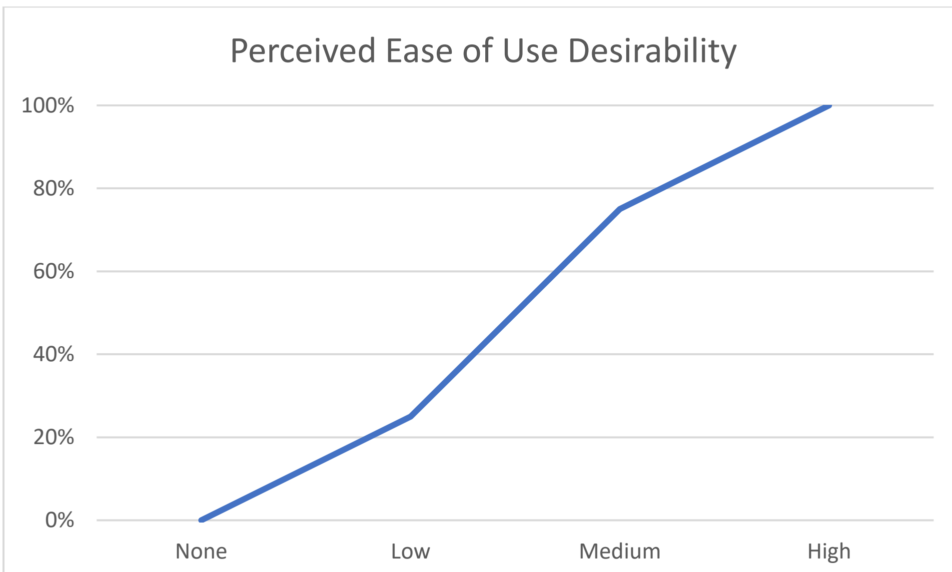

Figure 62 - Perceived Ease of Use Desirability Curve

CHAPTER 7 – CASE STUDIES

This chapter aims to convey the applicability of the HDM model built through the research framework by presenting two case studies where the model can provide added value to real-world organizational challenges related to the adoption of Clinical Decision Support Systems.

Case studies are essential to HDM-based research as they provide an in-depth understanding of how AHP can be applied in real-world scenarios. A case study involves the investigation and analysis of a specific situation or phenomenon, and it enables researchers to identify the factors that influence decision-making and the choices made.

Also, case studies provide a way for researchers to understand how HDM models can be used to address complex decision-making problems in various fields and in our particular research framework, Healthcare. Case studies also allow for the exploration of the practical implementation of HDM models. They provide an opportunity to examine the decision-making process, including the identification of criteria and alternatives, the evaluation of criteria, and the synthesis of results. Through case studies, researchers can also identify the strengths and limitations of HDM models and make recommendations for their future use.

Two cases will be presented. The first one will present a traditional use of our HDM model where an organization will assess its readiness for implementing Clinical Decision Support Systems and use the results to explore options to improve its chances of successful adoption of CDSS. The second one will present an unconventional use of the HDM model from a CDSS vendor perspective. In the latter case, the idea is to apply the model to a prospective client and adopt the CDSS tool for a successful deal close and higher customer satisfaction.

7.1 Case Study 1: CDSS Adoption in the Context of a Medical Center Acquisition

7.1.1 Background

Medical Centers in the United States

Medical centers are essential institutions that provide a range of healthcare services to individuals and communities in the United States. These centers are usually large, comprehensive facilities that offer a wide range of medical services, including primary care, specialty care, and emergency care.

In the United States, medical centers are typically operated by hospitals, academic institutions, or private corporations. They are staffed by a team of healthcare professionals, including physicians, nurses, pharmacists, and other allied health professionals, who work together to provide coordinated and high-quality care to patients.

Medical centers play a critical role in the US healthcare system, serving as hubs of medical innovation and research, as well as providing care to patients with complex medical conditions. Many medical centers are also involved in clinical trials and research studies, which help to advance medical knowledge and improve patient outcomes.

One of the most well-known medical centers in the United States is the Mayo Clinic, located in Rochester, Minnesota. The Mayo Clinic is a world-renowned medical institution that provides a range of healthcare services, including cancer care, cardiology, neurology, and transplant services. The clinic is known for its patient-centered approach, which focuses on providing personalized care and treatment plans to each patient.

Another well-known medical center is the Cleveland Clinic, located in Cleveland, Ohio. The Cleveland Clinic is a non-profit academic medical center that provides a range of healthcare services, including cardiology, neurology, and oncology. The clinic is also known for its research and innovation in healthcare, with a focus on improving patient outcomes and advancing medical knowledge.

In addition to these large medical centers, there are also many community-based medical centers throughout the United States. These centers provide essential primary care services to individuals and families in their local communities, including preventive care, chronic disease management, and other medical services.

National Medical Center A to acquire Regional Medical Center B.

The acquisition of Regional Medical Center B by National Medical Center A is a significant development that expands the presence of National Medical Center A in the United States healthcare sector. The acquisition is a testament to National Medical Center A's commitment to providing quality healthcare services to patients nationwide.

National Medical Center A has been in the healthcare industry for over 50 years, providing patient-centered care and innovative medical services. With the acquisition of Regional Medical Center B, National Medical Center A can now offer its patients more specialized treatments and services. National Medical Center A and Regional Medical Center B patients can expect to receive the same high level of care and expertise across all locations.

The healthcare professionals at National Medical Center A are highly trained and dedicated to providing personalized treatment plans that prioritize each patient's unique needs and preferences. They work with patients and their families to ensure they receive the best care in a welcoming and comfortable environment.

National Medical Center A remains committed to its mission of improving the health and well-being of individuals and communities. The acquisition of Regional Medical Center B is a significant step in that direction, as it provides National Medical Center A with a broader reach and increased capabilities to serve patients in need.

National Medical Center A commitment to CDSS and Regional Medical Center B lag

National Medical Center A has always focused on providing high-quality healthcare services to patients by investing in cutting-edge medical technologies, including Clinical Decision Support Systems (CDSS). National Medical Center A recognizes that CDSS can improve clinical outcomes, enhance patient safety, and increase efficiency by providing healthcare professionals with real-time access to patient data, clinical guidelines, and best practices.

However, after acquiring Regional Medical Center B, National Medical Center A has observed that Region Medical Center B is clearly behind in the use of CDSS. As a result, National Medical Center A has decided to make the adoption of CDSS at Regional Medical Center B one of its first operational endeavors.

National Medical Center A recognizes that implementing CDSS is not easy, as it requires significant planning, coordination, and investment. Therefore, National Medical Center A plans to strategize around the adoption of CDSS by conducting a thorough assessment of the current systems, processes, and workflows at Regional Medical Center B to identify the areas that need improvement.

National Medical Center A will work closely with the healthcare professionals at Regional Medical Center B to ensure that they are well-trained and well-equipped to use CDSS effectively. The healthcare professionals at Regional Medical Center B will be trained to use CDSS to help them make more informed clinical decisions and to provide better care for their patients.

National Medical Center A understands that the successful adoption of CDSS requires a collaborative effort between healthcare professionals, administrators, and IT specialists. Therefore, National Medical Center A will involve all stakeholders in the planning and implementation of CDSS at Regional Medical Center B.

Therefore, National Medical Center A has decided to use our HDM model to assess the readiness of Regional Medical Center B to implement Clinical Decision Support Systems. Through the use of the model, National Medical Center A aims to pinpoint the critical improvement points to focus on.

7.1.2 Quantification of the HDM model based on Regional Medical Center B levels

In this section, the idea is to determine the readiness assessment scores for Regional Medical Center B. It is important to note that, at this point, Regional Medical Center B is being assessed on its original status pre-acquisition. Therefore we will be able to make accurate recommendations based on the readiness results.

The following criteria levels have been consolidated based on the inputs of experts with diverse backgrounds but with hands-on experience and knowledge of Regional Medical Center B. The criteria-assessment levels are summarized in Table 61, and the final model scores are available in Table 62. In these tables, the acronym RMCB refers to Regional Medical Center B.

Perspectives	Criteria	RMCB Level
Clinical	Clinical Context	75%
	Care Workflow	80%
	Clinical Knowledge	80%
	Clinical Outcome	75%
Technological	Integration Capabilities	75%
	Information Delivery	25%
	Accessibility	75%
	Security	100%
Organizational	Investment Management	80%
	Leadership Support	15%
	Compliance	100%
	Change Management	65%
Cultural	Perceived Usefulness	75%
	Flexibility of Use	75%
	Perceived Ease of Use	80%
	Stakeholder Engagement	25%

Table 61 - RMCB Criteria Assessment Levels

In the following table, the Final Score is calculated based on the HDM literature methods (Alzahrani, 2021; Daim & Kocaoglu, 2016; Hogaboam & Daim, 2018) where the Criteria Global Weight and RMCB Level are factored as follows:

RMCB Final Score = Criteria Global Weight x RMCB Level

Perspectives	**Criteria**	**Criteria Global Weight**	**RMCB Level**	**RMCB Final Score**
Clinical	Clinical Context	7.6%	75%	5.7%
	Care Workflow	6.5%	80%	5.2%
	Clinical Knowledge	11.4%	80%	9.1%
	Clinical Outcome	9.0%	75%	6.7%
Technological	Integration Capabilities	5.6%	75%	4.2%
	Information Delivery	8.7%	25%	2.2%
	Accessibility	4.9%	75%	3.6%
	Security	6.7%	100%	6.7%
Organizational	Investment Management	6.0%	80%	4.8%
	Leadership Support	7.7%	15%	1.2%
	Compliance	4.3%	100%	4.3%
	Change Management	3.4%	65%	2.2%
Cultural	Perceived Usefulness	4.5%	75%	3.3%
	Flexibility of Use	3.3%	75%	2.5%
	Perceived Ease of Use	2.4%	80%	1.9%
	Stakeholder Engagement	8.4%	25%	2.1%
		100%		**65.8%**

Table 62 - RMCB Final Model Scores

7.1.3 Results Analysis and Recommendations

As we analyze the quantification results in section 7.1.2, we can clearly identify the strengths and weaknesses that Regional Medical Center B is presenting for its readiness to implement Clinical Decision Support Systems. Table 63 summarizes theses the strengths and weaknesses in question.

S/W	Criteria	RMCB Score Description	RMCB Level Score
Strengths	Care Workflow	Multiple but similar workflows	80%
	Clinical Knowledge	Close to being globally accepted and set	80%
	Security	All systems are safe	100%
	Compliance	Compliant	100%
	Perceived Ease of Use	Medium-High	80%
Weaknesses	Information Delivery	Close to not existing	25%
	Leadership Support	Low	15%
	Stakeholder Engagement	Some engagement pratices	25%

Table 63 - RMCB Strengths and Weaknesses

The recommendations need to align back to the context of the merger. Indeed, while it is clear that RMCB's strengths are in the Clinical criteria of the HDM model, we can capitalize on these as this perspective has the highest weight. However, the weaknesses need to be closely watched by National Medical Center A (NMCA). The idea is to identify the added value that NMCA can bring to the three weaknesses-driving criteria of RMCB.

Our recommendation is to capitalize on the fact that NMCA is a leading Medical Center for Clinical Decision Support Systems adoption and convey that expertise to RMCB.

The next section will quantify the impact of such a scenario on RMCB's readiness to implement Clinical Decision Support Systems.

7.1.4 Scenario Analysis: NMCA to RMCB level transfer

Table 64 compares the National Medical Center A and Regional Medical Center B levels for the three weaknesses-driving criteria identified in the result analysis.

Criteria	**RMCB Score Description**	**RMCB Level Score**	**NMCA Score Description**	**NMCA Level Score**	**Delta**
Information Delivery	Close to not existing	25%	Dynamic, adapts to the clinical context	95%	**+ 70%**
Leadership Support	Low	15%	High	100%	**+ 85%**
Stakeholder Engagement	Some engagement practices	25%	Embedded in the implementation project	95%	**+ 70%**

Table 64 - NMCA and RMCB Criteria Level Comparison

Given the delta between the two institutions and the new acquisition relationship, this scenario will address the effect of a transfer of score from one institution to the other, from National Medical Center A to Regional Medical Center B.

Through the organizational efforts NMCA is investing in RMCB, the newly acquired Regional Medical Center was able to absorb 90% of the delta initially identified. The following table shows the impact on the global readiness score of RMCB to implement Clinical Decision Support tools.

Perspectives	Criteria	Criteria Global Weight	RMCB Level	RMCB Final Score	NMCA impact on RMBC Level	New RMCB Final Score
Clinical	Clinical Context	7.6%	75%	5.7%	N/A	5.7%
	Care Workflow	6.5%	80%	5.2%	N/A	5.2%
	Clinical Knowledge	11.4%	80%	9.1%	N/A	9.1%
	Clinical Outcome	9.0%	75%	6.7%	N/A	6.7%
Technological	Integration Capabilities	5.6%	75%	4.2%	N/A	4.2%
	Information Delivery	8.7%	25%	2.2%	**88%**	7.7%
	Accessibility	4.9%	75%	3.6%	N/A	3.6%
	Security	6.7%	100%	6.7%	N/A	6.7%
Organizational	Investment Management	6.0%	80%	4.8%	N/A	4.8%
	Leadership Support	7.7%	15%	1.2%	**92%**	7.1%
	Compliance	4.3%	100%	4.3%	N/A	4.3%
	Change Management	3.4%	65%	2.2%	N/A	2.2%
Cultural	Perceived Usefulness	4.5%	75%	3.3%	N/A	3.3%
	Flexibility of Use	3.3%	75%	2.5%	N/A	2.5%
	Perceived Ease of Use	2.4%	80%	1.9%	N/A	1.9%
	Stakeholder Engagement	8.4%	25%	2.1%	**88%**	7.3%
		100%		**65.8%**		**82.5%**

Table 65 - Impact of NMCA on RMCB Readiness Score

As a conclusion to this Case, we can see that the HDM model can help companies like National Medical Center A to identify specific areas of improvement in the newly acquired area of the organization. In the scenario analysis, we demonstrated that acting on the areas of improvement might raise the readiness score in a topic of importance like Clinical Decision Support Systems Adoption; in this case, we show an increase of more than 16 points.

7.2 Case Study 2: CDSS Editor C’s Tailored CDSS Solutions

7.2.1 Background

CDSS Editor C is a company that specializes in providing Clinical Decision Support Systems (CDSS) to healthcare providers. They understand the importance of providing tailored solutions to their customers to ensure quick and efficient adoption of their CDSS.

The company recognizes that every healthcare provider has unique needs and requirements regarding CDSS. Therefore, CDSS Editor C strives to provide customized CDSS solutions that meet each customer's specific needs. They work closely with clients to understand their workflow, data sources, and clinical decision-making processes. This allows them to create a CDSS that seamlessly integrates into the client’s existing systems and workflow.

CDSS Editor C has a team of well-versed experts in healthcare and technology. They use their expertise to design and implement CDSS solutions that are user-friendly, efficient, and effective. They make sure that their CDSS solutions are easy to use and provide clinicians with the necessary information to make informed decisions quickly.

One of the key advantages of working with CDSS Editor C is their ability to provide quick and efficient adoption of their CDSS solutions. They understand that the success of CDSS implementation depends on clinicians' level of adoption. Therefore, they provide comprehensive training and support to ensure clinicians are comfortable with the new system and can quickly integrate it into their daily workflow.

In addition to customized CDSS solutions, CDSS Editor C provides ongoing maintenance and support to ensure that the system continues to meet the evolving needs of the healthcare provider. They work closely with their customers to ensure that their CDSS is up-to-date and provides the necessary support for their clinical decision-making processes.

CDSS Editor C is a company that is always looking for innovative ways to improve its services and enhance customer satisfaction. They are currently exploring new methodologies to assess the readiness of prospective customers, such as the D Dental Clinics Group, to adopt one of their CDSS tools. The HDM model developed in this research project is considered to identify customization opportunities that can facilitate the adoption process and increase the chances of successful implementation.

Based on the findings of the assessment, CDSS Editor C will develop a customized CDSS solution that meets the specific needs of the D Dental Clinics Group. This will involve tailoring the CDSS to fit seamlessly into their existing workflow and clinical decision-making processes while also considering their unique data sources and IT infrastructure.

By adopting this methodology, CDSS Editor C is taking a proactive approach to ensure the success of its CDSS implementation at D Dental Clinics Group. This approach is designed to identify potential barriers to adoption early on in the process and develop customized solutions to help overcome these barriers.

7.2.2 Quantification of the HDM model based on D Dental Clinics Group levels

This section aims to determine the readiness assessment scores for the D Dental Clinics Group. The following criteria levels have been consolidated based on the inputs of experts with diverse backgrounds but with hands-on experience and knowledge of D Dental Clinics Group. The criteria-assessment levels are summarized in Table 66, and the final model scores are available in Table 67. In these tables, the acronym DDCG refers to D Dental Clinics Group.

Perspectives	Criteria	DDCG Level
Clinical	Clinical Context	85%
	Care Workflow	90%
	Clinical Knowledge	80%
	Clinical Outcome	85%
Technological	Integration Capabilities	25%
	Information Delivery	15%
	Accessibility	75%
	Security	100%
Organizational	Investment Management	90%
	Leadership Support	90%
	Compliance	100%
	Change Management	70%
Cultural	Perceived Usefulness	75%
	Flexibility of Use	75%
	Perceived Ease of Use	80%
	Stakeholder Engagement	70%

Table 66 - DDCG Criteria Assessment Levels

In the following table, the Final Score is calculated based on the HDM literature methods (Alzahrani, 2021; Daim & Kocaoglu, 2016; Hogaboam & Daim, 2018) where the Criteria Global Weight and DDCG Level are factored as follows:

DDCG Final Score = Criteria Global Weight x DDCG Level

Perspectives	**Criteria**	**Criteria Global Weight**	**DDCG Level**	**DDCG Final Score**
Clinical	Clinical Context	7.6%	85%	6.4%
	Care Workflow	6.5%	90%	5.9%
	Clinical Knowledge	11.4%	80%	9.1%
	Clinical Outcome	9.0%	85%	7.6%
Technological	Integration Capabilities	5.6%	25%	1.4%
	Information Delivery	8.7%	15%	1.3%
	Accessibility	4.9%	75%	3.6%
	Security	6.7%	100%	6.7%
Organizational	Investment Management	6.0%	90%	5.4%
	Leadership Support	7.7%	90%	7.0%
	Compliance	4.3%	100%	4.3%
	Change Management	3.4%	70%	2.4%
Cultural	Perceived Usefulness	4.5%	75%	3.3%
	Flexibility of Use	3.3%	75%	2.5%
	Perceived Ease of Use	2.4%	80%	1.9%
	Stakeholder Engagement	8.4%	70%	5.8%
		100%		**74.7%**

Table 67 - DDCG Final Model Scores

7.2.3 Results Analysis and Recommendations

As we analyze the quantification results in section 7.2.2, we can first note that D Dental Clinics Group scores 74.7% based on the HDM model for their readiness to implement Clinical Decision Support Systems. We can also note that two apparent weaknesses stand out as far as the criteria levels. Table 68 summarizes these weaknesses.

W	**Criteria**	**DDCG Score Description**	**DCCG Level Score**
Weaknesses	Information Delivery	Close to not existing	15%
	Integration Capabilities	Minimal capabilities	25%

Table 68 - DDCG Weaknesses-Driving Criteria

We recommend that CDSS Editor C addresses the weaknesses in Information Delivery and Integration Capabilities as critical to the successful implementation of CDSSs. Therefore, the company needs to commit to customizing its offering to account for these weaknesses and facilitate the adoption of its tools from a technical standpoint.

Therefore, we recommend that CDSS Editor C collaborates with D Dental Clinics Group to understand its unique needs and requirements. CDSS Editor C's technical team should work closely with D Dental Clinics Group to ensure that the CDSSs are seamlessly integrated with the organization's information delivery and integration capabilities.

The benefits of this methodology are numerous. It can help to reduce the risk of CDSS implementation failure, increase the efficiency of the implementation process, and ultimately improve the quality of care provided by "D Dental Clinics Group" to their patients. In addition, by providing customized solutions that are tailored to the specific needs of the "D Dental Clinics Group," CDSS Editor C can increase customer satisfaction and strengthen its reputation as a provider of high-quality CDSS tools.

CHAPTER 8 – RESEARCH VALIDITY

In this chapter, we assess the Research Validity of the research framework's output. The primary objective of research validation is to guarantee that the research model has accurately identified and accounted for meaningful perspectives and criteria that impact the readiness of Healthcare Organizations to implement Clinical Decision Support Tools.

To achieve accurate and reliable outcomes, the research will employ three different measures of validity, namely Construct Validity, Content Validity, and Criterion-related Validity. These measures will help ensure that the research model is valid and that its findings can be applied confidently in practical settings. Construct Validity will ensure that the research model accurately measures the concepts it is supposed to measure, Content Validity will ensure that the research model covers all relevant aspects of the topic being studied, and Criterion-related Validity will ensure that the research model is effective in predicting real-world outcomes.

This study has taken inspiration from previous successful dissertations that have explored the topic of research validity (Alzahrani, 2021; Barham & Daim, 2020; Hogaboam & Daim, 2018; Lavoie & Daim, 2020; Shaygan, 2021).

8.1 Construct Validity

Construct Validity examines whether the research approach aligns with the underlying theories and if the model's structure is suitable for addressing the research problem. Construct Validity tests the instruments' ability to collect data from participants.

A decision model was initially developed based on a literature review to validate the research model in this study. During the comprehensive exam milestone, this model was tested using input from pseudo-experts, who were asked to participate as experts in piloting the research model. The pseudo-experts provided feedback on the model constructs and desirability level and then quantified both the model and desirability curves. The validation of the model and desirability metrics, as well as the quantification of the desirability metrics, were carried out using Qualtrics survey software, while the quantification of the model was done using HDM software.

The results of this validation process demonstrated the model's structure's effectiveness in addressing the research problem and the validity of the initial model as a suitable tool for collecting data from respondents. The comprehensive exam study has helped to ensure the research model's reliability and validity and provides a strong foundation for further research.

8.2 Content Validity

Content validity is an important measure of whether the model contents properly represent all relevant aspects related to the research topic. It ensures that the model has included the most important factors and accurately reflects reality. The content validity measure was conducted during the model development phase and involved expert panels who validated the model elements using validation surveys.

The experts who validated the model had in-depth knowledge of Clinical Decision Support Systems and related fields. They came from diverse backgrounds and had different experiences. They were allowed to suggest edits to the model, add or remove items, or reorganize the importance of the model's components.

Validation of the model was, for the most part, unanimous. Giving special attention to the validation process is essential to ensure reliable results and a generalizable model. The results of the content validity measure are discussed in Chapter 6. Based on the results, we can confirm the Content Validity of this research project.

8.3 Criterion-related Validity

Criterion-related validity is an essential concept in research that refers to the degree to which a research model can accurately describe a real-life organizational challenge and predict its outcomes. It involves evaluating the model's effectiveness in performing well and accurately predicting the situation being studied.

In order to assess the criterion-related validity of a research model, experts were involved in reviewing the results and determining whether they were accurate and valid. This experts review is an important step in ensuring that the research model is effective and can be used to inform decision-making in the real world.

In the case of the research model described here, two case studies were conducted to assess the readiness of healthcare organizations to implement Clinical Decision Support Systems. The results of these case studies were then shared with the organizations' experts to determine whether the assessment framework was appropriate. The experts found the framework to be helpful and appropriate, providing further evidence of the effectiveness and validity of the research model.

8.4 Generalizability of the Research Model

Expert panels with diverse backgrounds and deep knowledge of Healthcare, Clinical Decision Support Systems, and Information Systems validated and quantified the research model. This approach ensured a high level of generalizability of the model and increased its acceptance and applicability in other organizational settings. The experts were also asked to verify whether the model could be generalized to other applications beyond the case studies, and they confirmed its suitability as an assessment tool. Additionally, the model was applied against two case studies, and the organizations found it useful for readiness assessment.

In order to guarantee dependable outcomes and a model that can be widely applied, several measures of validity were employed. These included assessing discrepancies in expert opinions, evaluating disagreement among expert panel members, and performing sensitivity analyses to assess the model's strength and ability to cope with changes in rank priorities in anticipated situations.

It should be emphasized that the generalizability of the research findings depends on the context and time in which they were obtained. As a result, the Clinical, Technological, Organizational, and Cultural aspects may not remain constant in the future as they were during the study. Therefore, prudence is advised when employing the research model in distinct contexts or periods.

CHAPTER 9 – CONCLUSION

The literature review conducted in this research has played a critical role in defining research gaps and questions related to assessing the readiness of healthcare organizations to implement Clinical Decision Support Systems (CDSS). Through this review, we stressed the need for a multidimensional approach assessment and pointed out the adequate methodologies to do so.

Therefore, we developed an initial Hierarchical Decision Model (HDM) based on the insights gained from the literature review. This model was designed to assess the readiness of healthcare organizations to implement CDSS under four perspectives and fifteen criteria.

Expert panels were formed to refine, validate, and quantify the HDM model. The input and feedback from domain experts were invaluable in refining the model and ensuring its relevance and applicability to real-world healthcare settings.

Once the HDM model was deemed acceptable in terms of its quantification, it was applied to two case studies in different healthcare organizations. The real-world application of the model provided valuable insights into the readiness of these organizations to implement CDSS. The case studies' findings demonstrated the HDM model's practical applicability and utility in assessing organizational readiness for CDSS implementation. This research framework allowed us to revisit the research questions initially identified in the literature review and make academic contributions at various levels of the research process, as addressed in the sections below.

9.1 Review of the Research Questions

This research aimed to address three key research questions that were identified through the literature review.

The first research question aimed to identify the main challenges that healthcare organizations face when implementing CDSS and how these challenges interact. The literature review highlighted various challenges, such as resistance to change, lack of resources, and inadequate training. However, it was not clear how these challenges interact and influence each other. Therefore, this study aimed to provide a comprehensive understanding of these challenges and their interactions.

The second research question aimed to classify the challenges under different perspectives and criteria to provide a comprehensive view of the successful implementation of CDSS. This was crucial to ensure that all aspects of CDSS implementation were considered, and no critical factors were overlooked. The proposed Hierarchical Decision Model provided a framework to classify the challenges into four perspectives and sixteen criteria. This enabled a multi-dimensional assessment of the challenges, ensuring a comprehensive view of CDSS implementation.

Lastly, the third research question aimed to identify the most impactful factors that organizations should consider when implementing CDSS. By identifying these factors, healthcare organizations could prioritize their efforts and allocate their resources effectively. Through the case studies presented in this study, the HDM model was applied to identify the most critical factors that impacted CDSS implementation. The study's findings provide recommendations to help organizations address these factors and improve their readiness for CDSS implementation.

Overall, this study addressed important research questions related to CDSS implementation, providing insights and recommendations to help healthcare organizations overcome the challenges and improve their readiness for CDSS implementation. By addressing these questions, this study contributes to the broader effort to improve healthcare delivery and patient outcomes through the effective use of technology.

9.2 Contribution to the Technology Management Literature

As framed in the previous sections, my research project interacts with multiple academic fields. Considering support tools within complex decision-making processes occurring in clinical settings puts us at the intersections of Operation Research, Clinical Decision Support, and Technology Management.

Technology Management is a multi-disciplinary field; its contributing research thrives when adding related fields and technologies. My research focuses on a significant Healthcare decision-making support tool, Clinical Decision Support Systems. CDSS is a technology that poses organizational challenges beyond the clinical aspect. Addressing this technology from a multi-dimensional point of view, if successfully completed, could add to the Technology Management research.

Finally, the research framework I propose, combining Literature Review, Action Research, and HDM, could also contribute to the Technology Management research. Indeed, the uniqueness of its association with the healthcare industry can be seen as another advocate for the field's multi-disciplinary characteristics.

9.3 Contribution to the Healthcare Industry

One of the main topics discussed in the research surrounding Clinical Decision Support Systems is the impact of CDSS on patient health, also known as patient outcome. My model could potentially add to that subfield of research by the attempt, through further research, to link the successful adoption of CDSS to patient healthcare.

Healthcare organizations should be able to use and benefit from the model I intend to build. Assessing their readiness to implement Clinical Decision Support Systems can be a crucial contribution to the industry. Such a model could help overcome the challenges organizations face downstream after an unsuccessful implementation. The repercussions of failed implementation can potentially be harmful to patients, let alone to the organization itself.

CDSS vendors can also leverage this multi-dimension model for customer selection and segmentation. Assessing the readiness of an organization to implement CDSS can be used to narrow down the product offering to a tailored proposal for customers based on their readiness. That can potentially positively impact the net new sales as well as the upsell and cross-sell business.

9.4 Contribution to the Multi-Criteria Decision Making

One of the research gaps I initially identified was the lack of multi-dimensional studies on Clinical Decision Support Systems adoption and, more specifically, the lack of multi-dimensional studies around the assessment of healthcare organizations' readiness to implement CDSS. The specific combination of CDSS and Multi-Criteria, Decision-Making methods constitutes a contribution to this underlying academic research.

From a more methodological standpoint, the use of Action Research combined with MCDM would be one of the very few attempts to do so. Therefore, if successful, that could be a significant contribution to the academic literature surrounding Multi-Criteria Decision Making.

9.5 Contribution to the HDM Approach

Similar to the Multi-Criteria Decision Making contribution, I would like to raise the uniqueness of applying an HDM model to the field of Clinical Decision Support Systems. As highlighted in the added value section, one of the standing differentiators of my proposal compared to other HDM models is the application to CDSS and the use of a Clinical Perspective. Other healthcare-related HDM models have looked at Clinical criteria from broader perspectives. Therefore, the impact of CDSS on my HDM model could be considered a contribution to the HDM approach.

From an HDM process standpoint, the addition of Action Research to the model validation would be the second tentative with the uniqueness of allowing a second round of literature review to enhance the model. This process, if successful, could contribute to the literature around HDM.

Finally, the hybrid potential usage of the HDM model could also be a contribution to the HDM research. By allowing a model to be used by both the receiver and designer of the technology, CDSS, the Case Study could set a precedent in HDM research.

9.6 Limitations

One of the limitations of this study is that the proposed model was developed and validated specifically for assessing healthcare organizations' readiness for CDSS implementation. As a result, if the model were to be applied to other types of organizations, it would require re-validation and re-quantification of the model elements and their weights using experts from those intended sectors and fields. Therefore, caution must be exercised when applying this model to organizations outside of the healthcare sector.

The second limitation of this study stems from the reliance on expert panels. Despite the systematic and careful selection of experts with relevant expertise, their judgments may be susceptible to biases and subjectivity that are difficult to detect. To address this limitation, the model's results underwent a validation process, including a thorough analysis of disagreement and inconsistency among expert opinions. This was done to ensure that the results were as objective and reliable as possible, despite the potential for subjective influences.

Lastly, a limitation of this study is that the clinical, technological, organizational, and cultural aspects that were considered during the research may not remain constant in the future. As such, caution is recommended when applying the research model in different contexts or time periods. The dynamic nature of these aspects means that the model's relevance and accuracy may be affected over time or in different organizational settings. Therefore, it is important to take this into account when using the model for decision-making purposes.

9.7 Future Research

Future research opportunities are vast and varied in the field of Clinical Decision Support Systems. This study has identified several gaps in the literature and provided a hierarchical decision model for assessing the readiness of healthcare organizations for CDSS implementation. However, there are several areas that require further investigation to improve the implementation of CDSS and enhance patient care.

One area for future research opportunities is to employ Action Research to refine the Hierarchical Decision Model components. Action Research involves an iterative process of planning, acting, observing, and reflecting on the intervention's outcomes, aiming to improve the quality of practice. In the context of CDSS implementation, action research could involve applying the HDM model in real-world settings and using the implementation outcomes to refine the model. For instance, action research could be used to refine the criteria used to assess organizational readiness or to identify new criteria that were not captured by the initial HDM model. This could lead to a more comprehensive and accurate model that can better guide healthcare organizations in implementing CDSS.

Another future research opportunity is to explore the potential use of the Hierarchical Decision Model to assess the readiness of healthcare organizations to adopt other healthcare tools beyond CDSS. As healthcare continues to evolve, new technologies and tools are being developed to improve patient outcomes and care delivery. The HDM model has been shown to be effective in assessing the readiness of healthcare organizations to adopt CDSS, and it may be applicable to other healthcare tools as well. Therefore, it would be interesting to investigate the feasibility of adapting the HDM model to assess the readiness of healthcare organizations to adopt other tools, such as telemedicine, mobile health applications, or electronic health records. This could provide valuable insights into the factors that influence the adoption of different healthcare tools and help organizations make informed decisions about which tools to prioritize and how to prepare for their implementation.

9.8 Personal Aspects

A Clinical Decision Support System vendor currently employs me. In my department, we are constantly looking for efficient ways to increase our products' footprint in the market. My research project and doctoral studies will allow me to add general and academic expertise in Clinical Decision Support Systems. That expertise is of great value to my professional career evolution. Building and validating a model that evaluates the readiness of healthcare organizations helps me build unique knowledge that can be used in market segmentation and customer identification.

Moreover, this professional position allows me to grasp a practical use case for my intended research. My employer can leverage the multi-dimension model for customer selection and segmentation. Assessing the readiness of an organization to implement CDSS can be used to narrow down the product offering to a tailored proposal for customers based on their readiness. That can potentially positively impact the net new sales as well as the upsell and cross-sell business.

Beyond my employment, I intend to stay close to academia through research and teaching. This research endeavor and my doctoral studies will help me gain the skillsets and legitimacy to contribute to the academic space. Complex decision environments, clinical care, and technology management are critical topics, especially today. I would be honored to continue my humble contribution after my doctorate studies in some shape or form.

Finally, I wanted to mention my activism and engagement in the sustainable development cause. Indeed, I have been involved in Sustainability and, more specifically, with the United Nations' Sustainable Development Goals (SDGs) through multiple volunteering experiences. This research project is directly linked to the 3rd SDG, "Good Health and Well-Being". It is personally fulfilling to me to contribute through my research to a more sustainable society humbly.

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APPENDICES

Appendix A – Letter of Invitation to Experts

Dear [Name],

I hope this email finds you well. My name is Oussama Laraichi, and I am a Ph.D. candidate at Portland State University.

As part of my thesis, I am conducting a survey aimed at assessing healthcare organizations' readiness to implement Clinical Decision Support Systems (CDSS).

As a [Expertise] professional with experience in this field, your input and insights would be instrumental to my research. The survey will take approximately 10-15 minutes to complete, and all responses will be kept confidential.

This survey aims to gather data and insights on the current state of healthcare organizations' readiness to implement clinical decision support tools, as well as the factors that influence their adoption.

The results of this survey will help provide a comprehensive understanding of the barriers and facilitators to the implementation of these tools and may inform future efforts to improve their adoption.

If you are interested in participating, please follow this link [Link based on Panel #] to access the survey. If you have any questions or concerns, please do not hesitate to contact me.

Thank you in advance for your time and consideration. I truly appreciate your support in my research.

Best regards,

Oussama Laraichi

Appendix B – Model Validation Through Qualtrics

HDM Model Validation - Clinical Perspective

In this section, focusing on the Clinical perspective, please indicate whether the following are important factors to assess the readiness of healthcare organizations to implement Clinical Decision Support Systems.

Please refer to the description below for a description of the perspective and the underlying criteria.

Clinical	The clinical perspective encompasses all the clinical components of a given healthcare organization that are crucial to the clinical decision process	(Greenes, 2007c) (McCoy et al., 2015) (Jiang et al., 2017) (Jenders, 2017)

Criterion	Description	References
Clinical Context	The clinical context criterion assesses the knowledge needed for a Clinical Decision Support System. A CDSS is a contextual system. The nature of clinical care provided is the initial step in defining the context of a CDSS. It is critical and needs to be thoroughly described and mapped out	(Greenes, 2007c)
Care Workflow	The care workflow criterion evaluates the framework in which the clinical decision support is offered to the clinicians. It is a step-by-step events sequence that results in the CDSS generating decision support and applying it to deliver care.	(McCoy et al., 2015)
Clinical Knowledge	This criterion evaluates clinical knowledge that is intended to be used by the system to provide support to clinicians. Driven by the context, the clinical expertise needed can take several forms.	(Jiang et al., 2017) (Jenders, 2017)
Clinical Outcome	This criterion assesses the maturity level of identifying the desired Clinical Outcome for patients while using Clinical Decision Support tools.	(Kwan et al., 2020) (Castiglione et al., 2019) (Xie et al., 2022)

Clinical Criteria Importance

	Important	Not Important	Not Applicable
Clinical Context	○	○	○
Care Workflow	○	○	○
Clinical Knowledge	○	○	○
Clinical Outcome	○	○	○

HDM Model Validation - Technological Perspective

In this section, focusing on the Technological perspective, please indicate whether the following are important factors to assess the readiness of healthcare organizations to implement Clinical Decision Support Systems.

Please refer to the description below for a description of the perspective and the underlying criteria.

Technological	The Technological perspective covers all technical skills and capabilities to acquire to ensure a smooth Clinical Decision Support System implementation	(Kaplan, 2001) (Wasylewicz & Scheepers-Hoeks, 2019) (Beeler et al., 2014) (Berlin et al., 2006) (Vinks et al., 2020)

Criterion	Description	References
Integration Capabilities	The Integration Capabilities criterion evaluates the ability of a healthcare organization to integrate decision support solutions into their existing information system environments.	(Kaplan, 2001) (Wasylewicz & Scheepers-Hoeks, 2019)
Information Delivery	The information delivery evaluates the capabilities of a healthcare organization to deliver accurate information at the right time.	(Beeler et al., 2014)
Accessibility	The accessibility criterion assesses the technological accessibility of information systems within the healthcare organization and its accessibility towards healthcare providers.	(Berlin et al., 2006)
Security	The security here assesses the ability to use information systems in a safe and secure technology setting to ensure the patient's data and health is not jeopardized.	(Vinks et al., 2020)

Technological Criteria Importance

	Important	Not Important	Not Applicable
Integration Capabilities	○	○	○
Information Delivery	○	○	○
Accessibility	○	○	○
Security	○	○	○

Comments or concerns about the Technological Criteria Importance

→

HDM Model Validation - Clinical Perspective

In this section, focusing on the Clinical perspective, please indicate whether the following are important factors to assess the readiness of healthcare organizations to implement Clinical Decision Support Systems.

Please refer to the description below for a description of the perspective and the underlying criteria.

Clinical	The clinical perspective encompasses all the clinical components of a given healthcare organization that are crucial to the clinical decision process	(Greenes, 2007c) (McCoy et al., 2015) (Jiang et al., 2017) (Jenders, 2017)

Criterion	Description	References
Clinical Context	The clinical context criterion assesses the knowledge needed for a Clinical Decision Support System. A CDSS is a contextual system. The nature of clinical care provided is the initial step in defining the context of a CDSS. It is critical and needs to be thoroughly described and mapped out	(Greenes, 2007c)
Care Workflow	The care workflow criterion evaluates the framework in which the clinical decision support is offered to the clinicians. It is a step-by-step events sequence that results in the CDSS generating decision support and applying it to deliver care.	(McCoy et al., 2015)
Clinical Knowledge	This criterion evaluates clinical knowledge that is intended to be used by the system to provide support to clinicians. Driven by the context, the clinical expertise needed can take several forms.	(Jiang et al., 2017) (Jenders, 2017)
Clinical Outcome	This criterion assesses the maturity level of identifying the desired Clinical Outcome for patients while using Clinical Decision Support tools.	(Kwan et al., 2020) (Castiglione et al., 2019) (Xie et al., 2022)

Clinical Criteria Importance

	Important	Not Important	Not Applicable
Clinical Context	○	○	○
Care Workflow	○	○	○
Clinical Knowledge	○	○	○
Clinical Outcome	○	○	○

HDM Model Validation - Organizational Perspective

In this section, focusing on the Organizational perspective, please indicate whether the following are important factors to assess the readiness of healthcare organizations to implement Clinical Decision Support Systems.

Please refer to the description below for a description of the perspective and the underlying criteria.

Organizational	The organizational perspective covers the operational readiness of the healthcare provider to take on a CDSS implementation	(Sutton et al., 2020) (Bonczek et al., 2014) (Aljarboa & Miah, 2020)

Criterion	Description	References
Investment Management	This criterion evaluates the investment management skills of organizational leaders. They are critical in the implementation of a CDSS. Leaders need to understand the investment level that will fit the organization's goals.	(Sutton et al., 2020)
Leadership Support	It evaluates the leadership support for a CDSS implementation is also crucial. C-level executives need to engage in and sponsor the implementation efforts to ensure its success.	(Sutton et al., 2020)
Compliance	The compliance criterion is to assess the level of legal and regulatory compliance of the organization aiming to implement the CDSS	(Bonczek et al., 2014)
Change Management	Change management is critical when implementing a CDSS. This criterion assesses the level of change management existence in a given organization	(Aljarboa & Miah, 2020)

Organizational Criteria Importance

	Important	Not Important	Not Applicable
Investment Management	○	○	○
Leadership Support	○	○	○
Compliance	○	○	○
Change Management	○	○	○

Comments or concerns about the Organizational Criteria Importance

→

HDM Model Validation - Cultural Perspective

In this section, focusing on the Cultural perspective, please indicate whether the following are important factors to assess the readiness of healthcare organizations to implement Clinical Decision Support Systems.

Please refer to the description below for a description of the perspective and the underlying criteria.

Cultural	The Cultural perspective focuses on the cultural aspects that will make influence the implementation of a CDSS and eventually make it successful or not	(Sutton et al., 2020) (Aljarboa & Miah, 2020) (Wasylewicz & Scheepers-Hoeks, 2019)

Criterion	Description	References
Providers' Trust	This criterion assesses the level of trust healthcare providers have for the CDSS. The more trust, the better adoption we have.	(Sutton et al., 2020)
Flexibility of Use	This criterion evaluates the flexibility given to providers as far as using or not the CDSS. The flexibility helps getting the buy-in of late adopters of CDSS and initially reluctant providers	(Aljarboa & Miah, 2020)
Stakeholder Engagement	Here we evaluate the presence of engagement practices during the implementation period. All stakeholders need to be associated with the CDSS project continuously and as early as possible	(Wasylewicz & Scheepers-Hoeks, 2019)

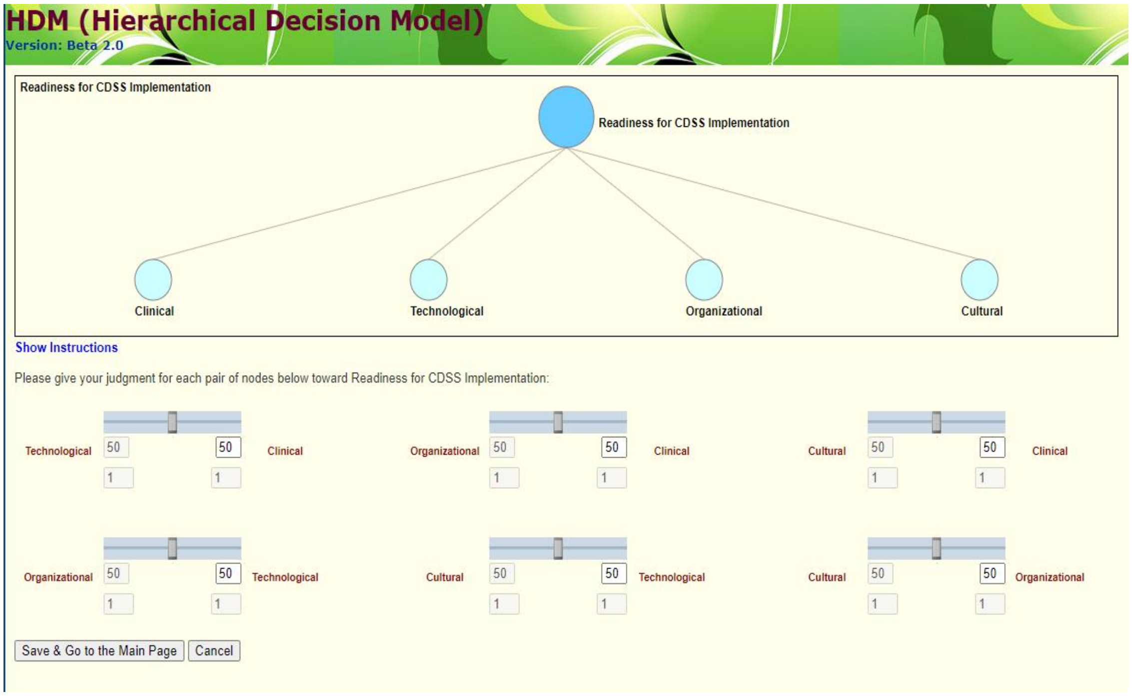
Cultural Criteria Importance

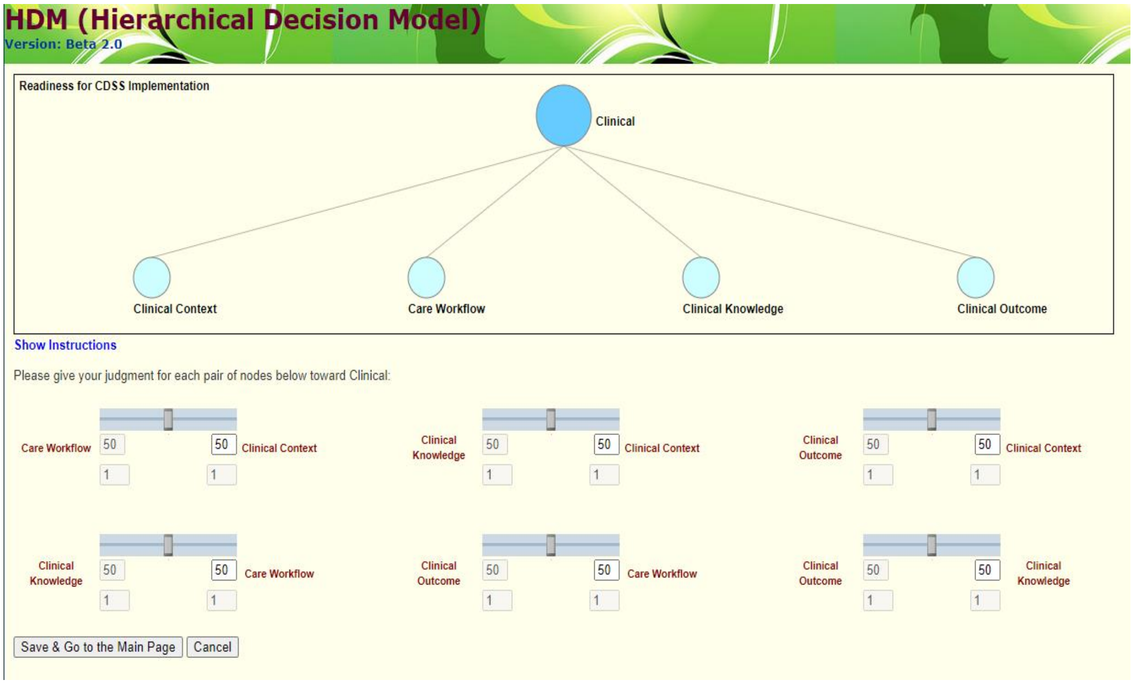
	Important	Not Important	Not Applicable
Perceived Usefulness	○	○	○
Flexibility of Use	○	○	○
Perceived Ease of Use	○	○	○
Stakeholder Engagement	○	○	○

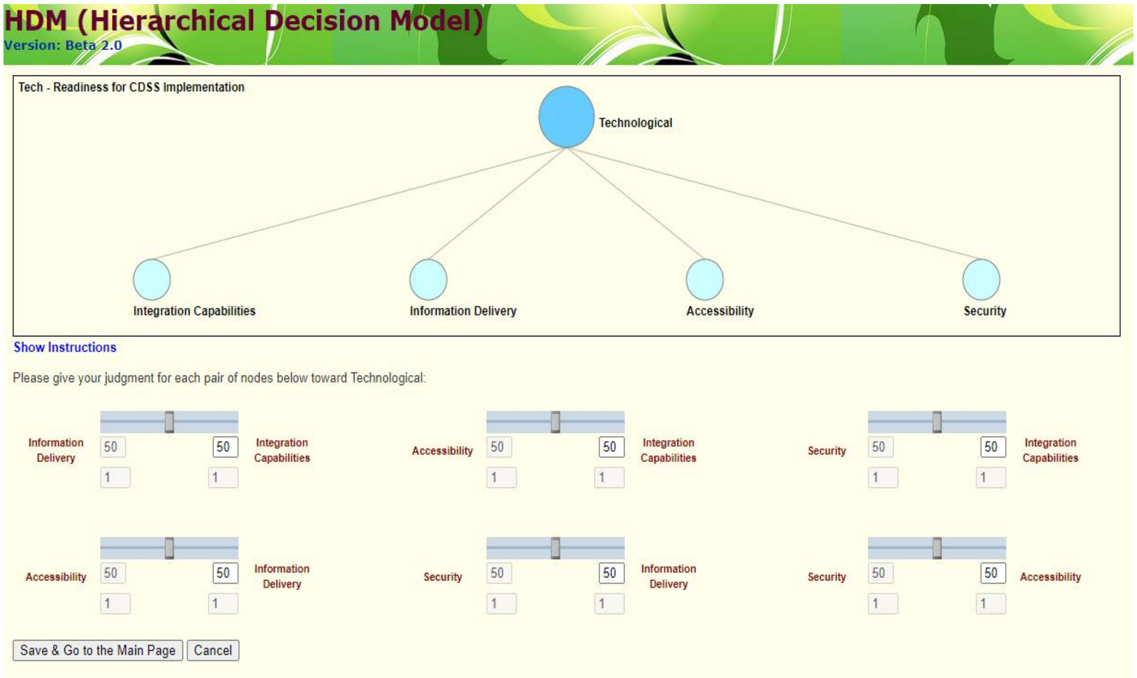
Comments or concerns about the Cultural Criteria Importance

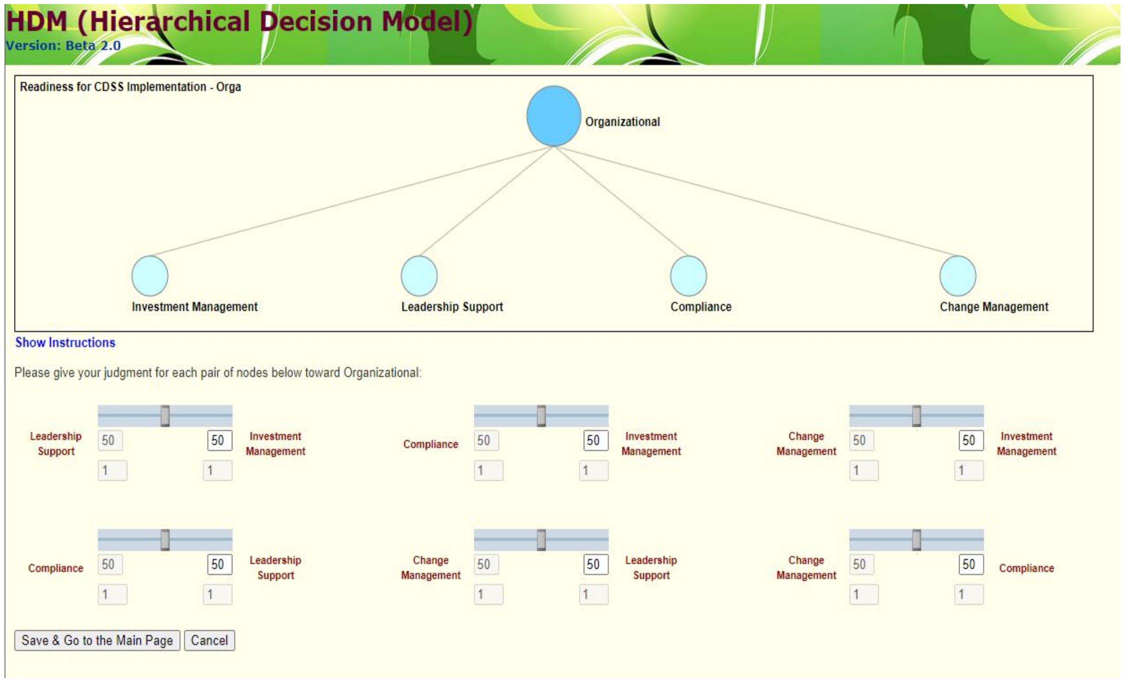
→

Appendix C – Model Quantification Through HDM Tool

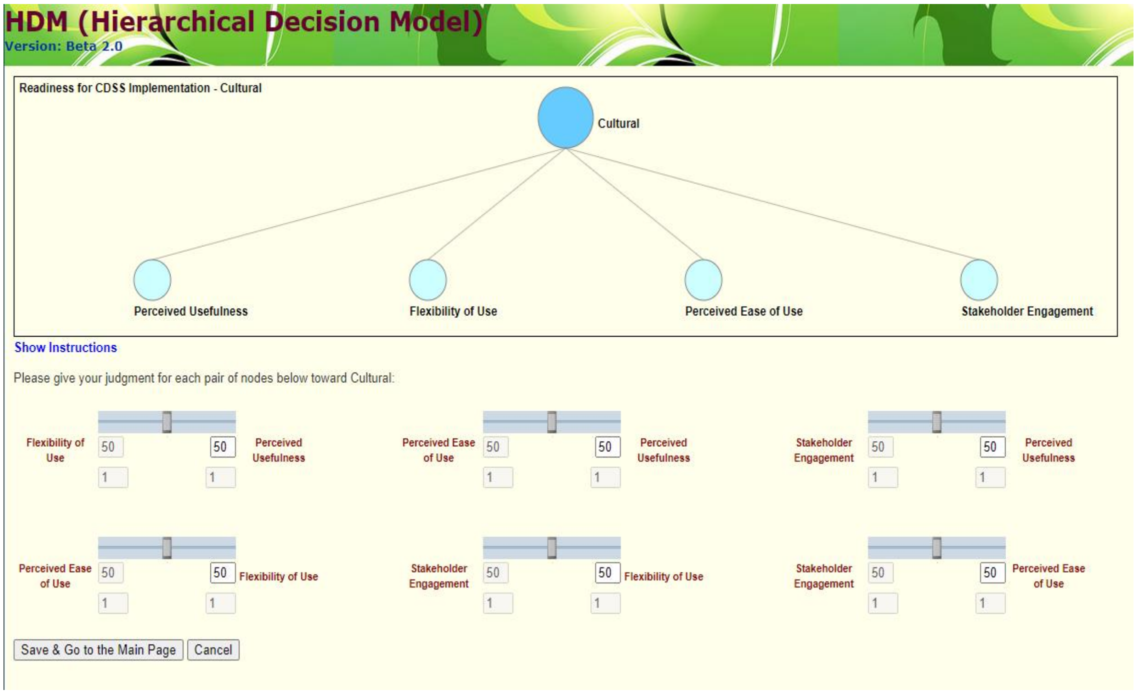



HDM (Hierarchical Decision Model)
Version: Beta 2.0
Readiness for CDSS Implementation
Clinical
Clinical Context
Care Workflow
Clinical Knowledge
Clinical Outcome
Show Instructions
Please give your judgment for each pair of nodes below toward Clinical:
Care Workflow
Clinical Context
Clinical Knowledge
Clinical Context
Clinical Outcome
Clinical Context
Clinical Knowledge
Care Workflow
Clinical Outcome
Care Workflow
Clinical Outcome
Clinical Knowledge
Save & Go to the Main Page
Cancel


HDM (Hierarchical Decision Model)
Version: Beta 2.0
Tech - Readiness for CDSS Implementation
Technological
Integration Capabilities
Information Delivery
Accessibility
Security
Show Instructions
Please give your judgment for each pair of nodes below toward Technological:
Information Delivery
Integration Capabilities
Accessibility
Integration Capabilities
Security
Integration Capabilities
Accessibility
Information Delivery
Security
Information Delivery
Security
Accessibility
Save & Go to the Main Page
Cancel



HDM (Hierarchical Decision Model)
Version: Beta 2.0
Readiness for CDSS Implementation - Orga
Organizational
Investment Management
Leadership Support
Compliance
Change Management
Show Instructions
Please give your judgment for each pair of nodes below toward Organizational:
Leadership Support
Investment Management
Compliance
Investment Management
Change Management
Investment Management
Compliance
Leadership Support
Change Management
Leadership Support
Change Management
Compliance
Save & Go to the Main Page
Cancel


HDM (Hierarchical Decision Model)
Version: Beta 2.0
Readiness for CDSS Implementation - Cultural
Cultural
Perceived Usefulness
Flexibility of Use
Perceived Ease of Use
Stakeholder Engagement
Show Instructions
Please give your judgment for each pair of nodes below toward Cultural:
Flexibility of Use
Perceived Usefulness
Perceived Ease of Use
Perceived Usefulness
Stakeholder Engagement
Perceived Usefulness
Perceived Ease of Use
Flexibility of Use
Stakeholder Engagement
Flexibility of Use
Stakeholder Engagement
Perceived Ease of Use
Save & Go to the Main Page
Cancel

Appendix D – Desirability Quantification Through Qualtrics

Desirability of Clinical Context

0 10 20 30 40 50 60 70 80 90 100

Not framed, not identified

Framed but undergoes considerable changes

Framed with limited changes

Framed and completely set

Desirability of Care Workflow

0 10 20 30 40 50 60 70 80 90 100

No workflows

Multiple and diverse workflows

Framed with limited changes

Framed and completely set

Desirability of the Integration Capabilities

0 10 20 30 40 50 60 70 80 90 100

Not existing

Limited

Strong

Exhaustive

Desirability of Information Delivery

0 10 20 30 40 50 60 70 80 90 100

Not existing

Manual, needs the provider to request it

Dynamic, adapts to the clinical context

Desirability of Integration Management

0 10 20 30 40 50 60 70 80 90 100

No skills

Limited skills

Complete skillset

Desirability of Leadership Support

0 10 20 30 40 50 60 70 80 90 100

None

Low

Medium

High

Desirability of Perceived Usefulness

0 10 20 30 40 50 60 70 80 90 100

None

Low

Medium

High

Desirability of the Flexibility of Use

0 10 20 30 40 50 60 70 80 90 100

None

Medium

High