Decision theory, design theory and innovative policy design for conflict transformation and management

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“History isn’t something you look back at and say it was inevitable. It happens because people make decisions that are sometimes very impulsive and of the moment, but those moments are cumulative realities.” – Marsha P. Johnson

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Contents

List of Figures

Chapter 1

Introduction

1.1 Motivations

Conflicts are inherent to the interactions between individuals, organizations, institutions, classes, groups, and states, stemming from divergent interests and perspectives at various times (see Galtung, 1999). Fundamentally, the presence of conflict is not inherently problematic and can, in fact, serve as a catalyst for creativity and innovation. However, the issue arises when conflicts escalate violently, leading to destruction and loss—of lives, assets, and infrastructures—often without resolving the underlying issues. This observation, coupled with the increasing frequency and complexity of conflicts, has catalyzed the development of an interdisciplinary research domain focused on conflict transformation and peace studies.

The violent degeneration of conflicts underscores a critical challenge: the need for effective methodologies that not only address conflicts constructively but also prevent their destructive escalation. Traditional approaches to conflict resolution often fall short in addressing the multifaceted nature of contemporary conflicts, pointing to the necessity for innovative, multidisciplinary methods that encompass not just the resolution but also the transformation of conflicts into opportunities for growth and development.

This thesis is motivated by the pressing need to explore and develop such methodologies, integrating problem structuring methods and formal design methods, merging decision theory and design theory to offer new insights and pathways for conflict transformation. By leveraging these tools, the research aims to bridge the gap between conflict as a natural occurrence and the innovative policy design that can transform these conflicts into constructive dialogues, fostering sustainable solutions and preventing violent outcomes.

Thus, the motivation behind this research lies in its potential to contribute to the broader field of conflict transformation and management, offering practical tools and theoretical insights that can be applied to various conflict scenarios. Through this interdisciplinary approach, the thesis seeks to enhance our understanding of conflicts not as decisive problems but as opportunities for innovation, dialogue, and resolution.

Moreover, the quest for innovative policy design extends beyond conflict transformation and management, which is also public policy, addressing a broad spectrum of complex public policy issues. The challenges inherent in public policy-making—ranging from environmental management to socio-economic development—are often characterized by diverse stakeholder interests, intricate legal frameworks, and multifaceted socio-economic dynamics. These challenges necessitate reevaluating traditional policy-making approaches, highlighting the critical need for innovation, adaptability, and participatory design in policy formulation and implementation.

1.2 The theoretical perspective

In this thesis, we embark on an interdisciplinary journey that explores three key dimensions:
(i) improving Problem-Structuring Methods (PSMs), specifically Cognitive Maps and Value Trees, by integrating these methods for conflict transformation and complex decision-making;
(ii) merging decision theory with design theory, grounded in Concept-Knowledge theory, for the generation of out-of-the-box alternatives important for conflict transformation and management;
(iii) integrating design theory with policy design to innovate policy formulation for conflict transformation and management in the realm of public policy.

Violent degeneration of conflicts poses significant challenges, often leading to loss and destruction without resolving the underlying issues (see Galtung, 1969, 1976; Körppen et al., 2011; Rogers and Ramsbotham, 1999). This has led to an extensive body of research in the field, with contributions from Decision Analysts and Operational Researchers (see Bartolucci and Gallo, 2010; Gallo, 2013; Hipel et al., 2020). The thesis adds to this discourse by exploring unconnected problem structuring methods as tools for facilitating effective conflict transformation and management.

In the realm of Decision Analysis and Operational Research, Problem Solving Methods (PSMs) have emerged as a critical branch, or for some, an alternative perspective. These methods underscore the philosophy that comprehending a problem is equally vital as solving it. This viewpoint is supported by notable scholars (see Ackoff, 1979a,b; Checkland, 1981; Franco et al., 2006; Rosenhead and Mingers, 2001; Shaw et al., 2007). Our research focuses on two prominent PSMs: Cognitive Mapping (see Eden et al., 1983; Eden, 1988) and Value Trees (see Keeney and McDaniels, 1992; Keeney, 1992) chosen for their relevance in aiding conflict transformation and management. However, it's essential to approach these methods with a critical lens.

Predominantly, PSMs are descriptive. They excel in delineating the nuances of who is facing which problems and the reasons behind them. This descriptive nature is integral in assisting stakeholders embroiled in complex situations, aiding them to develop comprehensive assessments and establish common ground (see Ackermann, 2012b). While this is undoubtedly valuable, these methods fall short in being design-oriented; they do not necessarily offer practical solutions or pathways to resolve the identified problem which needs to take into account generally 'out-of-box' alternatives or 'wicked situations' (see Simon 1954)'.

There are, however, exceptions like the "Strategic Choice Approach" (see Friend and Hickling, 1987) and "Value Trees" (see Keeney and McDaniels, 1992). Yet, these methods too have limitations, particularly in understanding the structural dynamics of problem situations and the intricacies of decision aiding (see Tsoukiàs, 2007, 2008). Recent scholarly contributions have highlighted the need for a more "design-oriented" approach in decision support activities (see Colorni and Tsoukiàs, 2020; Ferretti et al., 2019; Pluchinotta et al., 2019a). For example, Lami and Todella (2023) present the Strategic Choice Approach (SCA) and the Analytic Network Process (ANP) combination to structure qualitative steps into a formal multi-criteria decision analysis (MCDA) process. This integration provides a systematic framework for handling complex decision problems by linking qualitative understanding to quantitative evaluation. While this approach helps organize problem understanding, there remains a critical gap in operational guidance—specifically, how to transition from understanding a problem situation to designing and evaluating alternative solutions. The call is for methods that not only describe problem situations but also guide the design of alternative solutions. This shift from mere understanding to actionable design is important. Moreover, Yearworth and White (2013) illustrate how Causal Loop Diagrams (CLDs) enable the systematic integration of qualitative data analysis into decision-support models, effectively linking problem structuring with formal modeling. However, there is a need for more operational guidance on transitioning from problem description to solution design—clarifying the next steps once the problem is understood.

In this thesis, we advocate for PSMs that transcend their traditional descriptive roles and embrace a design-oriented approach. Our goal is to bridge the gap between comprehending a problem and crafting viable, innovative solutions. PSMs, particularly in the context of conflict transformation and management, should equip stakeholders not just with an understanding of the problem but also with actionable strategies to navigate and resolve these complexities.

In our exploration of problem-solving methodologies, we draw inspiration from Kelly's theory of human beings as innate problem solvers (see Kelly, 1955). This theoretical backdrop informs our understanding of cognitive mapping, as defined by Eden (1988). Eden's definition underscores the subjective nature of problem handling, emphasizing the importance of the problem owner's personal understanding and definition of the issue at hand. This perspective values the problem owner's perception of why a situation is problematic and how it intertwines with their unique system of values, beliefs, and objectives. This approach is not just about analyzing external variables, but more importantly, about delving into the cognitive system of the problem owner, which includes their values, beliefs, and objectives (see Kelly, 1955; Eden, 1994). While cognitive mapping adeptly captures the essence of the problem owner's perspective, it may not inherently offer direct strategies for resolving or managing the conflict, thus necessitating additional steps in the problem-solving process.

Conversely, value trees provide a more structured approach to problem structuring. Rooted in Keeney's value-focused thinking (VFT) (see Keeney, 1996a; Keeney and Keeney, 2009), this approach suggests that decision-making should prioritize values, rather than merely addressing problems based on available alternatives (see Keeney, 1994a). This shift towards a value-centric view can lead to the emergence of new and innovative solutions. Value trees, as a formal technique, effectively represent this value-focused thinking, delineating values in a structured and hierarchical manner. While value trees are instrumental in generating new alternatives, they may not always encapsulate the full complexity of the problem's structure. The absence of a universally accepted methodology for constructing value trees can lead to challenges like information loss and attribute asymmetry (see Jacobi and Hobbs, 2007; Pöyhönen and Hämäläinen, 1998). These potential limitations highlight the necessity for a critical and thoughtful application of value trees in any decision-making process.

The core ambition of our research is to synergize cognitive maps with value trees, transforming them into instruments for policy design in conflict transformation and management. This endeavor is anchored in two primary objectives. Firstly, our goal is to enhance and integrate these renowned Problem Structuring Methods in a synergistic fashion, as proposed by Marttunen et al. (2017). By merging the introspective depth of cognitive mapping, which centers on the problem owner's subjective understanding and values, with the structured, value-oriented thinking advocated by value trees, we aim to forge a comprehensive and robust approach to problem structuring. This integrated method will not only encapsulate the problem owner's perspective but also offer a formalized avenue for value exploration and decision-making.

Secondly, our strategy involves deriving a value tree directly from the cognitive map, effectively channeling the insights gleaned from the cognitive mapping process into the structured framework of a value tree. This innovative step seeks to transform the qualitative richness inherent in cognitive maps into a more systematic and formalized representation of values. Such a representation is invaluable for policy design and decision-making, enabling a seamless transition from qualitative understanding to quantitative analysis.

Delving deeper, the thesis explores the complex interplay between the graph structure of cognitive maps and the hierarchical tree structure of values. We introduce the concept of a "value cognitive map," an intermediary construct that illuminates the simplifications and assumptions inherent in transitioning from a cognitive map to a value tree. This hybrid structure not only retains the descriptive integrity of the cognitive map but also embraces the methodological strengths of value-oriented thinking and value trees. Consequently, our approach transcends traditional conflict resolution methods by facilitating decision-making, enriched by diverse perspectives and considerations from both the problem owner and value-oriented frameworks.

As a result, by integrating the descriptive cognitive map, which identifies the nature of a problem, with the value tree, which proposes innovative solutions without defining the problem itself, we capitalize on both the cognitive map's descriptive attributes and the value tree's innovative potential. We now transition to the second part, which involves adapting these enhanced Problem-Structuring Methods (PSMs) to design theory.

Design theory positions design at the core of professional practices, distinguishing it from natural sciences through its focus on creating preferred situations from existing ones Simon (1969). This foundational perspective views design problems as inherently "wicked," due to their complexity and the interconnectivity of solutions and issues Simon (1988).The interdisciplinary nature of design research, highlighted by Chakrabarti and Blessing (2016) showcases the evolution of design theory over the last fifty years. This evolution, as outlined by Bayazit (2004), demonstrates a shift from systematic and rational processes to embracing disruptive innovations and creative reasoning, recognizing the need for interdisciplinary approaches and user involvement in solving complex real-world problems.

Modern design theory, especially through the Concept-Knowledge (C-K) theory introduced by Hatchuel and Weil (2003), marks a significant progression by offering a structured framework for the innovative design process. A "concept" is understood as a proposition or a group of propositions without a definitive truth value within a specific knowledge domain (K), typically describing attributes that qualify entities (see Hatchuel and Weil, 2003) while ”knowledge” is based on existing definite attributes, truth and values. C-K theory, in particular, facilitates a systematic exploration of the unknown, enabling the generation of novel solutions by navigating the space between concepts (C-space) and knowledge (K-space).

In the C-K methodology, the process facilitates both concept expansion and knowledge expansion. Through knowledge expansion, a concept tree is formed, which systematically represents the unfolding of new ideas and potential solutions. The construction of a concept tree is a complex and labor-intensive process that requires thorough exploration and careful assessment of the relevance and interconnections between concepts. This task necessitates critical thinking, particularly when dealing with abstract or intricate concepts, and largely depends on the subjective intellectual effort, given the lack of a standardized methodology. The challenge highlights the important role of an individual’s or team’s interpretation and understanding in the development of the concept tree. This is supported by literature from Hatchuel and Weil (2009b) and Hatchuel et al. (2004), which emphasize the difficulties encountered in exploring and expanding the Concept space (C-space). Such efforts demand not only a broad range of creative contributions but also the ability to integrate these inputs into coherent and innovative solutions, reflecting the intricate nature of design thinking and innovation. Kazakçi et al. (2009) points out that elaborating the concept space in design entails a complicated process of segmenting concepts and validating them through K-space validation. This validation process evaluates the feasibility of design propositions based on existing knowledge, further illustrating the intricate dynamics involved in design theory and practice. We propose our value tree, derived from a cognitive map, to serve as a knowledge tree. This transformation captures all of the problem owner’s knowledge about the situation in a descriptive cognitive map format. Additionally, the hierarchical relationship within the value tree not only clarifies the values but also suggests new alternatives. Therefore, it is aptly recommended as a knowledge tree.

Our examination of advanced methodologies draws attention to the operational role of design theory in the policy-making process, as explored by Pluchinotta et al. (2019a). Hatchuel and Weil (2009b) and Agogué et al. (2014) introduces the KCP methodology (Knowledge, Concepts, Proposals), a tool designed for managing collaborative design processes, and is grounded in the C-K (Concept-Knowledge) theory (see Hatchuel and Weil, 2003). This theory elucidates the co-evolution of the C-space (concept space) and K-space (knowledge space) in design reasoning. The KCP methodology, while widely applied in sectors like transportation, agriculture, and energy, remains relatively underexplored in public policy domains. To bridge this gap Pluchinotta et al. (2019b) presents the Policy-KCP (P-KCP) framework as a participatory tool for innovatively designing policy alternatives. This approach is particularly pertinent in policy analysis, which often concentrates on evaluating existing alternatives, while the creation of novel policy solutions is frequently overlooked. P-KCP addresses this issue by offering a generative, participatory process based on C-K theory. The pilot application in the Apulia case study exemplifies its potential in generating innovative policy alternatives, fostering stakeholder collaboration, and encouraging long-term strategic thinking.

Building upon this, another improvement made in this field is the integration of Problem Structuring Methods (PSMs) with C-K theory, as discussed by Pluchinotta et al. (2020). This amalgamation aims to broaden the spectrum of policy alternatives and augment the efficacy of policy design. PSMs play a vital role in establishing a shared understanding and commitment among stakeholders, which is crucial for effective policy development. Simultaneously, the Concept-Knowledge (C-K) theory redefines the design process as a dynamic interaction between Concepts (C-space) and Knowledge (K-space). This integration was practically applied using Fuzzy Cognitive Maps (FCMs), a type of PSM, to capture and structure individual stakeholders' perspectives in the Cyprus case study (see Pluchinotta et al., 2020) . However, fuzzy cognitive mapping implies a causal relationship between nodes (see Kosko (1986). In contrast, in real-world problem descriptions, there is not necessarily any specific type of relationship between concepts. Therefore, in this thesis, we propose a cognitive mapping technique based on the problem owner's description of the problem, rather than a causal map. Moreover, while a causal map enhances the 'knowledge space,' it does not always foster design thinking by organizing the problem owner's values hierarchically, as does the value tree we advocate for. Furthermore, given the similar graph structures of the concept tree and the value tree—both being tree-based—we assert that the value tree, derived from a cognitive map, will more comprehensively expand the knowledge space.

After integrating Problem-Structuring Methods (PSMs) into design theory, a third aspect of our theoretical contribution is incorporating design theory into policy design. By doing so, we propose a formal method to structure the concept tree, with the process outlined as follows:
-Increasing descriptive knowledge through cognitive maps, and with a value tree derived from this cognitive map, we aim to enhance innovative thinking anchored in values..
-This value tree will be considered a form of knowledge expansion and will further enhance the design process.
-By integrating the P-KCP, we will propose a method to construct the concept tree. Ultimately, this will lead to an innovative policy design process applicable to both conflict transformation and complex decision problems.

1.3 Case studies

In this thesis, we explore two case studies: the Kurdish-Turkish conflict, which serves to test our transformation process from cognitive map to value tree, and the Tunisia groundwater management case, used to validate our proposition and demonstrate its applicability across diverse contexts.

Firstly, it should be noted that these two case studies are intentionally distinct. In the Kurdish-Turkish case study, we examine a declared conflict, whereas in the Tunisia groundwater management case, despite the presence of diverse stakeholders with varying interests, there is no declared conflict. This distinction is important for the policy design process because the applicability of every technical tool can vary depending on the context. In times of conflict, the mere initiation of dialogue or conflict mediation might seem sufficient. However, in situations where there is no declared conflict, finding innovative policy alternatives without exacerbating tensions is essential. Our methodology is carefully designed to address these differences, ensuring careful application across varied contexts.

In the Kurdish-Turkish conflict, our study highlights the effectiveness of specialized cognitive mapping techniques in facilitating the transformation process, thus uncovering common ground and areas where compromise is possible. Given the declared conflict, we construct cognitive maps for each party differently, leading to distinct value trees. The integration of cognitive insights with value-oriented thinking has produced innovative alternatives for conflict resolution from each perspective. This result emphasizes our approach's ability to not only conduct a comprehensive problem analysis but also to cultivate a collaborative spirit, unveiling shared values and potential zones of agreement. It showcases our framework's value in policy design and conflict management, particularly in complex and nuanced situations like the Kurdish-Turkish conflict.

Simultaneously, our study navigates the complexities of groundwater management in arid regions like Tunisia, characterized by diverse stakeholder interests and challenging climatic conditions. We introduce a novel approach that combines Problem Structuring Methods (PSMs) with the P-KCP methodology. Unlike the Kurdish-Turkish conflict, where cognitive maps are constructed separately for each party, here we employ aggregated cognitive maps to highlight common grounds without exacerbating conflict, while still recording all information. This is achieved by initially creating cognitive maps for each stakeholder separately and then combining them. This methodology, which integrates cognitive maps and value trees, is designed to encourage new collective practices in groundwater management, effectively bridging the divide between decision theory and design theory. Through the incorporation of PSMs and C-K theory within our framework, we expand the range of policy alternatives, highlighting the importance of participatory approaches, adaptability, and the generation of unconventional policy solutions. This framework aims to act as a practical guide for policy innovation and collaborative problem-solving in environmental management.

After successfully applying our algorithm to transform the Cognitive Map (CM) into a Value Tree (VT) in two case studies, we further extended the methodology in the Tunisia study. In that case, we utilized not just the cognitive map but also the top structure of the Value Tree to construct the Concept Tree (CT), allowing us to capture a more structured understanding of the problem space. The initial results were highly promising, as the generated Concept Tree provided deeper insights and creative alternatives for the stakeholders involved.

Encouraged by these fruitful results, we decided to formalize and expand our approach. Specifically, we focused on developing a structured procedure to systematically use the entire Value Tree, rather than just its top structure, to create a comprehensive Concept Tree. This formalization aimed to ensure that all levels of the value hierarchy are incorporated, enhancing the ability to explore new concepts, generate alternatives, and foster innovation. By doing so, we sought to improve the decision-making process and increase the utility of the Value Tree to Concept Tree transformation across various domains and contexts.

We applied this proposal to a popular problem situation (Alice example) to further evaluate its effectiveness.

It is important to note that the example we selected does not perfectly align with the traditional definitions of conflict transformation. However, the reason for choosing this specific example is to test the generality and applicability of our results beyond the realm of conflict transformation and management. By using a diverse problem scenario, we aim to demonstrate the flexibility of the Value Tree-to-Concept Tree methodology and assess its broader utility in solving complex, multi-dimensional problems across various fields.

Chapter 2

Literature review

Our literature review is divided into three well-defined parts, aligned with the thesis's structure. The initial section focuses on Conflict Transformation and Management, analyzing the decision theory and our advancements in developing Problem Structuring Methods (PSMs), cognitive maps, and value trees to address conflict situations and complex decision-making tasks. The second section moves into design theory, where we aim to further enhance PSMs by introducing innovative and out-of-the-box alternatives, with a particular focus on Concept-Knowledge (C-K) theory to create a meaningful connection between PSMs and C-K theory. The final section is dedicated to policy design, linking our research to Conflict Transformation and Management within the sphere of public policy, underscoring our interest in formulating effective public policy design.

2.1 Conflict transformation and management

Conflicts, inherent to the interactions between individuals, organizations, institutions, and states, emerge from divergent interests and perspectives at various points in time. Fundamentally, the presence of conflict is not problematic and can, in fact, serve as a catalyst for creativity and innovation. The issue arises when conflicts escalate violently, leading to destruction and loss—of lives, assets, and infrastructures.This simple observation, coupled with the increasing frequency and complexity of conflicts, has catalyzed the development of an interdisciplinary research domain known as "Conflict Transformation and Peace Studies."

One of the first contributions on the area is Galtung (1969) investigates personal and structural forms of violence, emphasizing the mission of peace research to address and mitigate these issues for peace attainment. Galtung introduces an insightful definition of violence, identifying it as the divergence between potential outcomes and actual conditions, particularly highlighting how violence either widens this gap or obstructs efforts to close it. Importantly, he marks 'avoidable' harm as a core element of violence, extending the concept beyond physical acts to include the broader spectra of social and structural injustices that are preventable. This expanded view urges peace research to confront both overt and hidden violence sources, advocating for a holistic approach to securing enduring peace.

In subsequent work, Galtung (1976) elaborates on the distinction between negative and positive peace. Negative peace refers to the absence of organized violence, such as war or internal conflicts between significant groups, including nations, races, and ethnicities. Positive peace, conversely, encompasses patterns of cooperation and integration among these groups. Galtung further refines the connection between concepts of violence and peace by differentiating peacekeeping and peacemaking—immediate responses to conflict—from peacebuilding. Peacebuilding is envisioned as a strategy to foster a sustainable peaceful future, extending beyond the mere absence of war to include societal conditions that promote harmony, respect, justice, and inclusiveness, thus contributing to the development of 'positive peace'.

Further Galtung (2007) approach to conflict transformation includes a spectrum of interventions from preventive to curative, integrating diverse strategies that challenge the predominant security discourse. He advocates for a shift towards peace culture and structure, emphasizing the development of societal systems that promote equality and address underlying causes of conflict. This model encompasses mediation to soften conflicts, peacebuilding to change perceptions and behaviors, and nonviolence as a principle. Conciliation focuses on healing trauma, while creating virtuous cycles aims to eradicate violence, fostering a peace process that balances empathy, non-violence, and creativity.

Rogers and Ramsbotham (1999) presents crucial implications for conflict transformation, emphasizing the necessity of addressing the root causes of conflicts and advocating for equitable relations to ensure long-term peace. Their interdisciplinary approach underscores the importance of integrating insights from various disciplines, including sociology, psychology, and anthropology, to fully comprehend and address the multifaceted nature of conflicts. The study advocates for the non-violent transformation of conflicts, highlighting the need for peaceful resolution methods that avoid further escalation and promote lasting solutions.

Frelin (2016) emphasizes that while no single method can fully analyze complex conflicts due to their inherent complexity, certain tools like conflict analysis, scenario analysis, sensitivity modeling, and fuzzy cognitive maps offer valuable insights. These tools form a 'complex conflict analysis portfolio' for understanding and navigating conflicts towards peaceful resolutions. The application of Complexity theory enhances the grasp of conflict dynamics, highlighting the importance of continuous, evolving conflict analysis within a knowledge-creating process. This approach, emphasizing ongoing analysis rather than one-off evaluations, promises to improve strategies for conflict resolution.

In our exploration of conflict transformation and management, we advocate for the use of Problem Structuring Methods (PSMs), specifically highlighting the dual strengths of cognitive mapping and value trees. Cognitive maps bring a descriptive power that adeptly captures the complexity of conflicts, laying out the interactions and perspectives involved to provide a clear understanding of the issues at hand. Complementarily, value trees offer a prescriptive approach, structuring potential resolutions and guiding decision-making processes based on aligned values and objectives. This synthesis promises to enrich the field by leveraging cognitive maps for their detailed exploration of conflict landscapes and value trees for their structured approach to crafting solutions. Thus, our literature review will delve into an analysis of these methods, aiming to showcase their potential to innovate conflict transformation and management.

2.2 Using Problem Structuring Methods

Traditional Operational Research (OR) methods assume problems are well-structured (see Rosenhead, 1996). However, in real-world scenarios involving multiple stakeholders and complex dynamics, these "hard-OR" techniques often fail to deliver effective solutions (see Ackoff, 1979a,b); Rosenhead and Mingers (2001) proposed Problem Structuring Methods (PSMs) to recognize the complexity and uncertainty in real-world decision problems. PSMs, like cognitive mapping and value trees, aim to develop assessments and establish common ground in complex situations (see Ackermann, 2012a).

PSMs enable stakeholders to identify key issues and explore different perspectives, generating new insights by structuring and organizing information. Notably, Keeney's value-focused thinking, which emphasizes values over alternatives, stands out as an exception in PSM literature, addressing innovative solutions vital for conflict situations or complex problems. Moreover, policy design theory benefits from design theory, emphasizing early stakeholder engagement (see Pluchinotta et al., 2020), while the Concepts-Knowledge (C-K) theory (see

Hatchuel and Weil, 2003, 2009b) is suggested as a fitting theoretical framework. Mainstream decision analysis often focuses on selecting alternatives without considering their generation (see Colorni and Tsoukiàs, 2018), a significant shortfall in conflict situations where current options are inadequate. In such scenarios, stakeholders need support in finding innovative solutions and common ground for constructive dialogue.

In the following section, we will closely examine the literature on cognitive maps and value trees. These two Problem Structuring Methods (PSMs) are increasingly recognized for their effectiveness in addressing complex decision-making scenarios, particularly in environments marked by conflict and uncertainty. By delving into the existing research, we aim to understand how cognitive maps and value trees have been applied in various contexts, their strengths and limitations, and the synergies they create when used together in problem-solving processes. This analysis will provide a comprehensive understanding of their roles in facilitating decision-making and conflict resolution.

2.3 Cognitive mapping

The concept of a cognitive map, introduced by Tolman (1948), has developed into a multidisciplinary analytical tool. Its original purpose in spatial cognition has expanded to a variety of fields such as psychology, urban planning, management, and political science which we eleborate in this section. This broad application underscores its efficacy in deciphering complex systems and decision-making mechanisms.

The distinctive aspect of cognitive mapping lies in its foundational goal to operationalize (see Kelly, 1955) 'Theory of Personal Constructs', as Eden and Jones (1984) and Eden (1988) elaborate on this theory, which views individuals as problem solvers who understand and predict the future by discerning contrasts and similarities among their knowledge and experiences (see Pyrko and Dörfler, 2018).

Eden (1988) discusses the concept of cognitive mapping within the context of operational research. Eden explores the history and development of cognitive mapping, its relationship with other disciplines, and its application in decision making. Eden (1988) delves into the theoretical underpinnings of cognitive mapping, its practical implications, and the role of language and ideas in managerial decision-making. It also examines the interplay between individual perceptions and organizational problem-solving, emphasizing the importance of understanding personal and organizational construct systems. Eden's exploration covers various aspects including the use of repertory grids, the significance of Kelly's theory in cognitive mapping, and the development of mapping techniques that reflect the richness and complexity of managerial thought processes. Swan (1997) examines various methodologies within cognitive mapping, highlighting their application in management research related to technological innovation. The methodologies discussed include content mapping, causal mapping, and argument mapping. These techniques are distinguished based on the nature of the relationships between concepts they analyze. The article emphasizes the importance of the validity of these cognitive mapping methodologies. It points out that the output of a cognitive mapping technique is not necessarily a direct reflection of an individual's mental model. Instead, it may be influenced by the specific approach taken, such as the type of questions asked during face-to-face interviews, which can alter the composition of the cognitive map. Further, Eden (2004) discusses the analytical techniques for cognitive maps in problem structuring. It explores the structural properties of maps, the role of feedback loops, and the identification of central concepts or 'nubs of issues.' In the concept of hierarchy in cognitive maps is addressed in the context of problem structuring. Eden (2004) notes that complexity often manifests in the form of a hierarchy, where each node in a cognitive map is supported by a 'tree' of other nodes, each having implications for the node of interest. This suggests that each node can be examined within its own hierarchical cluster. To effectively detect emerging features of a cognitive map, it is more beneficial to consider a subset of nodes and their hierarchical relationships, which suits our proposal in cognitive mapping with a fundamental node.

Another type of cognitive mapping is the Axelrod type (see Axelrod, 1976), which serves distinct functions within their respective frameworks despite sharing a common structure as a directed graph of ideas, Axelrod focuses on systematic analysis of causal assertions in decision-making, employing structured data collection methods while Ackermann and Eden (2020) building on Kelly's Personal Construct Theory, emphasizes collaborative mapping with groups to create aggregated maps (Bougon, 1992, see also congragrated maps) using open interviews and team discussions for collective knowledge construction (see Çoban and Seçme, 2005), as detailed by Cropper et al. (1990). As emphasized in Coopamootoo and Groß (2014), the fundamental difference is that the goal in the Axelrod-type cognitive map is to create a 'map of cognition', while in the Eden-type cognitive map, the aim is to serve as an 'aid to cognition'. Furthermore, as discussed in Marchant (1999), the meaning conveyed by the arrows in the Axelrod-type implies 'causal assertion', whereas in the Eden-type, there is an 'implication'. Eden

(1992) further elucidation on cognitive maps presents them as visual aids that encapsulate the mappers' understanding of specific elements of thought, providing a snapshot of cognitive elements at a given time. As it is inspired by Kelly (1955), the Eden-type cognitive map addresses the problem owner's perspective (see Eden, 1988); in this thesis, by recognizing the significance of structuring problems in the first phase (see Tsoukiàs, 2007) with stakeholder involvement (see Belton and Stewart, 2010) our first interest is the problem owner's perspective on the issue/ conflict. This approach contrasts with the 'fuzzy cognitive map' (see Kosko, 1986), which is developed from Axelrod-type cognitive maps with fuzzy logic based on expert knowledge (see Gray et al., 2013; Khan and Quaddus, 2004; Stach et al., 2010). FCMs expand on cognitive maps by introducing fuzzified causal relationships, assigning numerical values to links for nuanced influence representation, and incorporating a dynamic feedback system (see Khan and Quaddus, 2004). Although Axelrod maps are also used as a problem structuring method (see van Kouwen et al., 2009), in this thesis, we employ the Eden-type cognitive mapping because it's flexibility (see Ackermann et al., 1992) which will be crucial in complex problems and descriptively presents the stakeholder perspective (see Eden et al., 1992) which is fundamental for conflict situation as source of conflict depends on parties characteristics (see Fisher, 2000). Although Eden-type maps are descriptively effective in problem structuring, neither Axelrod-type nor Eden maps are innovative and prescriptive especially in conflict situtaion.

Within the spectrum of cognitive mapping methodologies, the integration of Strategic Options Development and Analysis (SODA) (see Eden, 1995) marks a pivotal evolution, extending cognitive mapping's utility into the realms of strategic management and organizational change. Originating from the foundational principles of 'personal construct theory' (see Kelly, 1955), SODA, as detailed by Ackermann et al. (2001), enriches the cognitive mapping landscape by fostering a collective construction of meaning. SODA is utilized as a strategy for thoroughly examining complex issues prior to decision making and incorporates either cognitive mapping or causal mapping as a fundamental method to support this detailed investigation (see Ackermann and Eden, 2020). This approach not only aids in streamlining negotiation and action planning but also highlights the critical role of facilitation in navigating complex decision-making processes; this methodology has been detailed in Eden and Ackermann (2013) illustrating its broad scope and versatility in various strategic contexts. Spanning from individual decisions to addressing international organizational challenges, SODA exemplifies cognitive mapping's versatility in exploring strategic goals and options. Further insights by Eden and Ackermann (2004) into cognitive mapping's applicability within Soft Operational Research (OR) underscore its importance in public sector policy analysis, illustrating the effective use of tools like Decision Explorer to manage and resolve intricate policy issues and example of usage of cognitive mapping in policy analysis in the public sector. The SODA methodology, enhanced by cognitive mapping and Decision Explorer software in the public sector study, demonstrated its value by creating a detailed knowledge base for policy analysis, enabling exploration of complex issues, and facilitating the presentation of policy options and outcomes, streamlining strategic decision-making processes (see Eden and Ackermann, 2004). Also Cunha and Morais (2016) analyse cognitive mapping in group decision making process, paper expand knowledge SODA, more specifically cognitive mapping usage in group setting.

The SODA (see Eden and Ackermann, 2013; Ackerman et al., 2005);, as demonstrated by Eden and Ackermann (2013) highlights the integration of individual maps into a collective framework for System Dynamics modeling, underscoring the technique's pivotal role in strategic development. Further emphasizing cognitive mapping's broad applicability (see Ackermann and Eden, 2005) and Ackermann et al. (2014) illustrate its use in identifying project risks and understanding the nuances behind project failures. Silva et al. (2019) extend its application to assess the openness of small and medium-sized enterprises to innovation, highlighting cognitive mapping's role in competitive strategy formulation. Moreover, Ahmad and Xu (2021) advances the methodology by proposing a systematic approach to manage and analyze complexity through cognitive mapping. This involves organizing stakeholder inputs into thematic groups and merging them for a holistic view, thereby enhancing both the analysis's depth and the coherence in understanding multifaceted issues from diverse stakeholder perspectives. The methodologies developed by Kato et al. (2007) and Nakagawa et al. (2010) present a compelling narrative in the evolution and application of cognitive mapping within the SODA framework for problem structuring methods (PSMs). Kato et al. (2007) introduce a methodology that diverges from traditional SODA approaches by focusing on elucidating the differences among stakeholders rather than aiming for consensus. This approach enhances the problem-structuring process by incorporating hypothetical cognitive maps and actively seeking new stakeholder insights. Nakagawa et al. (2010) build upon this foundation, applying the methodology to assess the societal impacts of nanotechnologies in Japan, thereby demonstrating the adaptability of cognitive mapping in addressing complex societal challenges. Together, these studies highlights the importance of recognizing and integrating diverse stakeholder perspectives for problem analysis and solution development. First Kato et al. (2014) using cognitive mapping to structure stakeholder perspective, then they construct value –driver matrix and a reciprocal expectation matrix to see feasibility agreements among stakeholders and categorize relationships. Also Georgiou (2012) combine SODA and SSM (Soft System Methodology) and show how SODA-T (SODA applied to transformations) mapping can structure transformations and aid in systemic planning by cutting through what might appear as chaotic interrelations between issues.

In both conflict situations and complex problems without conflict, when engaging in cognitive mapping with multiple stakeholders, it's important to determine whether to structure the 'situation' separately for each stakeholder or in a unified manner that encompasses all stakeholders. Damart (2010) addresses a gap in cognitive mapping research, particularly in managing problem structuring with multiple stakeholders as highlighted by Mingers and Rosenhead (2004). The authors develop a structured approach using cognitive mapping to effectively organize and analyze the diverse viewpoints of various actors in complex problem scenarios. The method involves systematically categorizing stakeholder inputs into thematic groups, enhancing the depth and clarity of problem exploration. This suits our argument posits that in situations of conflict, cognitive maps should be designed separately to accommodate differing perspectives and in the absence of conflict, individual cognitive maps can be merged to form a unified representation, which resonates with Langfield-Smith (1992) suggests that shared cognitive maps underscore their role in collective decision-making within organizations, revealing the dynamic nature of shared cognitions.

Further, for individual cognitive maps, Langfield-Smith and Wirth (1992) enhances the analytical applications of cognitive maps by developing quantitative measures for comparing different cognitive maps. Lee et al. (1992) emphasizes a participatory approach, introduce 'The Collective Cognitive Mapping System", COCOMAP, a system designed to support organizational learning through cognitive mapping. COCOMAP facilitates the creation, integration, and analysis of both individual and collective cognitive maps, aiming to enhance decision-making processes and knowledge sharing within organizations.. Tegarden and Sheetz (2003) specifically addresses the challenge of integrating individual cognitive maps into a unified, collective cognitive map. The article introduces a cognitive mapping-based methodology and system that effectively work with group cognitive mapping. This methodology supports the collection and analysis of data to reveal both individual and collective cognitive maps within organizations. This approach not only captures individual viewpoints but also effectively combines them to form a collective organizational perspective, thus enhancing the process of problem structuring in complex organizational environments. While the literature outlines the benefits of both group and individual mapping, it doesn't not explicit specifying the conditions under which cognitive maps should be either combined or kept separate for analysis.

In the exploration of the distinction between individual and group cognitive processes, it becomes imperative to underscore the variance between individual cognitive maps and those conceptualized for groups. Causal maps are a type of directed graph that encapsulate the cause-effect relationships inherent in managerial thinking and decision-making processes (see Fiol and Huff, 1992), and further elaborated by Eden (1992), a causal map is characterized as a directed graph with a hierarchical structure, commonly resembling a means/end graph. Cognitive maps articulate an individual's perception of scenarios, epitomized by the insight from Wickes, "how do I know what I think until I see how I act" (see Weick, 2015) and aims to illustrate an individual's thought processes (their cognition), while causal mapping focuses on representing the collective reasoning of a group (see Eden and Ackermann, 1998; Ackermann and Eden, 2020). Causal maps have been utilized across various domains (see Axelrod, 1976; Fiol, 1990; Swan, 1995; Laukkanen, 1994) to represent the beliefs and knowledge of decision makers, helping to identify the factors that influence their decisions in means-end relation.

Causal maps can be constructed by oval mapping techniques (manually) (see Bryson et al., 2014) for group dynamics or the aggregation of cognitive maps (see Ackermann and Eden, 2020) or with software (see Ackermann and Eden, 1994; Eden and Ackermann, 1998; Ackermann and Eden, 2020; Pyrko and Dörfler, 2018). Causal mapping, with its group-centric orientation, amalgamates and depicts the shared insights and collective thought processes within a group, unveiling how the ensemble interprets and constructs their reality rather than solely representing specific groups position (see Bryson et al., 2004, 2014). Through the formulation of argument chains in a "means-end" format (see Ackermann and Eden, 2004), causal mapping elucidates the pathways through which various concerns may eventuate into specific outcomes. Thus, it systematically organizes the group's collective rationale and perspectives, laying the groundwork for deliberation on potential actions and their consequences. Ackermann and Eden (2011) illustrate the practical application of causal mapping and Group Support Systems (GSS) in strategic decision-making processes and shows how GSS facilitates the collective cognitive change necessary for strategy negotiation, leveraging causal maps to structure and visualize the complex interplay of ideas and arguments within a team It's worth noting that Keeney suggests means-ends objective networks can be considered as causal maps, stimulating the generation of new alternatives (see Keeney and McDaniels, 1992). However, the structuring of a problem owner's subjective cognition does not necessarily conform to means-ends relationships. In this thesis, a mandatory means-end relationship between nodes in the cognitive map is not assumed; instead, an influence relationship prevails. While this broad and flexible relationship structure can encompass means-ends relationships, it is not confined solely to them.

The distinction between causal maps for groups and cognitive maps for individuals proves inadequate for conflict transformation. This is because it primarily advocates for group mapping, given the involvement of multiple actors inherent to conflict situations. Montibeller and Belton (2006) pointed out that conflicting objectives or aims can make inference from causal maps challenging, and it may be difficult to identify the most influential options (see Montibeller et al., 2008; Kosko, 1986). Yet, in instances of declared conflict, the objective shifts from merely illustrating a consensus through a group map to identifying potential common ground or points of compromise between the conflicting parties. This requires a detailed analysis of each party's approach to the conflict. Therefore, rather than focusing on shared aspects, recognizing the unique perspectives and structures of each conflicting party becomes crucial.

Although methods such as fuzzy cognitive maps (see Kosko, 1986; van Vliet et al., 2010; Glykas, 2013), Bayesian networks (see Nadkarni and Shenoy, 2001, 2004), and means-end analysis are recommended in MCDA evaluations (see Lue et al., 2014) to overcome the inference uncertainty of causal mapping, we suggest utilizing the descriptive nature of cognitive maps, as outlined by Kelly's theory, for problem structuring.

Ferretti (2016) combines cognitive mapping with Multi-Attribute Value Theory (MAVT) , as part of a mixed-method approach designed to support strategic choices and public policies. This integration aims to leverage the strengths of each method to provide a framework for analysis and evaluation. Cognitive mapping, informed by Personal Construct Theory (see Kelly, 1955), helps in structuring complex problems by visually representing the relationships between different concepts. MAVT, a technique within Multi-Criteria Decision Analysis (MCDA), is then used to evaluate the alternatives identified through cognitive mapping, based on a set of attributes that represent the objectives of the decision-making process. The rationale behind combining these methods is to create synergies that enhance the decision support framework. The sequential design chosen for this integration allows for the identification and structuring of the problem using cognitive mapping, followed by an evaluative phase using MAVT. This approach is particularly suited to policy making, where the planning process benefits from a structured method that can accommodate the complexity of public decisions and the multitude of stakeholder perspectives involved. Mendoza and Prabhu (2009) utilizes cognitive mapping to form and structure Value Trees (VTs) by employing concepts and tools of cognitive mapping alongside approaches from Tikkanen et al. (2006) and Kearney and Kaplan (1997). The process involves stakeholders collaboratively generating a cognitive map that represents their collective understanding of the problem's objectives and alternatives. This map is then structured into a Value Tree, organizing objectives and alternatives into a hierarchical and networked format. This organization reflects the goals and objectives at the top of the hierarchy, with strategies and alternatives detailed at lower levels, all connected through arrows indicating causal or contributory relationships.The motivation behind using cognitive mapping for constructing Value Trees is to enhance participatory decision-making by ensuring that the evaluation of project impacts incorporates the diverse values and perspectives of all stakeholders. By making the decision context explicit and understandable through a structured VT, the approach aims to improve stakeholder engagement, ensure transparency, and facilitate consensus-building on the prioritization of objectives and selection of alternatives.

In this thesis, we propose a formal method that transforms the descriptive structure of cognitive mapping into the prescriptive, design-oriented structure of a value tree. Unlike the approaches outlined in the previous papers, our methodology is anchored in a comprehensive algorithm. This algorithm is designed to systematically convert the rich, descriptive insights captured through cognitive mapping into a structured, actionable framework represented by the value tree. Our main motivation for adopting this approach is to leverage the intrinsic strengths of cognitive mapping—its ability to elucidate complex stakeholder perceptions and interactions—in service of creating a more directive, design-focused outcome that is essential for strategic decision-making and policy formulation.

The prior studies like Mendoza and Prabhu (2009) and Ferretti (2016) have contributed to our understanding of integrating cognitive mapping with value tree analysis. However, they primarily focus on employing cognitive mapping as a tool for facilitating stakeholder discussions and mapping out the decision context without a formalized pathway to transition these insights into a structured decision-making framework. Our critique centers on this gap: the need for a more rigorous, algorithmically driven process that not only captures but also translates the complexities of stakeholder perceptions into a hierarchically organized, strategy-oriented value tree. By introducing a formal algorithm, we aim to address these limitations, offering a methodology that not only enhances the participatory aspect of decision-making but also ensures that the transition from cognitive maps to value trees is seamless, structured, and replicable across different contexts.

2.3.1 Cognitive mapping: applications

In the remaining part of the section, we will examine the applications of the cognitive map in various fields and problem presentations.

Cognitive mapping, rooted in Kelly's Theory of Personal Constructs, has found extensive application in strategic management, enhancing decision-making and planning across various contexts. The integration of cognitive maps with systems like Woodstrat (see Carlsson and Walden, 1997) underscores its utility in aligning strategic planning with management teams' cognitive structures. Its application ranges from international market selection, where managerial cognition influences market perceptions and strategic positioning (see Andersen and Strandskov, 1997), to the nuanced balance of multiple map types for strategic insight (see Fiol and Huff, 1992). Given the complexity of organizations, Fiol and Huff (1992) points out that the cognitive maps at managers' disposal may only capture fragments of the full picture, often presenting conflicting viewpoints. Consequently, managers must excel at juxtaposing different maps to gain an understanding of various perspectives on current states, desired improvements, and strategies to bridge the gap.Furthermore, cognitive maps impact industry-specific strategic decision-making, shaping perceptions of industry structure and competitive dynamics (see Borroi et al., 1998), and facilitating business process redesign and organizational change (see Kwahk and Kim, 1999). Notably, its use in ethical banking Ferreira et al. (2016) demonstrates cognitive mapping's ability to structure complex decisions with ethical considerations, showcasing its versatility and benefits in strategic management. Wang et al. (2018) examine the effects of using cognitive mapping and note taking approach and shows that using a computer-based cognitive mapping approach improves the learning process of students.

Cognitive mapping's utility extends well beyond traditional strategic management, as demonstrated by Ackermann's work in project risk identification and the analysis of project failures (see Ackermann and Eden, 2005; Ackermann et al., 2014). This approach is further applied by Silva et al. (2019) to evaluate the innovation openness of small and medium-sized enterprises, reinforcing its significance in formulating competitive strategies. Additionally, Ahmad and Xu (2021) advances cognitive mapping methodologies by proposing a systematic framework for managing and analyzing complexity. This method involves categorizing stakeholder inputs into thematic groups and integrating them to achieve a comprehensive perspective, thereby deepening the analysis and ensuring a coherent understanding of complex issues from multiple stakeholder viewpoints.

In the evolving landscape of cognitive mapping literature, the application of cognitive maps offering innovative insights into complex decision-making processes. Ferreira et al. (2011) integrated MCDA and cognitive maps (CMs) to facilitate benchmarking evaluations in environments characterized by conflicting interests and multiple stakeholders. Oliveira et al. (2017) illustrate how cognitive mapping, combined with the MACBETH approach within Multi-Criteria Decision Analysis (MCDA), can enhance bankruptcy risk assessments in Small- and Medium-Sized Enterprises (SMEs). Furnari (2015) extends the application of cognitive maps into the realm of business models, arguing that these models transcend mere activity systems to represent cognitive understandings of such systems. By deploying cognitive maps to reveal business models' complexity, focus, clustering, and underlying causal mechanisms. Horlick-Jones and Rosenhead (2007) integrated cognitive maps (CMs) with ethnography within a cross-disciplinary, multi-methodological framework.

In terms of risk management Van Winsen et al. (2013) discusses the use of cognitive mapping to capture and present the complex risk perceptions of farmers. The study demonstrates that cognitive maps can serve various functions, such as facilitating communication, acting as a risk management tool, and promoting mutual learning among farmers, policymakers, researchers, and extension agents. Vaz et al. (2022) using cognitive mapping for strategic analysis in the question of smart cities, and they compare their results within SODA. Also, another interesting application of cognitive mapping by using decision explorer Ellis et al. (2018) discovered motivations of food tourism in the literature. Nyffenegger et al. (2024) used cognitive mapping for stakeholders in supply chain transitions. They extracted stakeholders' perceptions about the issue, and they made a group cognitive maps with common interpretations.

In environmental sciences, Isaac et al. (2009) employs cognitive mapping to delve into the agroforestry management practices of Ghanaian cocoa farmers, emphasizing the importance of local knowledge in crafting adaptable management strategies. Cognitive maps revealed intricate management variables and their interrelations, centralizing ecological processes and showcasing farmers' capacity to control farm characteristics. Tikkanen et al. (2006) presents a study that utilizes cognitive mapping to understand and describe the objectives forest owners have for their forest ownership and management in a hierarchical manner. These insights suggest that cognitive mapping can effectively integrate qualitative and quantitative research methods in objective surveys and could serve as a valuable tool for qualitative objective analysis in environmental studies, the similar approach also Hjortsø (2004) studied improve participation in natural resources management in the umbrella of soft OR and SODA. Also Kropf et al. (2021) using cognitive mapping in an environmental setting, they developed aggregated cognitive map of the Seewinkel region, in Australia, on relationships of environmental themes of the stakeholders.

The utilization of Fuzzy Cognitive Mapping (FCM) as a versatile tool in assessing socio-economic impacts and policy-making is highlighted through several studies, including privatization effects on employees in Turkey (see Çoban and Seçme, 2005), Gupta and Gupta (2017) used FCM for modeling of economic variables in India, and Papageorgiou et al. (2019)'s application in socio-economic development for rural Indian communities and Özesmi and Özesmi (2004) approach provides a methodology for ecological modeling and stakeholder analysis and introduces a multi-step fuzzy cognitive mapping (FCM) approach to incorporate both expert and local knowledge into ecological models.

2.3.2 Cognitive mapping: discussions

Cognitive mapping, commonly recognized for its problem-oriented approach in decision support, features structures on the map that are propositional and indicative of specific actions (see Eden, 1988, 2004). However, a critical examination of cognitive maps in the literature reveals that their definitions tend to be primarily functional, focusing on their role as a method for problem structuring. This functional orientation contrasts with a more design-oriented perspective, which might prioritize visual or structural aspects of the maps.

In this context, the definition of cognitive maps put forth by Eden, drawing inspiration from Kelly (1955) 'theory of human beings as problem solvers', is particularly noteworthy. Eden and Kelly's approach characterizes cognitive maps not as design tools but as descriptive instruments. These maps are widely accepted for their ability to elucidate how problem owners perceive and articulate complex issues. This descriptive nature of cognitive mapping is important as it shifts the focus from mere visual representation to a deeper understanding of the cognitive processes underlying problem-solving.

Eden's interpretation accentuates the cognitive map's role in making tacit knowledge and personal constructs explicit, transforming intricate mental models into a structured format conducive to analysis and collaborative discussion. This perspective is instrumental in fields such as strategic management (see Swan, 1997; Wood et al., 2012), policy development (see Farsari et al., 2011; Ferretti, 2016), and organizational behavior (see Lee et al., 1992; Tegarden and Sheetz, 2003; Mondschein et al., 2006) where understanding and integrating diverse viewpoints are essential.

Thus, Eden's and Kelly's conceptualization enriches the discourse on cognitive mapping by emphasizing its capacity as a reflective tool for individual cognitions and a collaborative medium for exploring complex problems. This dual utility of cognitive maps, being introspective yet collaborative, signifies a evolution in the realm of problem structuring and decision support, marking a departure from traditional, design-centric interpretations.

Venturing into a more critical examination of the theory and application of cognitive maps, particularly in the context of conflict transformation and management, uncovers several limitations. This critical perspective is imperative for a comprehensive understanding of cognitive mapping, as it sheds light on the constraints and challenges inherent in their practical application for managing and resolving conflicts. While cognitive maps have been lauded for their ability to elucidate complex problems and facilitate decision-making processes, their effectiveness in the specific domain of conflict transformation warrants a closer scrutiny. This analysis aims to explore the nuanced aspects where cognitive maps may fall short, questioning their adaptability and efficacy in conflict-laden scenarios. Understanding these limitations is not only important for advancing the theoretical framework of cognitive mapping but also for enhancing their practical utility in real-world conflict management and resolution strategies.

Firstly, a fundamental limitation of cognitive mapping in the realm of conflict transformation and management lies in its primary function of providing a descriptive understanding of the problem from the perspective of the problem owner. While it proficiently captures how the problem owner structures and organizes information about the conflict, this approach may not necessarily yield innovative or creative solutions for its resolution. The importance of understanding the problem owner's viewpoint is undeniable; however, this understanding alone may not suffice for the actual resolution of the conflict.

In numerous conflict scenarios, the existing solutions or alternatives often prove to be inadequate or ineffective in addressing the deeper, underlying issues at play. This inadequacy suggests that mere knowledge of how the problem is perceived by the owner may not lead to effective conflict resolution. Instead, there emerges a need for novel and previously unexplored alternatives that transcend the existing knowledge and understanding surrounding the problem. Cognitive mapping, while useful in delineating the cognitive structures of stakeholders, does not inherently facilitate the generation of transformative solutions. As Miall (2004) suggests, conflict transformation involves not just reframing positions or identifying mutually acceptable outcomes but also engaging in a deeper process of transforming the relationships, interests, and discourses that sustain the conflict.

Cognitive mapping, in its traditional application, does not always extend to providing actionable insights about the solution or suggest previously unconsidered strategies regarding conflict drivers and the problem owner's configuration of the problem. For effective conflict transformation and management, it is imperative to not only comprehend the drivers of the conflict but also to innovate creative and strategic solutions to address them (see Galtung, 1999; Lederach, 1996). Cognitive mapping, in this regard, may fall short in offering guidance on how to actually resolve the conflict or in generating new, uncharted alternatives that could potentially be transformative.

The domain of conflict transformation and management necessitates methodologies that extend beyond the scope of cognitive mapping. Design-oriented methods, in contrast, lay a strong emphasis on creative problem-solving, the generation of new ideas, and the design of interventions capable of inducing positive change in the dynamics of the conflict. These methods prioritize the creation and exploration of new pathways and solutions. Cognitive mapping, predominantly descriptive in nature, may not fully align with or support these design-oriented structures, which are integral for effective conflict transformation and management.

Secondly, the process of obtaining information about the source of a conflict is pivotal for effective conflict transformation and management (see Galtung, 2009; Ramsbotham et al., 2011). A deeper understanding of the underlying root of a conflict is essential for a focused and solution-oriented approach in conflict analysis. By identifying the source, it becomes feasible to discern which conflict drivers are active and to develop strategies that address them effectively (see Dudouet, 2006).

However, the task of defining the 'source of conflict' presents significant challenges, largely due to the absence of a universally accepted definition. The concept of a conflict's source is multifaceted, potentially encompassing elements such as conflicting values, differing perceptions, and opposing tasks. To effectively resolve a conflict's source, there is a need for a profound understanding of the intentions and attitudes of the stakeholders involved. It requires delving into their motivations for seeking resolution and making sense of the dynamics that underpin these motivations.

As elucidated in the work of Watzlawick et al. (1974) , effecting change in a problematic situation involves the ability to modify the dynamics of how such a situation evolves. This approach emphasizes the necessity to identify and comprehend the driving forces behind a conflict, rather than merely describing it. By achieving this level of understanding, conflict resolution efforts can be more precisely targeted, addressing the root causes instead of merely treating the symptoms of the conflict.

This critique underscores the crucial need to integrate the concept of the conflict source into cognitive mapping and other conflict analysis methodologies. Incorporating this dimension allows for a more comprehensive and solution-oriented conflict management strategy. It calls for an expansion of cognitive mapping techniques to encompass not just the depiction of the conflict but also an in-depth analysis of its foundational causes, thereby enhancing the effectiveness of conflict resolution initiatives.

Thirdly, an important aspect of resolving conflicts is the establishment of a 'common ground' among stakeholders, where similarities, shared concerns, and mutual interests are recognized and valued (see Galtung, 1999; Pikas, 2002; Melone et al., 2002; Jameson et al., 2014). Cognitive mapping, in theory, with its graphical representation of problems, plays a important role in facilitating this discovery. It enables the analysis of relationships between concepts, thereby contributing to effective problem structuring. By graphically delineating the relationships among various elements of a problem, cognitive mapping aids in recognizing patterns, interdependencies, and causal linkages, which are instrumental in comprehending the complexity of the conflict.

Furthermore, cognitive mapping can be an effective tool in identifying common ground by visually highlighting areas of agreement and disagreement among conflicting parties. This visual representation can serve as a basis for constructive dialogue, pinpointing potential areas for compromise and collaboration. However, a common practice in cognitive mapping is constructing a single map for a group of stakeholders. This approach, while useful in some scenarios, may not be entirely appropriate in severe conflict situations where the very act of discussing together might be contentious.

To address these limitations, incorporating systematic stakeholder involvement methods, such as Hierarchical Process Modelling (HPM), is essential. HPM, as highlighted by Davis et al. (2010), emphasizes structured engagement through pre-workshop preparations, facilitated discussions, and continuous involvement, ensuring a shared understanding among stakeholders for to create group cognitive mapping.

However, HPM has limitations, including being time-consuming, requiring skilled facilitation, and facing scalability and integration challenges. These challenges necessitate careful planning and skilled facilitation when applying HPM in conflict resolution contexts.

The effectiveness of cognitive maps in such contexts greatly depends on their application. For instance, constructing individual cognitive maps for each stakeholder involved in the conflict can provide a more nuanced understanding of how the conflict is perceived, understood, and experienced by each party. This approach allows for a more personalized and empathetic understanding of each stakeholder's position, potentially leading to more effective conflict resolution strategies.

In conclusion, while cognitive mapping can be invaluable in identifying common ground and facilitating dialogue, its utility in severe conflicts may be limited by traditional group mapping practices. Adapting the method to create individual maps for each stakeholder can enhance its effectiveness, allowing for a deeper, more empathetic understanding of the conflict and paving the way for more tailored resolution strategies.

In summarizing our critical analysis, we contend that cognitive mapping methodologies employed for conflict transformation and management should integrate several fundamental elements to enhance their effectiveness:

1-Identification of Root Causes: These cognitive structures should be instrumental in providing a comprehensive understanding of the conflict's underpinnings. This involves facilitating the identification of the core sources or root causes of the conflict, which is essential for developing targeted and effective solutions.

2-Highlighting Common Grounds: An effective cognitive map should assist in identifying and emphasizing areas of agreement or common ground among the conflicting parties. Recognizing these shared interests or concerns is crucial, as they can form the basis for constructive dialogue and conflict resolution.

3-Exploration of New Alternatives: Cognitive map structures need to transcend beyond merely identifying known alternatives. They should actively facilitate the exploration of previously unknown possibilities, broadening the scope for innovative conflict resolution strategies.

4-Stakeholder-Specific Maps: We advocate for the necessity of constructing distinct cognitive maps for each stakeholder involved in the conflict. This approach allows for a more personalized and in-depth understanding of each party's perspective, perceptions, and experiences related to the conflict. Such tailored maps can foster empathy and a deeper appreciation of the complexities involved, potentially leading to more nuanced and effective resolution methods.

Incorporating these elements into cognitive mapping practices for conflict transformation and management will enhance their utility. It will allow for a more holistic, empathetic, and solution-oriented approach to understanding and resolving conflicts.

2.4 Value trees

Values play a pivotal role in shaping everyday life situations, as noted in Rescher (1969) and are integral to decision-making processes, particularly in complex and multifaceted scenarios and crucial for operational research (see Keeney, 1994b).

Conflicts and tensions among stakeholders are often rooted in a fundamental discordance of values and priorities (see Balint, 2011). Guided by this perspective, we will delve into value-focused thinking as a foundational benchmark.

Keeney and McDaniels (1992) intoroduced 'Value-Focused Thinking: A Path to Creative Decisionmaking,' is instrumental in introducing key concepts critical to understanding modern decision-making processes. Central to this discourse are the concepts of Value-Focused Thinking (VFT) and Alternative-Focused Thinking (AFT). To fully appreciate Keeney's contribution, it is essential first to define and distinguish these two approaches.

Value-Focused Thinking (VFT) revolves around the idea that decision-making should be guided primarily by the values and objectives of the decision-maker. In this approach, values are identified and clarified at the outset, forming the foundation upon which decision opportunities and alternatives are then developed. VFT is proactive, emphasizing the creation of decisions that align with and fulfill the identified values.

In contrast, Alternative-Focused Thinking (AFT) is a more traditional approach to decision-making. This method typically begins with identifying existing alternatives or options, followed by evaluating these alternatives to make a decision. AFT often focuses on choosing the best available option from a given set, rather than on creating new options that might better align with the decision-maker's underlying values and objectives.

Keeney's work highlights the transformative potential of shifting from AFT to VFT, demonstrating how a value-centric approach can lead to more innovative, effective, and satisfying decision-making outcomes. By prioritizing values in the decision-making process, VFT allows for a more goal-oriented approach that can better capture the true intent and desires of the decision-maker.

Keeney and Keeney (2009) also shows that articulating values in decision-making is a nuanced and essential process. Keeney emphasizes the importance of both conscious reflection and the discovery of subconscious values. Conscious reflection involves deliberate thinking about known values, aiding in articulating what one is already aware of in a decision-making scenario. Meanwhile, uncovering subconscious values broadens the perspective, revealing hidden objectives and preferences.

Keeney's concept of 'hard thinking' is central to revealing values (see Keeney, 1994a, 2008; Keeney and Keeney, 2009). It necessitates explicit value judgments and precision in their meaning, encompassing a wide range of elements such as ethical principles, desired traits, outcomes, guidelines for action, and attitudes toward risk. This deep, reflective process aims to unearth and define what truly matters to the decision-maker, ensuring that the identified values are meaningful and directly applicable to the decision at hand.

Keeney and McDaniels (1992) and again Keeney (1992) further elucidates the Value-Focused Thinking approach, highlighting the necessity of 'hard thinking' in the process of revealing values. He underscores that identifying fundamental objectives, central to uncovering these values, is a complex task requiring considerable creativity, time, and rigorous intellectual effort.

In the realm of value tree construction, there is no universally formalized, explicitly defined, universally agreed-upon method as Borcherding and von Winterfeldt (1988) point out, value structuring can be considered as art, relies on the subjective efforts of individual analysts, and different weighting and lacks systematic validation, underscoring the need for more robust methodologies universally agreed-upon method, reflecting the diversity and complexity inherent in capturing and structuring stakeholders' values within decision-making processes. While Keeney and Keeney (2009) thoroughly explores the process of identifying values through introspection and 'hard thinking', it does not explicitly provide a formalized method for this process. Keeney et al. (1990) proposes a method called the "public value forum" for constructing a value tree. This approach integrates focus group discussions and direct multiattribute value elicitation techniques to clarify public values relevant to public policy decisions. Keeney et al. (1987) introduces a method for constructing value trees through top-down and bottom-up procesures. The top-down method is deductive, starting with general values and drilling down to specific criteria, while the bottom-up approach is inductive, beginning with specific criteria and aggregating them into broader value categories. Keeney et al. (1987) also discussed combined value tree of individuals which involves creating a list of general criteria from the individual trees, ensuring that all values are included in the combined tree. Mustajoki and Hämäläinen (2000) introduces Web-HIPRE, a web-based tool for global decision support combining Value Tree and Analytic Hierarchy Process (AHP) (see Saaty et al., 1980) analysis. It uses multiattribute value theory (MAVT) (see Keeney and Raiffa, 1993) and AHP to structure decision problems, prioritize, and analyze results.(see Keeney and Raiffa, 1993) does not provide a direct method for stakeholders to input their values for the construction of value trees within the Web-HIPRE system. Instead, it focuses on the use of Web-HIPRE for multi-criteria decision analysis, incorporating both MAVT and AHP for structuring decision problems and analyzing results. Keller and Ho (1988) emphasizes the importance of structuring decision problems effectively before evaluating different action options and discusses how attributes or goals for evaluating options are often represented hierarchically in a value tree, criteria for evaluating the sufficiency of a value tree are mentioned, as previously Keeney and Raiffa (1976) and Von Winterfeldt and Edwards (1993) studied about the efficiency of value tree in criteria evaluating however there is no method discussed how to construct value tree. The idea of deriving value trees from cognitive maps is not entirely new. For instance, Bana e Costa et al. (1999) introduced this concept, which was further developed by ,Franco and Montibeller (2010) use cognitive mapping to structure value trees. Through cognitive maps, they identify objectives and the means-ends relationships between these objectives. By leveraging these means-ends relationships, they structure value trees; however it depends on ability of analysts and stayed an ”art” to get values from cognitive maps. However, in this thesis, we provide a formal method by detailing a method that transforms cognitive maps into value trees through intermediate steps. This involves first creating value cognitive maps, then developing ends-means maps, and finally constructing the value tree and discussions about the synergies between cognitive mapping and value tree construction have been elaborated in Marttunen et al. (2017). In contrast, our approach formalizes this process by introducing a graph transformation algorithm that systematically derives value trees from cognitive maps. This algorithm operates on both the nodes and arcs of the influence relationships within the cognitive map, ensuring a structured and replicable procedure.

Although there is no formalized method for revealing values as outlined Keeney and Keeney (2009); also in Keeney (2008) introduces two pivotal concepts that aid in this endeavor: the means-end objective network and the hierarchy of values. These concepts are important for understanding how values influence decision-making processes. The means-end objective network is a structured approach that connects specific actions or means directly to their end objectives or values. This method is instrumental in visualizing and comprehending the relationship between actions and their desired outcomes, offering a clear pathway from means to ends. Conversely, the hierarchy of values involves organizing values in a structured manner, typically from more general to more specific. This hierarchical arrangement helps in discerning the priority and significance of different values within decision-making contexts. Both the means-end objective network and the hierarchy of values are fundamental to Keeney's framework, underscoring a structured approach to decision-making that is deeply rooted in the decision-maker's core values and objectives.

Gregory and Keeney (1994), also introduce use of the means-end objective network for revealing values and discusses a practical application of this concept in the context of developing a combined list of fundamental and means objectives for an Environmental Impact Assessment (EIA). The distinction between what participants fundamentally care about (fundamental objectives) and what matters through its effect on these fundamental concerns (means objectives) is central to the process. This approach emphasizes that means objectives, though instrumental, are as crucial as fundamental objectives in shaping policy decisions. Gregory and Keeney (1994) exemplifies how this means-end objective network, integral to Value-Focused Thinking, can be effectively applied in complex, real-world policy settings, further illustrating Keeney's emphasis on revealing and structuring values in decision-making processes.

In Keeney (1996b), the Value-Focused Thinking (VFT) methodology is expounded with a more detailed procedure that includes the use of a means-ends objective network. This network is a fundamental aspect of the VFT procedure, as it helps in categorizing and analyzing objectives in a structured manner. The procedure begins with compiling an initial list of objectives, a critical first step in the VFT process. These objectives are then categorized into 'means objectives' and 'fundamental objectives.' The means-ends objective network is employed to map out the relationship between these objectives, illustrating how achieving specific means objectives (actions or strategies) can lead to the realization of fundamental objectives (ultimate goals or values). This network is instrumental in understanding the hierarchy and interdependencies among different objectives, thereby providing a clear visual representation of the decision-making process

Keeney (2007) primarily focuses on specifying objectives from values, a crucial step in the Value-Focused Thinking (VFT) process. This method involves first identifying general values and then translating these into specific objectives. For instance, if a value identified is "quality of service," this is converted into a tangible objective like "maximize the quality of vendor service." Similarly, a personal value such as "having fun" could be transformed into an objective to "maximize fun." These examples illustrate the initial step of translating abstract values into concrete, actionable objectives.

After this initial step, Keeney (2007) suggests a structuring process for these objectives, categorizing them logically into four distinct types. This categorization and structuring are essential to organize the objectives in a way that facilitates decision analysis and aligns with the identified values. This method builds on the foundation laid in Keeney (1996a) by providing a more detailed and systematic approach for deriving specific objectives from broader values, thus enhancing the practical application of VFT in decision-making.

Keeney (1996a) and Keeney (2007) contribute significantly to the field of decision-making by highlighting the importance of integrating values into this process. His approach, centered around Value-Focused Thinking (VFT), advocates for identifying personal or organizational values and translating these into specific, actionable objectives. While this framework is insightful and offers a valuable perspective on decision-making, it tends to rely on the decision-maker's subjective interpretations and personal judgment in identifying and articulating these values. This subjective aspect, although providing flexibility and adaptability to a wide range of scenarios, might also lead to variability in how values are uncovered and prioritized. Keeney's methodology, in its essence, serves more as a conceptual guide, encouraging decision-makers to introspect and align decisions with their core values, rather than providing a rigid, universally applicable procedure for the systematic discovery of values. This nuanced approach, while beneficial in many contexts, suggests room for further development in terms of a more structured process for value identification in decision analysis such as value tree.

Keeney (1994a) introduces the 'means-end objective networks,' a pivotal method for identifying objectives in decision-making. However, it's crucial to recognize that this technique might not fully unravel the structure of the value tree. The differentiation between objectives and values is key here; objectives, as Barber and Taylor (1990) suggests, are the necessary actions for achieving specific goals. In contrast, values, as defined by scholars (see Kluckhohn, 1951; Rescher, 1969; Znaniecki, 1940), are normative standards that influence decisions, alternatives, or human behavior. This distinction underscores the complexity and depth in discerning the underpinnings of decision-making processes. In essence, values are instrumental in shaping decision-making processes and outcomes and crucial for grasping the ethical and normative dimensions of decision-making. This is highlighted by Jacobi and Hobbs (2007), who emphasize the significant role values play in guiding ethical considerations and normative judgments in decision-making scenarios. This underlines the complexity of integrating values, which are often abstract and deeply personal, into the more concrete and observable realm of decision-making objectives.

Value-Focused Thinking, as delineated by Keeney, notably enhances the generation of innovative alternatives by prompting decision-makers to introspect their personal values, as detailed in Keeney and McDaniels (1992). In parallel, the 'value tree' procedure offers a formal representation of values (see Keeney et al., 1987). It stands as a distinctive method that systematically and hierarchically organizes an individual's values, complementing Keeney's approach. This method not only structures the visualization and prioritization of values but also enriches the decision-making process by providing a formal framework to articulate and analyze an individual's core principles and beliefs.

All in all, Value-Focused Thinking (VFT), as conceptualized by Keeney, lacks a formal method for revealing values, primarily because the nature of objectives and values differs fundamentally. The means-ends objective network, a key component of VFT, is adept at mapping objectives but does not formally facilitate the unveiling of underlying values. In contrast, the value tree procedure fills this gap by providing a systematic and hierarchical way to represent individual values in problem-solving contexts. This approach offers a more structured format for articulating and examining values, enhancing the decision-making process. However, it's important to acknowledge the limitations noted in the literature, such as those mentioned by Dreyfus (1992), regarding the representation of complex ideas through finite set procedures. These reservations highlight the challenges in capturing the nuances and breadth of values within a structured framework, pointing to the inherent difficulty in fully encapsulating subjective and multifaceted values in a fixed methodology.

Due to their hierarchical structure and single-parent node property, value trees often result in information loss and/or attribute asymmetry, as highlighted in various studies. Particularly, Pöyhönen et al. (2001) examining the use of value trees in public policy analysis revealed implications for the weighting and ranking of attributes. The study found that the division of attributes in value trees can either increase or decrease the weight of an attribute, subsequently altering its rank. This effect is primarily driven by two factors: the decision-makers' tendency to reflect only the rank of attributes (not the full strength of their preferences) and the normalization of attribute weights. Furthermore, the research discussed biases in attribute weighting, such as the splitting bias, suggesting that these biases might stem from common origins like the unadjustment phenomenon. This phenomenon occurs when decision-makers do not adequately adjust their responses to the division of attributes within a value tree. These insights underline the complexities and potential pitfalls in using value trees for decision analysis, especially in multi-attribute settings, bringing to light the issues of information loss and asymmetry in attribute representation inherent in value trees. Similarly, Pöyhönen and Hämäläinen (1998) have raised concerns regarding value trees, specifically highlighting how normalized weighted averages might lead to false conclusions; they also explore how structural variations in value trees can influence the weighting of attributes. They emphasize that changes in the structure, such as the level at which an attribute is placed or its division into sub-attributes, can notably affect its weight. This observation challenges the assumption that biases at the group level accurately reflect individual decision-making biases, as group averages can misrepresent individual preferences. Pöyhönen and Hämäläinen (1998) further argue that the use of weight ratios based on attribute rank order can introduce biases when the value tree structure is altered, even if individual evaluations remain consistent. Their insights underline the potential for structural aspects of value trees to inadvertently introduce biases, thereby questioning the reliability of normalized weighted averages in multi-attribute decision-making processes. Also, it should be noted that value trees may not fully capture the complexity of a problem, because of the tree structure which leads to overfitting (see Carvalho et al., 2018) which mainly occurs in complex models ((see Warren et al., 2014).

Pitz and Riedel (1984) delve deep into the intricacies of constructing value tree representations, highlighting the challenge of accurately capturing the essence of an individual's values. They question the efficacy of the hierarchical structure commonly employed in value trees, probing whether it truly reflects a person's intrinsic values or merely represents an inferential construct. The authors explore the potential dissonance between the subjective nature of personal values and their structured, external representation. This exploration raises critical questions about the distortion or oversimplification of complex value systems when they are mapped onto a predefined, hierarchical framework.

Pitz and Riedel (1984) also discuss the limitations inherent in the top-down and bottom-up approaches used in constructing value trees, echoing concerns about potential information losses due to these methodologies. The study critiques the conventional wisdom that these approaches can seamlessly translate nuanced and interconnected personal values into a structured format without any loss of meaning or context. They emphasize the challenge of maintaining the integrity and depth of values when transitioning them into a value tree's architecture, pointing to the risk of oversimplifying or misrepresenting these values.

Integrating this with the broader discourse on value representation, as Keeney noted, conducting a detailed semantic value analysis requires a complex interplay of various elements, potentially exacerbating the likelihood of information loss during the attribute alteration process. Lakoff (1982) suggestion of using "idealized cognitive models" (ICMs) to represent concepts is presented as a possible alternative to the decompositional models of value trees, acknowledging the difficulties in capturing complex meanings within the latter's structure. However, Pitz and Riedel (1984) caution that even the application of ICMs may not be entirely feasible or consistent with the structured nature of value trees, potentially leading to inaccuracies and inconsistencies in representing a decision-maker's values. Their critique emphasizes the need for a nuanced approach in value representation, one that carefully considers the complexities and potential limitations of value trees in encapsulating multifaceted, subjective value systems.

The literature, while acknowledging the advantages of value-focused thinking and value trees as highlighted by von Winterfeldt (1987), also brings to light its limitations, particularly in the context of the value tree procedure. These limitations include the potential for information loss and the challenges in accurately representing complex values and decision-making processes. Despite these structural reservations and the absence of a universally accepted formal method for constructing value trees, they remain a valuable tool for visualizing and analyzing a decision maker's values in a hierarchical format. However, it is important to recognize that value trees, in isolation, may not fully capture the multifaceted nature of complex problems . While they offer a useful framework for understanding and dissecting values, relying solely on value trees may not yield a comprehensive understanding of an issue. Therefore, it is often necessary to integrate other methods and techniques to achieve a more holistic and thorough analysis. This approach ensures that all the subtleties and complexities of a complex problem are adequately addressed and represented.

2.5 Cognitive Maps vs Value Trees: Summary of the idea

In summary, the existing literature sheds light on the distinct roles and limitations of cognitive maps and value trees in addressing complex problems, particularly in conflict resolution. Cognitive maps serve as a valuable tool for structuring and understanding the problem at hand. As descriptive models rooted in the perceptions of the problem owner, they provide a clear framework for mapping out the problem. However, cognitive maps have certain limitations: they (i) often fail to generate new, innovative alternatives, (ii) may not effectively identify the root causes of conflicts for comprehensive recommendations, and (iii) might not reveal common ground or shared concerns that could mitigate conflict drivers. This renders them less effective in proposing actionable strategies for problem resolution.

On the other hand, value trees offer a more innovative approach to conflict transformation and decision-making. They encourage the exploration of novel solutions by aligning decision-making with the core values of the stakeholders involved. However, value trees come with their own set of challenges. They lack a formal, universally recognized structure for construction, which can lead to (i) informational asymmetry due to the absence of a standard method to build these structures, and (ii) potential biases in information representation, whether through top-down or bottom-up approaches. Despite their design-oriented nature, value trees might not completely encapsulate the complexities inherent in conflict resolution scenarios. They offer a creative lens but may require supplemental methods for a truly comprehensive analysis, given their limitations in fully addressing the nuances of complex problems.

2.6 Design theory

Simon (1988) explores the foundational aspects of design within various professional practices, emphasizing design as a core of professional training distinct from the sciences. Simon (1969) also articulates how design involves devising courses of action to change existing situations into preferred ones, bridging the gap between natural sciences and the creation of artificial artifacts. Simon (1969) described design problems as "wicked," highlighting the complexity and interconnectivity of solutions and subsequent issues.

The debate on design and its research is wide-ranging and complex, reflecting its interdisciplinary nature. Chakrabarti and Blessing (2016) illustrates this by compiling various theories and models from the last fifty years, highlighting the field's evolution and the diversity of thought. This compendium reveals how design research encompasses philosophical, theoretical, and empirical dimensions, showing the challenges in creating a unified theory that suits the varied applications and practices within design. It emphasizes the necessity for continuous exploration and adaptation in design theory and research to accommodate the evolving nature of design practices across different domains.

The evolution of design theory is characterized by a shift from emphasizing systematic, rational processes towards embracing disruptive innovations and creative reasoning (see Pluchinotta et al., 2019a). Initially, design was seen as a process to be systematized through scientific knowledge and engineering techniques, focusing on creating solutions within a structured framework (see Alexander, 1964; Archer, 1964, 1969), Bayazit (2004) provides a comprehensive overview of the evolution of design research over four decades. It traces the development from early systematic and rational methods to the integration of scientific techniques and knowledge into the design process. Bayazit (2004) highlights key shifts towards addressing complex real-world problems (as time goes by), emphasizing user involvement and interdisciplinary approaches. It also discusses the impact of information technology on design research, showcasing the growth from first-generation design methods to more nuanced, second-generation methods that accommodate user needs and preferences. This evolution reflects a broader understanding of design as a multidisciplinary field that encompasses not only architectural and engineering design but also incorporates insights from psychology, management, and ergonomics.

Modern design theory, however, addresses the need for breakthrough innovations by questioning existing attributes and developing new expertise (see Hatchuel et al., 2008; Elmquist and Segrestin, 2009). The Concepts-Knowledge (C-K) theory introduced by Hatchuel and Weil (1999) and Hatchuel and Weil (2003) represents a significant advancement, offering a framework for innovative design processes that transcend traditional limitations and encourage the generation of novel alternatives by leveraging known information to explore the unknown. In (C-K) theory, we are especially interested in it as we worked on it in this thesis.

Ferretti et al. (2019) underscore the overlap between decision theory and design theory within decision-making processes. They examine how integrating these theories with policy studies and operational research can enhance policy design approaches. Building on this foundational work, Pluchinotta et al. (2019b) and Pluchinotta et al. (2020) further develop our practical application of these theories in policy design. They introduce the KCP (Knowledge, Concepts, Proposals) and P-KCP (Policy-Knowledge Concept-Proposal) methodologies to bridge theoretical concepts and practical policy-making.

In this framework, a "concept" is defined as a proposition or a collection of propositions that do not have a definitive truth value within a specific domain of knowledge (K), usually describing the characteristics that define entities Hatchuel and Weil (2003).

The "concept space" (C-space) encompasses all such concepts linked to K and is inherently designed to expand, mirroring the dynamic nature of design and innovation. This space is a core element in C-K theory, emphasizing the creative aspect of the design process. Space C must be structured in the form of a tree (see Hatchuel and Weil, 2003; Le Masson et al., 2007), as it functions through the partitioning and inclusion of concepts. This structure facilitates the exploration and generation of new concepts or design objects, which is essential for navigating the complex possibilities in the design process (see Hatchuel and Weil, 2003).

Creating a concept tree is a detailed and labor-intensive process that involves in-depth exploration and careful consideration of each concept's significance and the relationships between them. It requires substantial critical thinking, particularly when handling abstract or complex concepts, and relies heavily on subjective judgment due to the lack of a standardized methodology. This process highlights the necessity of both individual and collaborative interpretation and understanding. This view is supported by the literature Hatchuel and Weil (2009b); Hatchuel et al. (2004), which emphasizes the challenges associated with expanding and navigating the C-space. Successfully undertaking this task requires a diverse array of creative inputs and the ability to integrate these into clear and innovative solutions, reflecting the nature of design thinking and innovation. Additionally, Kazakçı and Tsoukiàs (2005) build on C-K theory by introducing a third dimension called the Environment space (E-space). This extension takes into account the influence of external factors on the design process, including elements that interact with the designer, such as external data sources.Salustri (2005) introduces a formal action logic (ALX3) (see Huang, 1994) into C-K theory, developing ALX3d, which enhances the descriptive capabilities of C-K theory by incorporating elements such as beliefs and preferences. This formalism is applied to real-world design scenarios, providing a more structured framework for analyzing and guiding the design process.

Furthermore, Kazakçi et al. (2009) describes that developing the concept space in design is a complex task that involves partitioning concepts and validating them through K-validation, which evaluates the feasibility of design propositions using existing knowledge. This process becomes especially challenging when designers confront concepts related to objects beyond their current knowledge domain, requiring the acquisition of new knowledge to validate these novel ideas. To address this, Kazakçi et al. (2009) formalizes C-K theory using Intuitionist Logic, which supports reasoning with partial knowledge, unlike classical logic that demands every proposition be definitively true or false. Intuitionist Logic accommodates propositions that are not yet resolvable as true or false, which aligns with the iterative nature of concept exploration in C-K theory.

For a more adaptable approach, Kazakci et al. (2008) incorporate Non-Axiomatic Logic (NAL) (see Wang, 1995, 2006) into C-K theory. This approach facilitates managing the interaction between concepts and knowledge by addressing undecidable propositions and allowing knowledge to evolve based on experience. Additionally, Kazakci et al. (2008) suggest utilizing graph-based structures to represent the K-space, highlighting the imortance of managing undecidability in the formation of concepts.

Hatchuel et al. (2007) established a link between C-K theory, a design theory, and a mathematical technique known as Forcing, which was developed by Cohen (2002). Forcing, in set theory, is a method used to generate entirely new sets that adhere to the existing axioms or frameworks. This technique enables the creation of novel entities while maintaining consistency within the established mathematical structure. Hatchuel et al. (2007) drew a parallel between this mathematical approach and the design process in C-K theory, suggesting that both operate similarly: C-K theory allows for the creation of new concepts (ideas or objects) that fall outside the realm of existing knowledge but can be seamlessly integrated into the knowledge base without violating its foundational rules. This comparison underscores the innovative potential of C-K theory in expanding the boundaries of design while maintaining coherence within the existing knowledge framework.

Hatchuel et al. (2017) critically reevaluates traditional models of creativity, highlighting their limitations in adequately capturing the full spectrum of the creative process. They argue that these models often fail to account for the complexity and dynamism inherent in creativity. In contrast, C-K theory is presented as a more comprehensive framework, capable of encompassing the continuous and dynamic interplay between concepts (C-space) and knowledge (K-space).

Building on this foundation, Kazakçı (2013) delves into the connections between C-K theory and Intuitionist Mathematics, emphasizing how the theory can leverage the principles of Intuitionist Logic. They introduce the concept of "imaginative constructivism" within the C-K theory framework, which transcends the traditional constructivist approach. This perspective emphasizes the proactive role of designers in generating entirely new concepts through imaginative and inventive thinking, rather than merely modifying existing ideas. Also, kroll2023abduction posits that traditional abduction tends to underestimate the potential for generativity, a concept the authors refer to as "bounded generativity." By applying C-K theory, kroll2023abduction shows how abduction can be "unbounded," allowing for a broader exploration of unknowns and the generation of more innovative hypotheses.

Kazakçı (2013) highlights the importance of value exploration as a key aspect of creative design. Unlike the value achievement approach, which focuses on improving existing values, value exploration involves actively seeking to generate entirely new values throughout the design process. This approach encourages designers to go beyond predefined goals and explore innovative possibilities that may not have been considered initially.

The idea of starting the creation of a concept tree with a value tree arises from a shift from descriptive to prescriptive analysis. Kazakci et al. (2010) introduce the concept of the "partitioning power" of knowledge, suggesting that new knowledge can open up alternative paths in the design process, resulting in more diverse and resilient design solutions. By beginning with a cognitive map, developed through interviews, the value tree offers a foundational understanding of the issue, which helps in expanding the knowledge space (K-space). This prescriptive method, which utilizes a value tree derived from the descriptive findings of a cognitive map, capitalizes on detailed stakeholder insights to shape strategic and actionable policy frameworks. It provides a structured approach for transitioning from problem understanding to solution generation.

The proposal to initiate the creation of a concept tree with a value tree is based on the shift from descriptive to prescriptive analysis. Originating from a cognitive map, which in turn is developed from detailed interviews, a value tree provides a fundamental understanding of the issue at hand, effectively meeting the need for expansion of the knowledge space (K-space). This prescriptive approach, utilizing a value tree derived from the descriptive insights of a cognitive map, harnesses detailed stakeholder perspectives to guide the formulation of actionable and strategic policy frameworks. It offers a structured method to transition from comprehending the issue to generating solutions.

By employing the tree structure common to both value and concept trees, this process seamlessly integrates the semantics of nodes to facilitate systematic policy development.

2.7 Policy design

The development of policy design as a discipline has a complex journey, weaving through the democratic theory (see Dahl, 1956; Lowi, 1969), applied social sciences (see Merton, 1949; Dunn and Popper, 1999) and participatory governance (see Innes and Booher, 2003; Fung and Wright, 2001; DeLeon, 1997). The journey begins with Dewey (1927) pivotal assertion in "The Public and Its Problems," advocating for the enlightenment of the public and the enhancement of communication methods as essential for democracy. Dewey's critique of Walter Lippmann's elitist perspective emphasized the potential of public discourse in shaping democratic governance, setting a foundational tone for the evolution of policy design (see Dewey, 1983; Lippmann, 1965), 1927

As pointed out DeLeon and Vogenbeck (2017) and Lasswell and Lerner (1951) work positions the policy sciences as a bridge between knowledge and practical problem-solving. Influenced by Dewey's pragmatism and Lynd (2015) call for the pragmatic application of social sciences, Lasswell and Lerner (1951) aimed to render social sciences directly relevant to addressing real-world political and social problems. This shift towards a problem-oriented approach in policy science was further consolidated by Lasswell (1954), who distinguished between the understanding of policy instruments and the separation of policy formulation from implementation. Further, Lasswell (1956) characterized the policy sciences as intrinsically focused on resolving issues, prioritizing practical solutions over the theoretical examination of phenomena.

In the literature, various studies underscore a multidimensional approach to policy design, where values, creativity, and the incorporation of diverse viewpoints and knowledge bases are fundamental to developing effective and innovative policy solutions (see Sidney, 2017; Wildavsky, 1972). Alexander (1982) advocates for a deliberate design phase to explore policy alternatives, underlining the necessity of creativity in this process. Linder and Peters (1984) further this notion by offering a methodology that allows policy analysts to systematically generate and assess alternative solutions, thereby enhancing the scope and depth of policy analysis. Bobrow and Dryzek (1987) stress the critical importance of developing policies tailored to specific contexts, urging the inclusion of diverse values and a wide range of perspectives to spur innovation and creativity in policy design. Weinter (1992) emphasizes that while the literature has extensively covered the evaluation of policy impacts, the design of new alternatives has not received much attention. This parallels what has been noted in the decision analysis literature by Colorni and Tsoukiàs (2018), who stated that the literature on decision analysis concentrates on how to "choose" an alternative without considering how these alternatives can be established. Rixecker (1994) highlights that the infusion of creativity in policy dialogue emerges from the participation of varied voices, while Fischer (2000) posits that incorporating local knowledge into policy design is pivotal for unveiling novel alternatives. Ananda and Herath (2003) underscore the importance of balancing conflicting stakeholder objectives and values through the Multi-Attribute Value Theory, which assesses the value of alternatives against ordinal preferences.

The integration of democratic principles into policy design via participatory policy analysis, as promoted by DeLeon and Vogenbeck (2017) , Beierle (2010) Fischer (2003), and Dryzek (1990), leads to policy solutions that are both inclusive and reflective of a broader spectrum of societal interests. This approach is further enhanced by the application of social network analysis, as elaborated by Wasserman (1994), which extends policy design to encompass a wide range of actors across society, thereby emphasizing the value of collaborative methodologies. Morevover Howlett et al. (2015) highlights the need for a deeper understanding of how different policy tools can be effectively combined to achieve desired policy outcomes and the resources required for their operation Pluchinotta et al. (2019b) observations align with these trends, pointing to a contemporary focus on decentralized processes and collaborative governance that includes non-governmental actors (see Howlett, 2011). This shift signifies a movement away from traditional top-down approaches (see Pülzl and Treib, 2017; DeLeon and deLeon, 2001), towards policy design practices that are more participatory and consultative in nature, as evidenced by the work of Alshuwaikhat and Nkwenti (2002), Hysing (2009), and Levi-Faur (2012). This evolution underscores a transformative period in policy design, where the emphasis is on engaging a multitude of stakeholders in the design process to achieve more democratic and effective policy outcomes.

Tsoukias et al. (2013) introduced the concept of Policy Analytics as a transformative approach in public policy-making, aiming to enhance the decision-making process to be more meaningful, operational, and legitimating. This approach addresses the complexities inherent in public decisions, which often involve multiple stakeholders, extended time horizons, and the need for legitimation and accountability De Marchi et al. (2016). Consequently, Policy Analytics is proposed as a novel framework designed to support the entire policy cycle, from issue identification through to policy implementation and evaluation, in a way that is both meaningful and operational, while also ensuring transparency and accountability. Complementing this, Pluchinotta et al. (2022) provides an overview of the policy cycle, underscoring the importance of a decision-aiding perspective. This perspective proposes integration of formal tools and methodologies to assist policymakers in making informed decisions throughout the various stages of the policy cycle.

Pluchinotta et al. (2019b) proposed to advance policy design through the introduction of the Policy-Knowledge-Concept-Proposals (Policy-KCP) methodology, which applies Concept-Knowledge (C-K) theory to the development of innovative policy alternatives. This approach addresses a shortfall in existing research, as identified by Ferretti et al. (2019) and Bobrow (2006), which is the lack of methodologies bridging theoretical concepts with the practical aspects of policy design. This gap is further highlighted by the critiques of Howlett (2019) and Lynn and Gould (1980), who argue for the creation of methodologies capable of producing actionable policy alternatives.

Chapter 3

Our proposal: Transformation process

We present a novel methodology that synthesizes the strengths of cognitive maps and value trees, aiming to address the limitations identified in each. The process involves a series of transformative steps. Lastly, we add a procedure to allow the transformation of a value tree to a concept tree

3.1 Notation

In our analysis, we employ the concept of a directed graph to model complex relationships. A directed graph is formally represented as a set $G = \langle V, E \rangle$, where V and E are the fundamental components of this graph. Here, V denotes the set of 'nodes,' which can be thought of as individual elements or entities within our system of study. These nodes are specifically denoted as $V = x_1 \cdots x_n$, representing a finite and countable collection of entities ranging from x_1 to x_n.

On the other hand, E represents the set of 'directed arcs,' which are essentially the connections or relationships between these nodes. These arcs are denoted as $E = x_i x_j : x_i, x_j \in V$, signifying a directional relationship from node x_i to node x_j. In this representation, it's crucial to note that $E \subseteq V \times V$, indicating that every arc in E is an ordered pair of nodes from V.

From a semantic perspective, these directed arcs are more than just connections; they represent the presence of a specific binary relation E between pairs of elements in V. This implies that if an arc $x_i x_j$ is a member of E, then there is a relationship from x_i to x_j as defined by the context of our analysis.

Definition 3.1.1 *We consider a directed graph $G = \langle V, E \rangle$ and focus on defining what constitutes a directed path between two nodes within this graph. Specifically, if we have two nodes $x_0, x_n \in V$, a directed path from x_0 to x_n is defined as a subgraph of G. This subgraph is characterized by the existence of a sequence of nodes $x_1, \cdots, x_k$ such that there are directed arcs $x_0x_1, x_1x_2, \cdots, x_kx_n$ in E. It is crucial to note that all nodes x_i in this sequence are distinct, emphasizing the path's directed and non-repetitive nature.*

In the context of the directed graph $G = \langle V, E \rangle$, when considering two nodes $x_0, x_n \in V$, if there exists a directed path between them, we denote this path as $x_0 - x_n$ or in a more abbreviated form as p_{0n}. This notation is particularly important to distinguish it from x_0x_n, which we use to denote a direct directed arc from x_0 to x_n. Additionally, we define a directed graph as 'weakly connected' if, for any given pair of nodes x_i and x_j, there exists a path p_{ij} connecting them. This path need not be directed. In simpler terms, a directed graph is weakly connected if the graph, when considered without directionality (i.e., as an undirected graph), is connected. This definition helps in understanding the connectivity and reachability of nodes within the graph, irrespective of the direction of the paths.

Given a directed graph $G = \langle V, E \rangle$, we introduce the concept of 'arc length' to quantify the relationship between any two connected nodes. For any arc $x_ix_j \in E$, we define a positive real-valued function $w : E \mapsto \mathbb{R}^+$, which assigns a 'length' to each arc. The length of an arc x_ix_j is denoted by $w(x_ix_j)$ or simply $w(ij)$ for brevity. This 'length' can be interpreted as a measure of the strength, cost, or any relevant quantitative attribute of the relationship from x_i to x_j.

Considering any two nodes x_0 and x_n in the graph, there might be multiple paths connecting these nodes. To address this, we denote a generic path between these nodes as p^l_{0n}. The length of any such path p^l_{0n}, which is a summation of the lengths of all arcs that constitute the path, is given by $w^l(0n) = \sum_{x_ix_j \in p^l_{0n}} w(ij)$.

Furthermore, we define $L(x_0 - x_n)$ (or simply $L(0n)$) as the cardinality of the set of nodes forming the path $x_0 - x_n$. In scenarios where all arcs are of equal length (i.e., $w(ij) = 1$), the length of the path $w^l(0n)$ simplifies to $L(0n) - 1$, where $L(0n) - 1$ represents the number of arcs in the path.

Finally, irrespective of how the length of a path is computed, we denote $\hat{p}^l(0n) = \min_l(w^l(0n))$ as the shortest path from node x_0 to node x_n. This shortest-path represents the minimum cumulative length among all possible paths from x_0 to x_n, providing a crucial metric for understanding the most efficient or least costly path within the directed graph.

3.2 Cognitive Maps and Value Cognitive Maps

In the literature, various definitions of cognitive maps exists as we disscus in literature. In this study we introduce this definition:

Definition 3.2.1 *A cognitive map is a type of directed graph, specifically a weakly connected directed graph, denoted as $CM = \langle N, R \rangle$. In this context, N represents a set of 'concepts', which can alternatively be considered as topics, issues, or any significant elements within a given scenario. The unique aspect of a cognitive map lies in its 'influence' relation, denoted as R, which is the union of two distinct binary relations: R^+ and R^-.*

These relations are defined as follows: $R^+ \subseteq N \times N$ and $R^- \subseteq N \times N$: When we say $R^+(x, y)$, where $x, y \in N$, it should be interpreted as "concept x has a positive influence on concept y". This positive influence denotes a relationship where the presence or enhancement of concept x leads to a constructive or beneficial effect on concept y.

Conversely, $R^-(x, y)$, also where $x, y \in N$, translates to "concept x has a negative influence on concept y". This indicates that concept x adversely affects or diminishes concept y in some way.

The incorporation of both positive and negative influences in a cognitive map allows for a nuanced representation of the relationships between concepts, capturing the complex interplay of factors within a given system or scenario.

For our analysis, we place an important constraint on the relations R^+ and R^- within the cognitive map: both are irreflexive. This means, in practical terms, that a concept x does not exert influence upon itself, aligning with the intuitive understanding that "x has no influence upon x". Such a constraint ensures the logical consistency and clarity of the relationships represented in the cognitive map.

The transformation of a cognitive map into a value tree involves an intermediate step: the creation of what we term a **Value Cognitive Map**. To achieve this, we need to shift our focus from the set of concepts N in the original cognitive map to a new set A, which represents values. This transformation process involves associating each concept in the Cognitive Map with a corresponding value. However, it's important to recognize that not all concepts may directly translate into values. Therefore, we consider $A \subseteq N$, indicating that the set of values is a subset of the concepts. This step is crucial in reorienting the cognitive map from a concept-focused framework to one that is value-centered, setting the stage for the subsequent development of a value tree.

Although the semantics of the nodes in the graph have transitioned from concepts to values, the relations R^+ and R^- retain their semantic roles. In the context of a set A comprising values, these relations are interpreted as follows: - $R^+(x, y)$ should be read as “value x having a positive influence upon value y”; - $R^-(x, y)$ should be read as “value x having a negative influence upon value y”.

This transition from concepts to values within the realm of the cognitive map necessitates a linguistic adaptation. We introduce the prefix ’valuing’ before each value to reflect the subjective nature of these values, which correspond to the original concepts. This adaptation not only captures the essence of the values but also emphasizes the significance of both positive and negative aspects within the value cognitive map. The inclusion of ’valuing’ acknowledges the full spectrum of narratives, from affirmative to adverse, highlighting the importance of a holistic analysis within the given context. This linguistic approach, while seemingly unconventional for some concepts, is a strategic choice to underscore the nature of the analysis and to facilitate a broader range of expression and understanding for the stakeholders involved.

Considering the graph $\{A, R\}$, where $R = R^+ \cup R^-$, we can treat this graph as a cognitive map if it is weakly connected. To distinguish it from a standard Cognitive Map, we denote this as VCM (Value Cognitive Map), emphasizing that the set of nodes in this map, A, represents a set of values. This distinction underscores the shift in focus from abstract concepts to more concrete values, allowing for a nuanced understanding of the influence relationships in the context of value-oriented analysis.

Definition 3.2.2 *Consider a value cognitive map $VCM = \langle A, R \rangle$ and a node $x_o \in A$ such that: $\forall x \in A\ \neg \exists R(x_o, x)$. We define x_o as a fundamental node of the value cognitive map or a “fundamental value”.*

In simpler terms, a fundamental value is a node that does not exert influence on any other node within the value cognitive map. It stands as a terminal point or an end goal within the map, representing values that are not instrumental to others but are desired for their own sake. These fundamental values are key in understanding the intrinsic motivations and end goals within the value cognitive map, offering insights into the ultimate objectives or priorities of the system or individual being analyzed.

Proposition 3.2.1 *Given a value cognitive map $VCM = \langle A, R \rangle$ having a fundamental node x_o, there is always a directed path connecting any $x \in A$ to x_o.*

Proof. Since the graph is weakly connected and by the definition of the fundamental node there is at least one arc such that $R(x, x_o)$ holds. Given any node of the graph, either it is a fundamental one and in this case we know there is path reaching it, or is a generic node. In this case, since the graph is weakly connected given the node x_j there is always a node x_i such that $R(x_i, x_j)$ holds. By induction on the number of nodes within the graph we show that there is always a directed path connecting the fundamental node x_o to any node of the graph. ■

This proposition and its proof establish a fundamental characteristic of value cognitive maps with a fundamental node. It guarantees that, irrespective of where one starts within the map, there is always a path leading to the fundamental value. This path symbolizes a sequence of influences relationships that ultimately culminate in the fundamental value, reflecting the interconnected nature.

This proposition and its proof reveal a key aspect of value cognitive maps with a fundamental node. It affirms that a fundamental value, while being influenced (directly or indirectly) by all other values in the map (due to the graph's connected nature), does not exert any influence on other values. This one-way influence relationship underscores the unique status of the fundamental value as a terminus or ultimate objective within the value cognitive map. Every other node, is connected to this fundamental node via a directed path. This structure ensures that the fundamental value, as an endpoint, is influenced by the entire network of values, yet it remains an influencer to none, highlighting its singular importance and the hierarchical nature of the value cognitive map.

Definition 3.2.3 *Given a value cognitive map $VCM = \langle A, R \rangle$ and a generic node $x_j \in A$, we define the rank of x_j (denoted as $r(x_j)$) as the length of the shortest path from the node x_j to the fundamental value x_o.*

For simplicity and without loss of generality, we assume that the length of any arc within the value cognitive map is equal to 1. This assumption means that the rank of any node in the value cognitive map essentially counts the number of steps (or nodes) separating it from the fundamental value along the shortest path. By this logic, the fundamental value itself, x_o, naturally has a rank of 0, denoted as $r(x_o) = 0$, since it is the endpoint and does not have any further nodes to traverse to reach itself. Henceforth, our focus will be on Value Cognitive Maps where a fundamental value exists, as this allows for a structured and hierarchical analysis based on the rank of each node in relation to this fundamental value. The concept of 'rank' in this context serves as a quantitative measure of how closely or distantly connected each node is to the fundamental value. A lower rank implies closer proximity to the fundamental value, indicating a more direct or significant influence on or by the fundamental value. Conversely, a higher rank suggests a more indirect connection. This ranking system provides a clear hierarchy within the value cognitive map, illustrating the layers of influence and importance among the values, and offers a structured way to analyze and interpret the relationships and priorities within the map.

The existence and uniqueness of the fundamental value in a CM an VCM is a key property in We formally state the following:

- **Existence:** A fundamental value may not always exist in a given structure. If no such node is identified, one can be artificially introduced to ensure a coherent decision-making hierarchy.
- **Uniqueness:** If a fundamental value exists, it must be unique. Formally, given a weakly connected directed graph $G = \langle V, E \rangle$, a node $x_o \in V$ is a fundamental value if and only if:

  $$\forall x \in V, \neg \exists E(x_o, x).$$

  Since the graph is weakly connected, if multiple fundamental values existed, they would necessarily be connected via a path, contradicting their definition. Thus, in any CM, VCM, EMM, or VT where a fundamental value is identified, it is unique.

Proposition 3.2.2 *In a weakly connected directed graph $G = \langle V, E \rangle$, there exists at most one fundamental value.*

Proof
Assume, for the sake of contradiction, that there exist two distinct fundamental values x_o and x'_o. By definition, neither x_o nor x'_o has any outgoing arcs, meaning:

$$\forall x \in V, \neg \exists E(x_o, x) \quad \text{and} \quad \forall x \in V, \neg \exists E(x'_o, x).$$

Since G is weakly connected, there must exist a path between any two nodes, including x_o and x'_o. However, since neither x_o nor x'_o can have outgoing arcs, no such path can exist between them. This contradicts the weak connectivity assumption.

Thus, our assumption was incorrect, and we conclude that there can be at most one fundamental value in a weakly connected directed graph. ■

3.3 Ends Means Map

Definition 3.3.1 *A Ends Mean Map is a weakly connected graph $EMM = \langle B, \Pi \rangle$ such that B is a set of "values" and $\Pi \subseteq B \times B$ is a binary relation to be read as follows: $\forall \chi, \psi \in B : \Pi(\chi, \psi)$ should be read as "value χ is an end to value ψ".*

In the provided definition of an Ends Mean Map (EMM), the concept is explained as a weakly connected graph where the set B represents a collection of values. The binary relation Π, a subset of $B \times B$, is essential for understanding the ends-means relationship within this context. The relation $\Pi(\chi, \psi)$, for any χ and ψ in B, should be interpreted as "value χ is an end to value ψ". This definition implies a directional relationship between the values, indicating that one value (the end) is the goal or objective, while the other value (the means) serves as a way to achieve or contribute to that end.

The inverse of this relationship, where value ψ is a means to value χ, reinforces the directed nature of these connections, highlighting the asymmetry inherent in the ends-means relationship. This structure is fundamentally irreflexive and acyclic, ensuring that no value can be an end or a mean to itself and that the relationships do not form cycles. This feature is crucial for maintaining a coherent, hierarchical structure in the Ends Mean Map.

The transformation of a Value Cognitive Map (VCM) into an EMM involves reinterpreting the relationships between values from a cognitive, descriptive perspective to a more goal-oriented, prescriptive perspective. This transformation requires a systematic approach to redefine and restructure the value relationships, ensuring they align with the ends-means framework.

The construction of the relation Π from R in the transition from a Value Cognitive Map (VCM) to an Ends Means Map (EMM) encompasses a detailed reinterpretation of value interactions. When we observe an influence relation, either positive or negative, between x_i and x_j in the VCM (denoted as $R(x_i, x_j)$), this implies that in the EMM, x_j becomes an 'end' to the value x_i. This semantic interpretation leads us to infer that if $R(x_i, x_j)$ holds, it logically follows that $\Pi(x_j, x_i)$ should also hold in the EMM context.

However, the complexity in this transformation arises as R comprises both positive and negative influences (R^+ and R^-), while Π represents a singular, unified relation. This distinction necessitates a thoughtful approach in translating these dual aspects of R into the singular ends-means orientation of Π.

Recalling that the VCM is represented as$VCM = \langle A, R \rangle$ and the EMM as $EMM = \langle B, \Pi \rangle$, we see the need to establish a robust connection between both the sets A and B, and the relations R and Π. To facilitate this, we introduce the set $\bar{A} = \{\neg x : x \in A\}$, representing the negations of elements in A. The set B is then derived as a union of A and $\bar{A}$, carefully ensuring the weak connectivity characteristic of EMMs: $B = \{x_i \in A \cup \bar{A} : \exists x_j \ (\pi(x_i, x_j) \vee \pi(x_j, x_i))\}$.

The implications connecting the relations R^+, R^-, and Π are pivotal in transitioning from a Value Cognitive Map to an Ends Means Map. The relations are defined within specific domains: R^+ and R within $A \times A$, and Π within $(A \cup \bar{A}) \times (A \cup \bar{A})$.

Definition 3.3.2
- $\forall x, y : R^+(x, y) \rightarrow \Pi(y, x)$ *If x has a positive influence upon y then y is an end to x*
- $\forall x, y : R^+(x, y) \rightarrow \Pi(\neg y, \neg x)$ *If x has a positive influence upon y then $\neg y$ is an end to $\neg x$*
- $\forall x, y : R^-(x, y) \rightarrow \Pi(y, \neg x)$ *If x has a negative influence upon y then y is an end to $\neg x$*
- $\forall x, y : R^-(x, y) \rightarrow \Pi(\neg y, x)$ *If x has a negative influence upon y then $\neg y$ is an end to x.*

These definitions provide an intricate framework for mapping influence relations from a Value Cognitive Map to an Ends Means Map. Positive and negative influences in VCM are recontextualized in EMM, translating the influence dynamics into a structured ends-means format. The positive influence of x on y not only establishes y as an end to x but also implies that the absence of y becomes an end to the absence of x, and vice versa for negative influences. This approach captures the complexity of value interactions, considering both presence and absence states, thus offering a comprehensive understanding of the decision-making landscape in EMM.

3.4 Algorithm

The algorithm provided bridges the gap between a Value Cognitive Map (VCM) and an Ends Means Map (EMM). It is designed to systematically transform the VCM, a graph represented as $VCM = \langle A, R \rangle$, into an EMM, represented as $EMM = \langle B, \Pi \rangle$. This process involves a series of steps that reinterpret the relationships and nodes within the VCM to fit the ends-means framework of the EMM.

Algorithm 1 Construction of a EMM

1. Import A
2. Import R^+ and R^-
3. Create $\bar{A}$
4. Label x_o
5. $\forall x \in A : \exists r^+(x, x_o) \rightarrow \pi(x_o, x)$ and eliminate $r^+(x, x_o)$
6. $\forall x \in A : \exists r^-(x, x_o) \rightarrow \pi(x_o, \neg x)$ and eliminate $r^-(x, x_o)$
7. Label all x for which $\pi(x_o, x)$
8. Label all $\neg x$ for which $\pi(x_o, \neg x)$
9. $\forall x$ labelled $: \exists r^+(y, x) \rightarrow \pi(x, y)$ and eliminate $r^+(y, x)$
10. $\forall x$ labelled $: \exists r^-(y, x) \rightarrow \pi(x, \neg y)$ and eliminate $r^-(y, x)$
11. $\forall \neg x$ labelled and x not labelled $: \exists r^+(y, x) \rightarrow \pi(\neg x, \neg y)$ and eliminate $r^+(y, x)$
12. $\forall \neg x$ labelled and x not labelled $: \exists r^-(y, x) \rightarrow \pi(\neg x, y)$ and eliminate $r^-(y, x)$
13. Label all y for which $\pi(x, y)$ or $\pi(\neg x, y)$
14. Label all $\neg y$ for which $\pi(x, \neg y)$ or $\pi(\neg x, \neg y)$
15. If no more $r^+(x, y)$ or $r^-(x, y)$ stop
16. Eliminate all unlabelled nodes.
17. For all cycles, if there is a unique longest path, eliminate the last arc.
18. If there are more than one longest paths of the same length, submit to the client the choice of which are eliminate.
19. Otherwise eliminate one arc of the cycle arbitrarily.
20. End.

We begin by importing the concepts from set A, which constitute the nodes in the value cognitive map (1). Next, we establish all the existing relations within the value cognitive map (2). We include the negation of all concepts except the fundamental value (3). The process initiates with the fundamental value (4). Firstly, we consider all nodes that have a positive direct relation with the fundamental value. To induce an ends-means relationship, we reverse the direction of the arc from the fundamental value to the node, while eliminating the existing positive arc between the node and the fundamental value (5). Similarly, for nodes that have a direct negative relation with the fundamental value, we redirect the arc from the fundamental value to the negation of the node to ensure a positive relation, and we eliminate the existing negative relationship between the fundamental node and the node. It is important to note that with steps (5) and (6), we commence changing the direction of arrows and transforming signs. In summary, positive relationships with the fundamental value are inverted, establishing an ends-mean structure. Negative relationships are transformed into positive ones by redirecting arcs to the negation of nodes and eliminating original negative links. In the subsequent steps, we label the nodes that have a direct positive (7) and negative (8) relationship with the fundamental node. Steps (9) and (10) involve examining the means of the labeled nodes. If a positive relation is identified, we modify the direction of the arc (9) (only changing the direction), whereas if a negative relation is found, we establish a relation between the negation of the mean (sign and direction simultaneously). It is worth noting that the process for the mean of the fundamental value follows the same procedure as outlined in steps (5) and (6). Steps (11), (12), (13), and (14) require us to induce the same direction and sign transformation for the subsequent nodes. The key insight here is that we consistently change the direction of arrows and perform sign transformations based on altering the means while preserving the ends. The process halts when there are no more nodes to be processed (15). In the case of cycles, a unique situation arises as the process cannot conclude in the previous steps. We eliminate all nodes which we do not need any more (the unlabelled ones, Step (16)). Step (17) instructs us to eliminate relationships for the node that has the longest unique path, if such a node exists. If multiple longest paths exist, the client is consulted for elimination (18). Otherwise, one of the relations in the cycle is arbitrarily eliminated (19). It is easy to prove the following propositions

Proposition 3.4.1 *The algorithm* 1 *converges in finite time.*

Proof
Straightforward. The algorithm contains no loops and each cycle (steps 5,6,9,10,11,12)

is defined upon a finite set of nodes. The number of r^+ and r^- arcs being finite it also takes a finite number of steps to construct the π arcs. ■

Proposition 3.4.2 *If the Cognitive Map has a unique fundamental node, then graph constructed through algorithm* 1 *has a unique fundamental node.*

Proof
Obvious. If the Cognitive Map has a unique fundamental node then the EMM will have a unique fundamental value. ■

This proposition emphasizes the inherent design of Algorithm 1, ensuring that the resulting Ends-Means Map (EMM) maintains a unique fundamental node. This is critical as it guarantees that the transformation process preserves the central focus of the original Cognitive Map. The uniqueness of the fundamental node in the EMM signifies a clear, unambiguous representation of the primary goal or value, essential for effective decision-making and analysis in complex scenarios.

Proposition 3.4.3 *The relation* Π *of the graph constructed through algorithm* 1 *is irreflexive and acyclic.*

Proof
Irreflexivity of Π is a direct consequence of irreflexivity of R. There are no $R(x, x)$ arcs and therefore there cannot be construction of $\Pi(x, x)$ arcs.
Acyclicity of Π is obtained by construction. Cycles of R arcs are eliminated substituting the A set with the B set ($B = A \cup \bar{A}$). Cycles not reduced by this step are further eliminated through steps 16, 17 and 18. ■

Proposition 3.4.4 *The graph constructed using algorithm* 1 *is weakly connected.*

Proof
Since the graph has a unique fundamental value, if for any node of the graph there is a path connecting it to such fundamental node then the graph is weakly connected. If a node is part of the graph (after applying the algorithm) it needs to be labelled. A node is labelled if there is an arc connecting it to a node already labelled or it is the fundamental value. Given any node, either there is a path of labelled nodes connecting it to the fundamental node or it is the fundamental node. Thus, given any two nodes (labelled), both of them are connected to the fundamental value and thus there is an undirected path connecting them. The graph is weakly connected. ■

Theorem 3.4.1 *The graph constructed through algorithm* 1 *up to Step 15 is unique with respect to the Value Cognitive Map from which it originates.*

Proof
Straightforward. Until Step 15, the algorithm is a sequence of deterministic steps and makes no choices. Thus, given any graph structure under the form of a Value Cognitive Map, there is a unique graph structure resulting from applying the algorithm. ■

This theorem asserts the uniqueness of the graph generated by Algorithm 1 up to Step 15 concerning its origin from a Value Cognitive Map. The proof is straightforward, as the algorithm's deterministic nature and absence of choices in its steps guarantee a one-to-one mapping between the original Value Cognitive Map and the resulting graph structure. This uniqueness property is significant for maintaining the integrity of the transformation process and ensuring consistent representations of cognitive maps in graph form. After step 15, since stakeholder/ decision maker can decide node elimination if there exist cycle, is it possible to have different kind of maps. However this situation does not changing sturcture of the transformation process since after each possible different decision same process applies.

Corollary 3.4.1 *The number of EMMs constructed from a given VCM is finite and depends on how many cycles have to be reduced through algorithm 1.*

Proof
Straightforward. ■

The finiteness of Ends-Means Maps (EMMs) derived from any given Value Cognitive Map (VCM) is an important property, particularly in the context of decision-making and problem-solving processes. This corollary suggests that the number of EMMs is directly linked to the complexity of the VCM, especially in terms of the cycles present within it. Algorithm 1 plays a crucial role in this process, as it provides a systematic method for reducing these cycles, thus converting a complex VCM into a manageable number of EMMs. The finite nature of EMMs ensures that the process of transforming cognitive insights into practical decision trees remains tractable, providing a structured approach to dealing with complex problems.

3.5 Value Trees

Let us recall that a value tree is a graph structure representing "ends-means" relations satisfying the properties of a "tree structure":

Definition 3.5.1 *A directed graph $\langle G, V\rangle$ is a tree iff it is acyclic and for any two nodes there is a unique path connecting them.*

A value tree, defined as a directed acyclic graph with unique paths between any two nodes, serves as a fundamental tool in decision analysis and problem-solving. The acyclic nature of a value tree ensures that it doesn't contain any cycles, which is crucial for maintaining a clear, hierarchical structure in decision-making processes. The uniqueness of paths between any two nodes in the tree implies that each decision or value proposition in the tree follows a distinct route, avoiding ambiguity and redundancies. This structure facilitates the clear tracing of decision paths and the understanding of how various options or actions lead to particular outcomes or goals, making the value tree an essential element in structured decision-making and strategic planning.

In the realm of decision analysis, the concept of a 'value arborescence,' as described by Keeney, takes on significant meaning. It embodies a hierarchical decision structure where all choices, options, or values are interconnected and trace back to a singular, overarching fundamental value, akin to the root of a tree. This singular connection point is critical in modeling decision-making processes, as it represents the core objective or goal that guides all subsequent choices. The structure of a value arborescence, where each node (value) is connected directly to this fundamental value, facilitates a clear understanding of how each sub-decision or value proposition aligns with and contributes to the overarching goal. This clarity is crucial in complex decision-making environments, ensuring alignment of all decisions with the central objective and enabling efficient evaluation and comparison of different decision paths. The value arborescence model is particularly beneficial in strategic planning and policy development, where clear alignment with core objectives is essential.

An EMM $\langle B, \Pi\rangle$ is an irreflexive, acyclic and weakly connected graph, a structure central to its function in mapping complex decision-making processes. This graph is defined by a unique 'root', representing the fundamental value, crucial for establishing the foundational objective of the decision hierarchy. The structure then branches into 'layers' of nodes, each layer, denoted as k, composed of nodes that are equidistant from the root, measured by the shortest path - with all arcs having the same length. This uniformity in arc length ensures consistent measurement across the structure. Nodes in a given layer k act as predecessors to the nodes in the subsequent layer $k+1$, delineating a clear hierarchy where each layer represents a progressively detailed level of decision criteria, cascading down from the overarching goal or value at the root.

In the structure of an EMM, it's common for nodes, viewed as 'means' or successors, to be connected to multiple 'ends' or predecessors. However, this multiplicity of connections disrupts the tree structure, as it contradicts the tree's requirement for unique paths between any two nodes. To convert an EMM into a value tree, a further careful reorganization is required

Let's consider a node x_k (at layer k), having two predecessors: x^1_{k-1} and x^2_{k-1}. We denote the fundamental node (the root) as x_o. Then there exist two paths from x_o to x_k:
- $(x_o - x_k)^1$: $\langle x_o \cdots x^1_{k-1} x_k \rangle$ and
- $(x_o - x_k)^2$: $\langle x_o \cdots x^2_{k-1} x_k \rangle$.

There are two cases.
1. Suppose $L(x_o - x_k)^1 < L(x_o - x_k)^2$. We can conclude that what matters in terms of ends-means relation is the shortest path. This allows to eliminate the arc $x^2_{k-1}x_k$ since we consider it less relevant. Therefore, we can eliminate all "predecessors" of any x_k which are on longest paths wrt to the fundamental node.
2. Suppose $L(x_o - x_k)^1 = L(x_o - x_k)^2$. In order to explain better how we suggest handling this problem let us introduce two small examples.

This technical scenario highlights a crucial aspect of transforming an EMM into a value tree. When a node x_k at layer k is connected to multiple predecessors, it creates multiple paths from the root x_o to x_k. The key step in the transformation process involves determining the relevance of these paths. In case one path is shorter, it's considered more relevant in the ends-means relationship, leading to the elimination of longer, less relevant paths. This ensures the uniqueness of the path in the value tree. However, if paths are of equal length, the decision becomes more complex, requiring further nuanced considerations or examples to resolve the ambiguity and maintain the tree structure.

Here we present two examples:

Example 3.5.1 *Suppose x_o represents "happiness," connected to two means: x^1_1 ("health") and x^2_1 ("pleasures"). Both these values, seen as ends, are linked to a common mean, x^1_2 ("food"). In this EMM, each node symbolizes a distinct value reflecting preferences. We can then pose a critical question to the user or client:* ***"Do your preferences regarding food, in terms of its impact on health, differ***

from its impact on pleasure?"
If the answer is "YES," indicating differing preferences (e.g., preferring junk food for pleasure but bio food for health), this necessitates a bifurcation of the "food" node into two distinct entities: - x_2^{11}: food in the context of health; - x_2^{12}: food in the context of pleasure.
This distinction is crucial in understanding the multi-dimensional impact of a single mean on various ends, allowing for a more nuanced and accurate representation in the value tree.

Example 3.5.2 *Consider a dinner scenario where the success of the dinner (x_o) is influenced by three means: x_1^1 (food), x_1^2 (drinks), and x_1^3 (ambience). The food value varies depending on whether it is x_2^1 (fish) or x_2^2 (meat), and this is intricately linked to the choice of drinks, either x_2^3 (red wine) or x_2^4 (white wine). Similarly, the appreciation of drinks is influenced by the food's quality. This creates a complex interdependence where x_2^1, x_2^2, x_2^3, and x_2^4 are all connected to x_1^1 and x_1^2.*
Here, we can pose a question similar to the previous example: ***"Does your preference for fish or meat affect your choice between red or white wine?"*** *Typically, these preferences are interconnected. In such cases, merging the nodes x_1^1 and x_1^2 into a single node x_1^{12} representing the combined preferences for food and drink is appropriate. This merging addresses the multiple predecessors issue, simplifying the decision network.*

Here is our presentation. Suppose node x_k^j is a successor of multiple predecessors $x_{k-1}^i, x_{k-1}^l \cdots$. We can proceed as follows:
- $\forall x_{k-1}^i$ find $i = \min_i L(x_o \cdots x_{k-1}^i x_k^j$.
- Drop all arcs $x_{k-1}^l x_k^j$ such that $L(x_o \cdots x_{k-1}^l x_k^j) > L(x_o \cdots x_{k-1}^i x_k^j)$.
- If x_{k-1}^i is unique, then stop, x_k^j has a unique predecessor.
- If there are more than one x_{k-1}^i $(i, i', i'' \cdots)$ then:
• If preferences in x_k^j as far as x_{k-1}^i are concerned are independent from the preferences in x_k^j as far as $x_{k-1}^{i'}$ are concerned, then split x_k^j in nodes x_k^{ji} and $x_k^{ji'}$.
• If preferences in x_k^j as far as x_{k-1}^i are concerned are conditions to the preferences in x_k^j as far as $x_{k-1}^{i'}$ are concerned (and/or viceversa), then merge x_{k-1}^i and $x_{k-1}^{i'}$ in $x_{k-1}^{ii'}$.

In transforming an EMM into a VT, we address nodes x_k^j with multiple predecessors. The initial step involves identifying the shortest path from the root x_o to x_k^j. Nodes on longer paths are disregarded. If multiple predecessors influencing

x_k^j remain:
- We split x_k^j into distinct nodes (e.g., x_k^{ji}, $x_k^{ji'}$) if the preferences at x_k^j influenced by different predecessors are independent.
- Conversely, if the preferences at x_k^j influenced by one predecessor are conditional on those influenced by another, we merge these predecessors into a single node (e.g., $x_{k-1}^{ii'}$). This ensures clear, unambiguous paths in the value tree, reflecting coherent sets of preferences or values.

The outlined procedure systematically addresses the complexity within an $EMM = \langle B, \Pi \rangle$ by resolving the issue of multiple predecessors for each successor. This is achieved through a finite series of steps involving the merging or splitting of nodes, and the addition or removal of arcs. The result is a transformation into a new graph, a $VT = \langle G, V \rangle$. In VT, the node set V is derived from B by strategically merging or splitting nodes to streamline the decision paths, while the relation set Π is redefined by modifying arcs to ensure a tree structure.

3.6 Value tree to Concept Tree

After we employed our algorithm cognitive map to value tree in two Case studies, we also used the top structure of the value tree in the Tunisia study to construct the concept tree. After that, since our result was fruitful, we decided to expand our procedure formally, how to use a value tree (not only the top structure of it) to construct a concept tree.

First we need to be clear on hierarchy levels in value tree.

Let $T = (V, R_T)$ be the Value Tree, where $V = \{v_1, v_2, \ldots, v_n\}$ represents the set of nodes, and $R_T \subseteq V \times V$ represents the hierarchical relationships between these nodes.

Define the hierarchy level $h(v_i)$ of a node $v_i \in V$ as the length of the shortest path from the fundamental node v_f (root of the tree) to v_i:

$$h(v_i) = \text{length of shortest path from } v_f \text{ to } v_i$$

The set of nodes at hierarchy level h is then:

$$V_h = \{v_i \in V \mid h(v_i) = h\}$$

This set V_h contains all nodes that are located at the same hierarchical level h in the Value Tree T.

For each hierarchy level h in the Value Tree, consider the set of nodes V_h at that level:

$$V_h = \{v_{h1}, v_{h2}, \ldots, v_{hm}\}$$

The corresponding set of negated nodes at this level is:

$$\neg V_h = \{\neg v_{h1}, \neg v_{h2}, \ldots, \neg v_{hm}\}$$

Generate all possible binary combinations between the nodes and their negations within the same hierarchy level:

$$C_h = \{(v_{hi}, v_{hj}), (v_{hi}, \neg v_{hj}), (\neg v_{hi}, v_{hj}), (\neg v_{hi}, \neg v_{hj}) \mid v_{hi}, v_{hj} \in V_h \text{ and } i \neq j\}$$

Thus, C_h represents the set of all binary combinations of nodes and their negations within the same hierarchical level h of the Value Tree.

Algorithm: Transforming a Value Tree into a Concept Tree

An ends-means relationship in the value tree results in a partition within the concept space. A concept is understood as a set that encompasses all entities partially defined by a set of shared properties. At the top of the concept tree, the initial concept—often representing the overarching design task or a shared concern—serves as the "ends." To refine this concept, we utilize the value tree to identify the "means," which represent the actions or attributes necessary to achieve the ends. In this context, the means themselves become a concept, incorporating all entities defined by both the ends and the selected means, effectively creating a partition of the original ends.

The partitioning process, as described above, can be expressed as the conjunction of a concept c with a predicate q or its negation $\neg q$. By leveraging the negation of each node in the Value Tree, we open up new possibilities for creative exploration. This approach enables us to systematically explore alternative scenarios and generate innovative concepts that might not emerge through standard logical reasoning alone. The use of negations challenges conventional thinking, sparking creativity by introducing opposites or contrasts that may reveal previously unconsidered insights and solutions. This process not only enriches the conceptual space but also broadens the spectrum of potential design paths.

When transitioning from a value tree to a concept tree, we begin by generating the negations of the nodes. This approach aligns with existing literature, where utilizing the negations of concepts in the construction of a concept tree is a well-established practice. The inclusion of a node's negation offers valuable counterpoints to the analysis, enabling the generation of alternatives that may have previously been overlooked or deemed insignificant. By doing so, we provide a broader scope for design and decision-making.

For cases where a hierarchy contains two nodes, generating binary combinations between the nodes and their negations, alongside the nodes themselves, allows for a more holistic approach to exploring the design space. This ensures that each element is considered thoroughly, providing a complete analysis. Importantly, including the nodes themselves in addition to the binary combinations is crucial when the node has subsequent child nodes. If we exclude the node from the binary combination, it becomes impossible to accurately position this node in relation to its child nodes. Moreover, from a set-theoretical perspective, including the nodes in their original form (in addition to binary combinations) ensures that all spaces in the concept space are accounted for, filling any potential gaps in the exploration of possibilities.

However, when the number of nodes in a hierarchy exceeds two, we face the risk of a combinatorial explosion, which increases complexity and reduces practicality. To mitigate this, in cases where there are more than two nodes within a hierarchy, we propose limiting the combinations to only the nodes themselves and their direct negations, avoiding binary combinations between them. This method reduces the risk of combinatorial explosion while maintaining the conceptual clarity needed for effective analysis.

The concept tree is ideally constructed in collaboration with stakeholders, allowing for real-time adjustments based on input. Our proposed algorithm, therefore, is designed to be flexible, allowing stakeholder intervention at each step when necessary

- **Step 1: Import all nodes in the Value Tree (VT)**
  Let $V = \{v_1, v_2, \ldots, v_n\}$ represent the set of nodes in the Value Tree (VT).

- **Step 2: Define hierarchy levels in VT**
  For each node $v_i \in V$, define its hierarchy level $h(v_i)$ as the length of the shortest path from the root node v_f (fundamental value):

$$h(v_i) = \text{shortest path}(v_f, v_i)$$

Define the set of nodes at hierarchy level h as:

$$V_h = \{v_i \in V \mid h(v_i) = h\}$$

Nodes will be processed in a breadth-first manner, starting from the root node and continuing level by level.

- **Step 3: Assignment of Fundamental Value to Shared Concern**
  Ensure that the fundamental value v_f from the VT corresponds to the shared concern c_f in the CT, such that:

  $$v_f := c_f$$

  This ensures that the root of the VT is aligned with the root of the CT.

- **Step 4: Transform Ends-Means Relationships into Concept Partitions**
  For each node $v_i \in V_h$, if the node represents an **end**, identify the means (child nodes of v_i) in the hierarchy:

  – The **ends-means relationship** in the Value Tree leads to a partition in the Concept Tree.

  – Use the end node to partition the means, transforming them into sub-concepts in the Concept Tree.

  – This transforms the set of means into a **concept set** defined by both the ends and the selected means, effectively partitioning the end.

  Concepts are defined as sets containing entities partly characterized by shared properties:

  $$C = \{c_i \mid c_i \text{ represents the set of entities characterized by shared properties of } v_i\}$$

  where c_i represents a concept associated with the means.

- **Step 5: Generate Negations of Concepts—except the fundamental node**
  For each concept $c(v_i) \in C_h$, generate its negation $\neg c(v_i)$. The set of concepts and their negations at each hierarchy level is:

  $$C'_h = \{c(v_i), \neg c(v_i) \mid c(v_i) \in C_h\}$$

- **Step 6: Handling hierarchy levels based on the number of nodes**
  For each hierarchy level h, perform the following steps:

- If $|V_h| = 1$:
  Include the node and its negation:

$$C''_h = \{c(v_1), \neg c(v_1)\}$$

- If $|V_h| = 2$:
  Generate all possible binary combinations of the nodes and their negations:

$$C''_h = \{(c(v_1), c(v_2)), (c(v_1), \neg c(v_2)), (\neg c(v_1), c(v_2)), (\neg c(v_1), \neg c(v_2))\}$$

  Also include the nodes themselves to preserve the parent-child relationships:

$$\{c(v_1), c(v_2)\}$$

- If $|V_h| \geq 3$:
  To avoid combinatorial explosion, include only the nodes and their direct negations without binary combinations:

$$C''_h = \{c(v_i), \neg c(v_i) \mid v_i \in V_h\}$$

- **Step 7: Construct the Concept Tree (CT)**
  Using the hierarchy levels $h(v_i)$ from the Value Tree (VT), structure the Concept Tree (CT) such that parent-child relationships are preserved:

$$CT = \{(c(v_i), c(v_j)) \mid v_i \text{ is a parent of } v_j\}$$

- **Step 8: Iteratively refine the Concept Tree with stakeholder feedback**
  For each level h, iteratively walk through the Concept Tree (CT) and consult stakeholders:

  - Ask stakeholders if any refinement is needed for concept nodes, binary combinations, or their negations.
  - Make adjustments according to the stakeholder's suggestions and continue to the next level of the tree.

- **Step 9: Final review and consistency check**
  Conduct a final review of the CT to ensure that all nodes and their relationships are logically consistent and aligned with the original VT's structure and stakeholder inputs.

The algorithm starts by importing all nodes from the Value Tree (VT) and defining their hierarchy based on the shortest path from the root node, which represents the fundamental value. This is crucial to ensure the hierarchical structure is preserved when transitioning to the Concept Tree (CT). Each node v_i is assigned a hierarchy level $h(v_i)$, which measures the distance of the node from the root node v_f (the fundamental value). This hierarchy structuring allows us to process nodes level by level, maintaining the relationships between parent and child nodes as we proceed with the transformation.

In the next step, the fundamental value from the VT is identicalized with the shared concern in the CT, meaning that:

$$v_f := c_f$$

This ensures that the root of the Value Tree corresponds to the root of the Concept Tree, keeping both trees aligned at the highest level. Once this identicalization is established, we begin transforming **ends-means relationships** from the VT into partitions within the CT. An **end** in the VT, which represents a goal or objective, is partitioned by the means (the child nodes) used to achieve it. These means become sub-concepts within the CT, reflecting the same functional and hierarchical structure seen in the VT, but now in terms of concepts instead of values.

The next phase introduces **negations** for each concept, excluding the fundamental value. For every concept node $c(v_i)$, a corresponding negation $\neg c(v_i)$ is generated. This step introduces alternatives to each concept, fostering creative thinking by exploring both affirmations and rejections of the concepts. By doing so, stakeholders are able to consider a broader set of possibilities, encouraging the identification of novel solutions or overlooked alternatives in the design process.

At each hierarchy level, we decide how to process nodes based on their number. If there is only one node, both the node and its negation are included. When there are two nodes, we generate all possible binary combinations of the nodes and their negations, ensuring that each node and its binary pairings are considered:

$$C''_h = \{(c(v_1), c(v_2)), (c(v_1), \neg c(v_2)), (\neg c(v_1), c(v_2)), (\neg c(v_1), \neg c(v_2))\}$$

For levels with more than two nodes, we avoid **combinatorial explosion** by including only the nodes themselves and their negations. Additionally, based on stakeholder preferences, we may opt for **Depth-First Search (DFS)** approach instead of the default **Breadth-First Search (BFS)**. While BFS processes all nodes at a given level before proceeding to the next, DFS allows stakeholders to focus deeply on specific concepts or branches of interest. However, DFS can disrupt the overall hierarchy, potentially making it harder to maintain a clear relationship between parent and child nodes at the same level.

Finally, the Concept Tree (CT) is constructed by preserving the parent-child relationships from the Value Tree (VT). An iterative process allows stakeholders to provide feedback and refine the concepts and their negations, with adjustments made based on stakeholder input. After all refinements, a final review ensures the CT is logically consistent, coherent, and aligned with the original structure of the VT, while reflecting insights gained through stakeholder engagement.

Chapter 4

Case Study-1: Kurdish-Turkish conflict

In this case study, we simulated a real conflict, the Kurdish-Turkish Conflict, to test our findings.

The conflict between Turkey and PKK (Partiya Karkerên Kurdistanê)[1]. , deeply rooted in the Kurdish revolts and explored by Yadirgi (2017), extends back to the Ottoman Empire's era. This historical struggle, described as the "Kurdish Question," encapsulates the Kurds' pursuit of self-determination against systemic oppression, a theme detailed in Yildiz (2012). The Turkish state's struggle with this issue, where it presumes all citizens to be uniformly Turkish as Ünlü (2014), has led to significant challenges for the Kurdish minority in preserving their distinct identity. According to Bozarslan (2008) Turkey's response, characterized by assimilative and oppressive policies that have suppressed Kurdish culture and language, contributed to the conflict's escalation in 1984.

The conflict's complexity is heightened by historical and cultural tensions, as well as geopolitical factors like regional power struggles, outlined by Çandar (2020). Yet, the human rights violations, both physical and political as categorized by Mousseau et al. (2019), have been a significant and tragic aspect of this conflict, impacting civilians deeply. Jongerden (2007) highlights the drastic measures Turkey took in the 1980s and 1990s, including village evacuations and burnings, underscoring the severity of the state's approach to the Kurdish issue.

Turkey's policies, particularly those limiting Kurdish cultural expressions, have not only exacerbated the conflict but also posed obstacles to democracy and peace,

[1] The Kurdistan Workers' Party (PKK) is an armed organization within the Kurdish movement.

as Ergil (2000) points out. The conflict, responsible for over 30,000 deaths since the 1980s, reflects the profound challenges of reconciling national identity with minority rights. Adalet ve Kalkınma Partisi (AKP)[2]. 's approach, constrained by its nationalist character as analyzed by Çiçek (2013), has further complicated efforts to resolve the conflict and disarm the PKK, revealing the deep-rooted and multifaceted nature of this ongoing struggle.

In recent times, the conflict has continued to manifest in various forms of political and human rights strife. May 2023 marked a poignant moment in this ongoing saga, as numerous Kurdish politicians and human rights defenders found themselves behind bars. This event serves as a stark reminder of the enduring nature of this conflict and the ongoing struggle for Kurdish rights within the complex political landscape of Turkey and the broader region.

In this study, two key stakeholders were selected to represent the diverse perspectives in the Kurdish-Turkish conflict. One, an academician specializing in Kurdish issues, embodies the Kurdish viewpoint. The other, a high-ranking politician from Turkey's main opposition party, Cumhuriyet Halk Partisi (CHP)[3]. , represents the Turkish side. Through comparative questioning, both stakeholders acknowledged a fundamental node of the conflict, revealing core motivations and underlying issues. However, it's important to recognize that insights from just two individuals may not fully capture the breadth of this complex conflict. The study's primary objective is to assess the proposed model's effectiveness, rather than offering a comprehensive solution to the deeply rooted and multifaceted Kurdish-Turkish conflict. Again, the core idea of this study, by involving two distinct stakeholders from the Kurdish and Turkish sides, is to showcase the replicability and practical application of the transformation process we've proposed. By analyzing their perspectives through our model, we aim to demonstrate how this method can be utilized to understand and dissect complex conflicts like the Kurdish-Turkish one. It's an exploration of the model's utility in a real-world scenario, emphasizing its potential in providing insights into multifaceted conflicts, rather than proposing a definitive solution to the deeply entrenched issues at hand.

The stakeholders' inputs align with existing literature on the Kurdish-Turkish conflict, such as the works of Bozarslan (2008) and Çandar (2020). This study aims to delve deeper into the conflict using cognitive maps, uncovering the complex web of values and examining the problem's value-based structure. By em-

[2]The Justice and Development Party (AKP) is a right-wing, conservative, nationalist ruling party in Turkey.

[3]The Republican People's Party (CHP) is the main opposition party in Turkey and is traditionally associated with social democracy.

ploying value trees, we explore the potential for new alternatives, a process enriched by conflict resolution theories like those outlined by Ozcelik (2006). These theories, including basic human needs and psychodynamic approaches, provide a multi-faceted understanding of the conflict, particularly the psychological aspects of identity and victimization.

Changes in domestic and international contexts, as Somer (2004) suggests, influence the Kurdish issue in Turkey. Analyzing these shifts can unveil evolving Kurdish identities and preferences, vital for policy-making. The maps also align with consideration of critical turning points and missed opportunities in the conflict's history, as pointed out Barkey and Fuller (1997), to enhance our understanding and identify new paths forward.

The role of civil society, as examined by Kaliber and Tocci (2010), highlights the diverse involvement of various organizations in the conflict resolution process. This multi-layered involvement is crucial for the our study. By integrating these diverse perspectives and methodologies, the study aims to analyze the Kurdish-Turkish conflict more effectively, exploring shared or conflicting values, and generating new alternatives for conflict resolution through cognitive mapping and value trees. Also, this case study has been submitted for publication (see Tosunlu et al., 2023).

4.1 Kurdish Perspective

4.1.1 The story

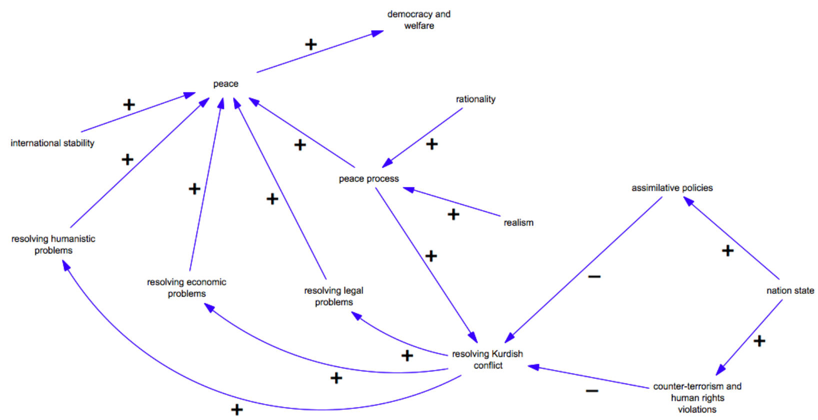

Figure 4.1: The Kurdish cognitive map

Democracy and welfare" stands as the fundamental node. This focus is singularly directed towards "peace," seen as crucial for resolving the conflict. According to the interviewee, peace hinges on a "peace process" and "international stability," addressing various humanitarian, economic, and legal issues. The stakeholder underscores the significance of "rationality" and "realism" in achieving an effective peace process. The Kurdish conflict, intertwined with "economic," "humanitarian," and "legal problems," indicates that resolving the conflict could positively impact these areas. The stakeholder views the Turkish nation-state's "assimilative policies" and approach to "counter-terrorism," which have led to "human rights violations," as key factors exacerbating the Kurdish conflict. These insights suggest a comprehensive view where economic, legal, and humanitarian aspects are deeply connected to the broader political and cultural landscape of the Kurdish question

The Kurdish perspective in the cognitive map aligns well with scholarly literature on the topic. Al (2019) emphasizes the profound impact of the Kurdish question on Turkish democracy, authoritarianism, foreign policy, and societal peace, reflecting the conflict's far-reaching implications. Ergil (2000) and Keyman (2012) highlights the Kurdish emphasis on cultural recognition and the end of restrictive policies, crucial for a peaceful resolution and Turkey's integration with Europe and the West. Somer (2004) discusses the rising consciousness and politicization of Kurdish identity, suggesting compatibility with Turkish identity for regional peace and stability. Geri (2017) notes the implications of the Turkish government's treatment of Kurds and the re-securitization of the issue, influencing the Kurdish perspective on peace. Lastly, Örmeci (2015) points out that the Kurdish conflict involves broader issues of democracy, human rights, and social justice, all seen as interconnected and vital for resolving the conflict. These scholarly insights resonate with the Kurdish stakeholder's perspective on democracy, welfare, and the fundamental node of "peace" in the cognitive map.

4.1.2 Transformation Process: Cognitive map to Value cognitive map

In transforming the Kurdish Cognitive Map into a Value Cognitive Map (VCM), the process involves converting the set N of concepts into a set A of values. This task entails assigning a value to each concept in the Cognitive Map wherever possible. It's important to recognize, however, that not every concept may seamlessly transform into a value. In the Kurdish Cognitive Map case, all concepts are translatable into corresponding values. Notably, 'realism' and 'rationality' are inherently values as articulated by the stakeholder. It's also crucial to understand that 'peace' in this context is not treated as a value per se but rather as an objective or a desired outcome of the process. This distinction is vital in accurately capturing the nuances of the Kurdish perspective in the value transformation process.

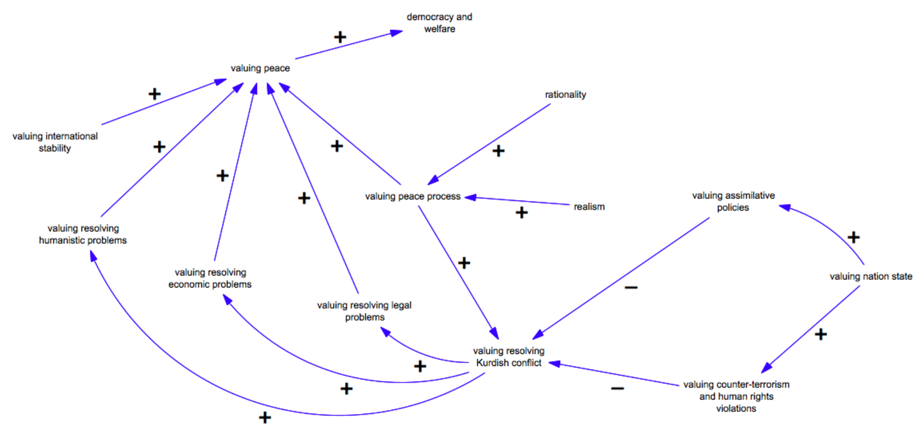

Figure 4.2: The Kurdish value cognitive Map

In the Kurdish Value Cognitive Map, "democracy and welfare" is established as the fundamental value. This map intricately shows how "valuing peace" positively influences "valuing democracy and welfare." Conversely, there are negative arcs indicating that "valuing nation-state" positively impacts counter-terrorism efforts and inadvertently contributes to human rights violations. Additionally, "valuing assimilative policies" negatively influences the resolution of the Kurdish conflict. The use of "valuing" as a prefix in this map is pivotal, allowing for the exploration of both beneficial and detrimental narratives within the Kurdish context. This approach offers nuanced insights into the potential outcomes of valuing certain policies or principles, shedding light on the complex interplay of values in the conflict.

The Kurdish Value Cognitive Map's alignment with scholarly literature indicates a resonance with key themes in the Kurdish-Turkish conflict. Turkish state policy's evolution, as noted by Updegraff (2012), from denial and assimilation towards cultural recognition mirrors the Kurdish demands for democracy and welfare represented in the map. Romano and Gurses (2014a) and Romano and Gurses (2014b) highlight the impact of the Kurdish conflict on democratization, reflecting the conflict's multifaceted nature involving national policies and socio-economic development, akin to the map's narrative. Karakoç and Sarıgil (2020) points out the relationship between Turkish nationalism and Kurdish ethnic identity, resonating with the map's depiction of assimilative policies and their impact.

Finally, Yörük and Özsoy (2013) discuss the shift in Turkish policies towards the Kurds, from coercive to paternalistic, including welfare provisions, aligning with the Kurdish perspective on welfare in the map. These scholarly perspectives collectively underscore the map's compatibility with the broader literature on the Kurdish-Turkish conflict.

4.1.3 Transformation process: Value cognitive map to Ends-Mean Map

In the process of transforming the Kurdish Value Cognitive Map (VCM) to an Ends-Means Map (EMM), we focus on constructing the relation Π from R. It is important to understand that in R, any influence relation, be it positive or negative, between x_i and x_j (denoted as $R(x_i, x_j)$), positions x_j as an "end" relative to the value of x_i, which acts as a "mean." Notably, while R includes both positive (R^+) and negative influences (R^-), Π is formulated solely from positive influences. Therefore, our algorithm begins by reversing the direction of arrows to induce ends-means relationships, followed by converting negative influences into positive ones, crucial for the transition to an EMM.

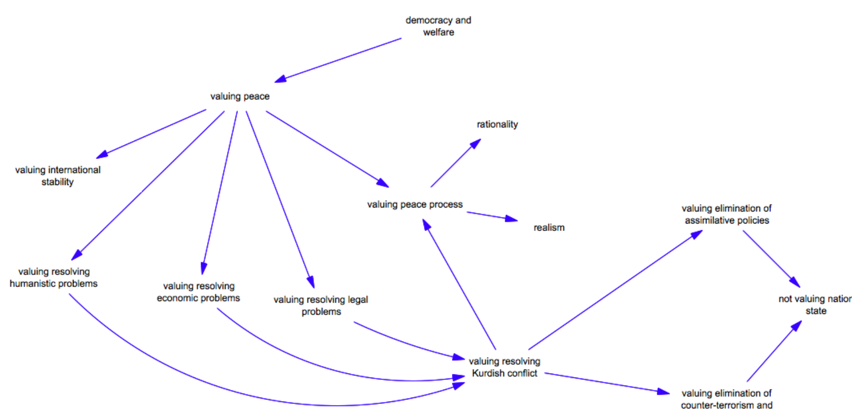

Figure 4.3: The Kurdish ends-means map

In the transformation from a Kurdish Value Cognitive Map to an Ends-Means Map (EMM), the initial step involves duplicating all nodes to facilitate the negation process necessary for sign transformation. This is particularly pertinent due to the presence of two negative relationships in our map: one between "valuing assimilative policies" and "valuing resolving Kurdish conflict," and the other between "valuing counter-terrorism and human rights violations" and "valuing resolving Kurdish conflict." According to the EMM framework, such negative relationships need to be addressed. As "valuing resolving Kurdish conflict" is the end in both relationships, the means - "valuing assimilative policies" and "valuing counter-terrorism and human rights violations" - are negated (as indicated in figure 4.3). This step is crucial in ensuring that the EMM reflects only positive relationships, adhering to its methodological framework.

The process of duplicating nodes and their negations in the Ends-Means Map (EMM) transformation offers advantages. By replacing "valuing assimilative policies" with "valuing elimination of assimilative policies," and "valuing counter-terrorism and human rights violations" with "valuing elimination of counter-terrorism and human rights violations," we effectively convert negative relationships into positive ones. However, this approach leads to the loss of the positive relationship between these original nodes and "valuing nation-state." To remedy this, we introduce the negation "not valuing nation-state." It's crucial to understand that while this narrative change alters the signs of relationships, our algorithm ensures that the ends are always prioritized over the means, maintaining the integrity of the value structure in the EMM.

4.1.4 Transformation process: Ends-Mean Map to Value Tree

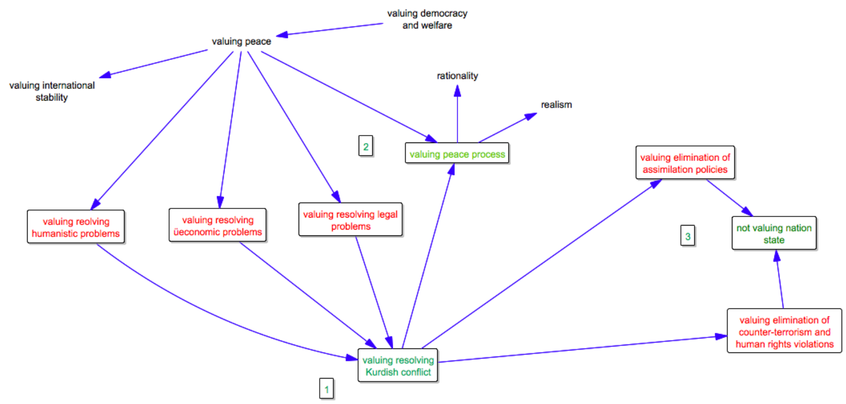

Figure 4.4: Multiple predecessors problem

To transform the Kurdish EMM into a Value Tree (VT), we focus on nodes with multiple predecessors, as these do not conform to a tree structure. In the Kurdish EMM, three nodes, highlighted in green, exhibit this issue. The primary step in our process involves examining their predecessors, highlighted in red, particularly assessing the shortest path each predecessor has to the fundamental value. This analysis is essential to restructure the EMM into a VT, ensuring it adheres to the tree structure's unique path requirement among any two nodes.

In analyzing Node 1 of the Kurdish EMM, which is focused on valuing the Kurdish conflict, we observe three predecessors: "valuing resolving legal problems," "valuing resolving economic problems," and "valuing resolving humanitarian problems." All these nodes have an equal shortest path length to the fundamental value. Given this equality, we cannot prioritize them based on path length alone. Further analysis reveals that these predecessors, being outcomes of the Kurdish conflict, do not exhibit independent preferences over means. Consequently, our approach is to merge these ends into a single, node named "valuing resolving general problems," thereby maintaining the integrity of the Value Tree structure.

For Node 2, "valuing peace process," the analysis involves two predecessors: "valuing peace" and "valuing resolving Kurdish conflict." The determination of the shortest path from these to the fundamental value is critical. In this scenario, "valuing peace" presents the shortest path. As a result, according to the methodology, we eliminate the arc between "valuing resolving Kurdish conflict" and "valuing peace process." This decision aligns with the aim to maintain a clear and unambiguous structure in the transformation to a Value Tree.

For Node 3, "valuing the not nation-state," we focus on its two predecessors: "valuing elimination of assimilative policies" and "valuing elimination of counter-terrorism and human rights violations." Similar to the predecessors of Node 1, these nodes have identical shortest paths to the fundamental value, which complicates the determination of their hierarchy based solely on distance. Therefore, we evaluate if these predecessors have independent preferences. Finding that their preferences are interdependent, we merge them into a single node, named "valuing elimination of oppressing policies." This merger is in line with the goal of achieving a coherent and streamlined Value Tree.

Finally, we have arrived at the Kurdish value tree, as shown in figure 4.5.

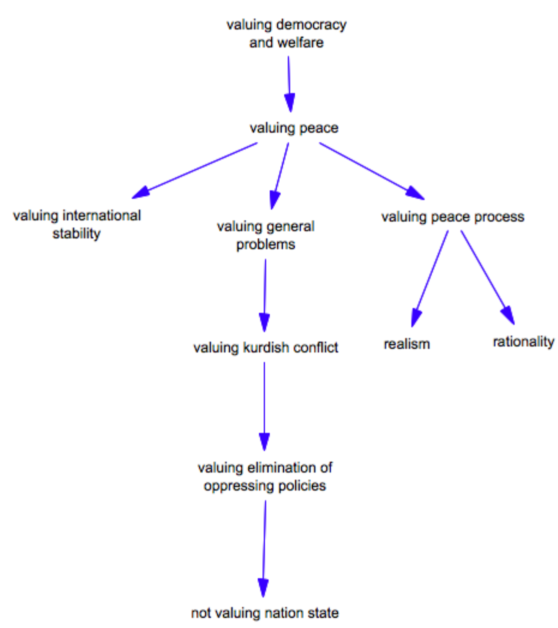

Figure 4.5: The Kurdish value tree

4.2 Turkish Perspective

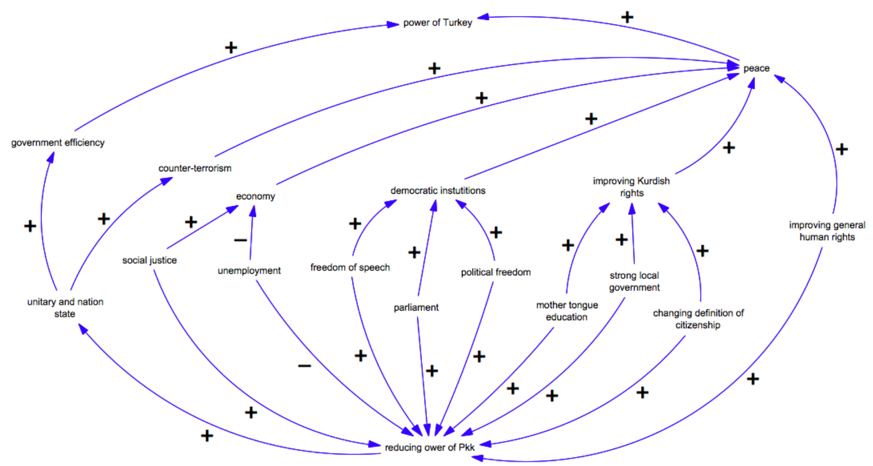

Figure 4.6: The Turkish cognitive map

The cognitive map derived from the Turkish stakeholder's insights (as shown in figure 4.6) reveals "The Power of Turkey" as the fundamental value. This value is underpinned by two main elements: "Peace" and "Government Efficiency". The stakeholder emphasizes peace not just as an essential value but as a means to enhance Turkey's overall well-being. To achieve this peace, the focus is on improving "Kurdish rights", "general human rights", "democratic institutions", and the "economy", alongside maintaining counter-terrorism measures. This cognitive map thus reflects a multifaceted approach to strengthening national power, balancing internal improvements with security concerns.

In the cognitive map of the Turkish stakeholder, "Government Efficiency" is a crucial component for upholding "The Power of Turkey". This efficiency is supported by the "Unitary and Nation-State" structure, which positively impacts counter-terrorism efforts, deemed essential for peace. However, the PKK negatively affects this "Unitary and Nation-States" node. While most sub-nodes related to "peace" counteract the influence of the "PKK", the "counter-terrorism" node stands as an exception. Furthermore, enhancing "democratic institutions" involves bolstering "freedom of speech", "parliament", and "political freedom", all of which diminish the "Power of PKK". Therefore, improvements in "economy", "democratic institutions", "general human rights", and "Kurdish rights" are seen as instrumental not only in reducing the "Power of PKK" but also in strengthening the overall peace structure.

In the Turkish stakeholder's cognitive map, "The Power of Turkey" is anchored by two key benchmarks: "Peace" and "Government Efficiency". The map indicates that the "Power of PKK" poses a threat to the "Unitary State", which is a precursor to achieving both "Government Efficiency" and "Peace". Significantly, the map suggests that enhancing the nodes related to peace not only bolsters peace itself but also diminishes the influence of the PKK. This, in turn, safeguards "Government Efficiency". The relationship between these elements highlights the interconnectedness of peace, governance, and the influence of the PKK in the Turkish perspective (as depicted in figure 4.6).

The Turkish cognitive map, as derived from the stakeholder's insights, aligns well with the literature on the Kurdish-Turkish conflict. This alignment is evident in the emphasis on "The Power of Turkey," rooted in "Peace" and "Government Efficiency." Mousseau (2012) discusses how the Turkish state's policies and resistance to granting cultural rights to Kurds impact democratization and peace efforts, resonating with the map's focus on improving Kurdish and general human rights for peace. Kuniholm (1996) highlights the critical balance between security and liberalization, reflecting the map's portrayal of counter-terrorism measures alongside democratic improvements. map's portrayal of counter-terrorism measures alongside democratic improvements. Örmeci (2015) notes the importance of enhancing democratic institutions for diminishing the PKK's influence, aligning with the map's emphasis on improving political freedom and government efficiency. Lastly, Brown (1995)Brown (1995) underlines the importance of Kurdish rights, democratic institutions, and economic development in reducing the PKK's influence, which is consistent with the map's portrayal of these elements as crucial for peace and national power. This alignment with the literature underscores the validity and relevance of the Turkish stakeholder's cognitive map.

4.2.1 Transformation Process: Cognitive map to Value cognitive map

In the transformation from the Turkish Cognitive Map to a Value Cognitive Map (VCM), the objective is to convert the set of concepts (N) into a set of values (A). In this context, all concepts in the Turkish Cognitive Map are translatable into corresponding values. Notably, values like social justice, freedom of speech, and general human rights have already been integrated into the map. It's important to highlight that the concept of peace in the Turkish map, similar to the Kurdish map, is used to represent the goal of achieving peace, rather than being a value itself. This distinction is critical in accurately capturing the nuances in the value representation of the map (as shown in figure 4.7).

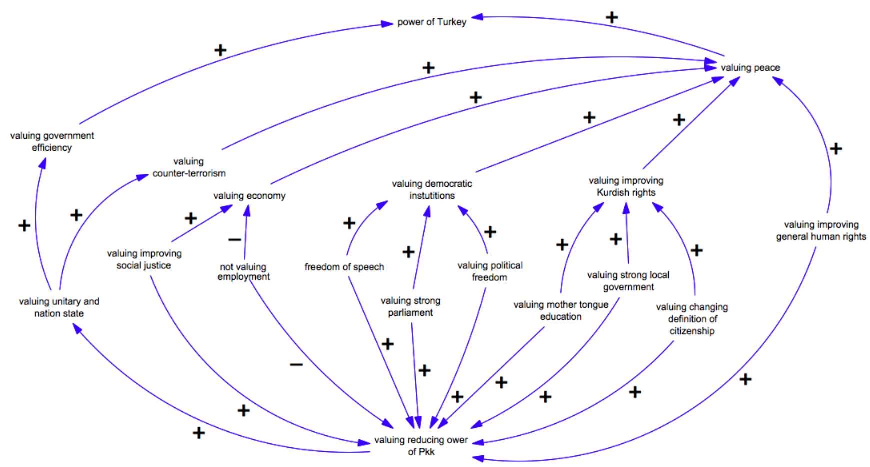

Figure 4.7: The Turkish value cognitive map

In the Turkish Value Cognitive Map, the values of "peace" and "Government Efficiency" play a pivotal role in enhancing the overarching concept of the "Power of Turkey." This highlights the fundamental value as perceived by the Turkish stakeholder. In contrast, the map introduces a unique element, "not valuing employment" (a reinterpretation of unemployment), which is seen to negatively impact "valuing reducing power of PKK." This representation indicates a nuanced understanding of the interplay between various socio-economic factors and their influence on broader national concerns, including the power dynamics with the PKK.

4.2.2 Transformation process: Value cognitive map to Ends-Mean Map

For the transformation of the Turkish Value Cognitive Map (VCM) to an Ends-Means Map (EMM), similar steps as used for the Kurdish map were followed. This involves changing the direction of arrows to uphold the ends-means relationship, along with necessary sign transformations. The algorithm requires duplicating nodes and establishing all positive relationships from ends to means, incorporating negations where needed. Notably, the absence of cycles in the Turkish map simplified the transformation process, allowing for a straightforward application of these steps (as depicted in figure 4.8).

In the transformation to the Turkish Ends-Means Map, the handling of "valuing reducing power of PKK" was key. This concept positively influenced all other elements, except for "not valuing employment". To address this, we introduced the negation of "not valuing employment" as "valuing employment". This approach also necessitated changing the negative relationship between "not valuing employment" and "valuing economy" to a positive one. By duplicating the node and adopting this narrative, we ensured the process is in line with our methodology, which emphasizes preserving ends over means.

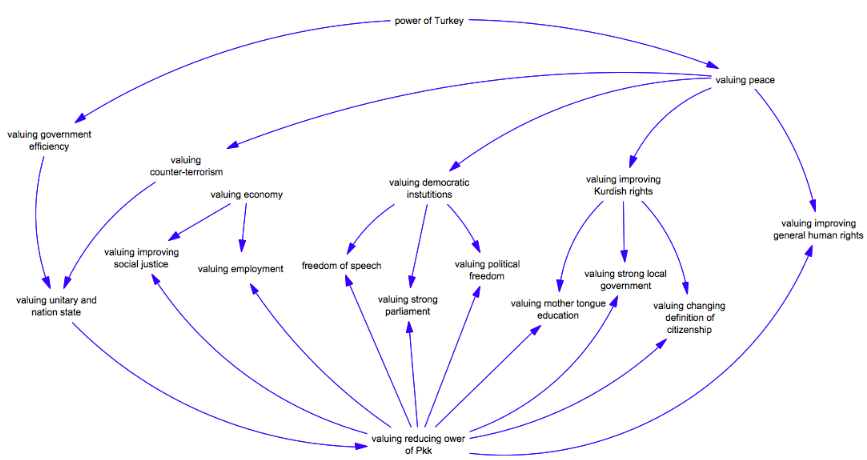

Figure 4.8: The Turkish ends-means map

4.2.3 Transformation process: Ends-Mean Map to Value Tree

In the transformation from the Turkish Ends-Means Map (EMM) to the Turkish Value Tree (VT), we identified ten nodes with multiple predecessors. According to our algorithm, the first step is to assess these predecessors by determining their shortest path to the fundamental value. This process is crucial to ensure that each node in the VT adheres to the tree structure's requirement for unique paths between any two nodes.

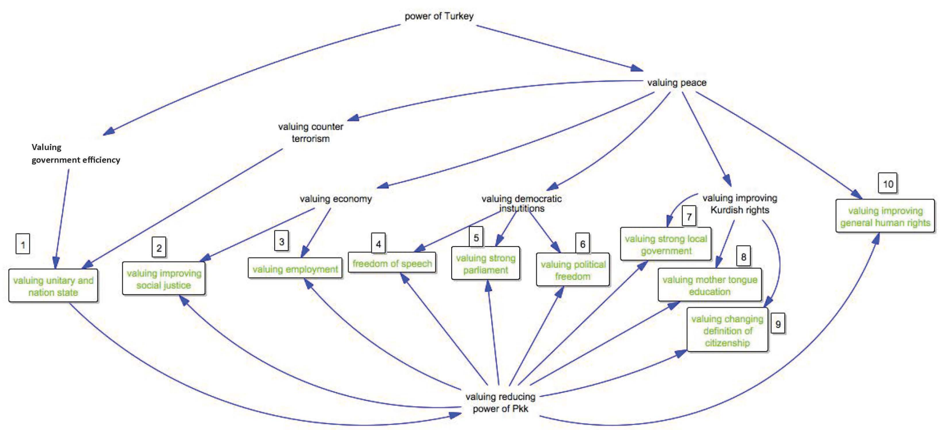

Figure 4.9: Multiple predecessors problem

In the first scenario of multiple predecessors (Case-1), the focus was on evaluating the shortest path between "valuing Government Efficiency" and "valuing counterterrorism." It was determined that "valuing Government Efficiency" had the shortest path. Consequently, the arc linking "valuing counterterrorism" to "valuing unitary and nation-state" was eliminated, aligning with the methodology of our algorithm to streamline the Turkish Value Tree structure.

In the transformation process for the Turkish EMM to the Turkish VT, the cases involving multiple predecessors are handled systematically. For Cases 2 through 10, "not valuing power of PKK" frequently emerges as a predecessor, but it consistently lacks the shortest path in comparison to other predecessors. As a result, the connections between "valuing reducing power of PKK" and various nodes are systematically removed. These nodes include "social justice" in Case 2, "valuing employment" in Case 3, "freedom of speech" in Case 4, "valuing strong parliament" in Case 5, "valuing political freedom" in Case 6, "valuing mother tongue education" in Case 7, "valuing strong local government" in Case 8, "valuing definition of citizenship" in Case 9, and "valuing general human rights" in Case 10. This methodical elimination of links is instrumental in forming the final structure of the Turkish Value Tree.

We have arrived at the Turkish value tree, as shown in Figure 5.2.

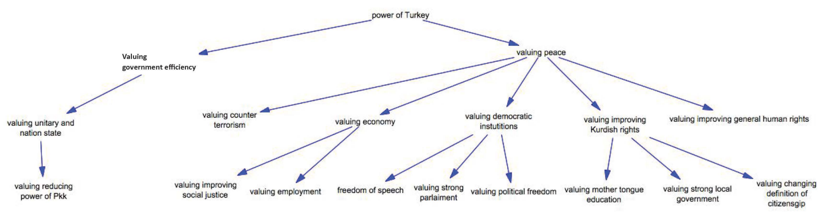

Figure 4.10: The Turkish value tree

4.3 Discussion

In expanding the discussion, an external advisor with access to the cognitive maps of the Kurdish and Turkish stakeholders might observe that initially, there appears to be no common ground for dialogue (shown in figures 4.1 and 4.6). The two maps, focused on their respective fundamental values and concerns, highlight the perception of threats posed by the opposing side. For the Kurdish side, it's the repressive policies of Turkey, and for the Turkish side, it's the threat of ”terrorism”. However, the advisor's role could be crucial in identifying underlying drivers and potential areas of convergence that are not immediately apparent in the descriptive representations of the maps. By dissecting these deeper elements and motivations, the advisor could facilitate a starting point for negotiations, moving beyond the surface-level threats and towards a more nuanced understanding of each party's fundamental concerns and objectives.

The value structures (see figures 4.5 and 5.2), on the other hand, provide a unique insight, revealing a common ground for initiating discussions between the

Kurdish and Turkish stakeholders. This convergence point is identified in the areas of reducing repressive policies, a concern for the Kurdish side, and improving democratic institutions, a focus for the Turkish side. Though these topics may initially seem disparate, they offer a potential platform for dialogue, aiming to find actionable ways to mitigate and transform the conflict. This insight into the value structures suggests a deeper level of agreement that could be explored further for conflict resolution.

The hierarchical structure of the value tree simplifies the analysis of relationships from the bottom up, allowing us to track how progress in specific areas will lead to improvements in fundamental values. By following this roadmap, critical points of convergence, such as the redefinition of citizenship within the Turkish framework, can be identified and addressed. If citizenship continues to be defined by a purely nationalistic narrative, as it has been historically, the chances of any dialogue leading to a sustainable solution are slim. However, if both parties are willing to explore the notion of Turkish citizenship based on shared human and democratic rights, there lies the potential for a long-term, sustainable resolution of the conflict. While these topics may initially seem unrelated, they provide a basis for initiating conversations focused on reducing tensions and transforming the conflict. The hierarchical organization of the value tree helps pinpoint intermediate steps or nodes that can serve as opportunities to build consensus between the conflicting parties.

Has the simulated experiment demonstrated the effectiveness of our approach (see Landry et al., 1983) Was it beneficial? The value tree suggests innovative policy approaches. For example, the Turkish side's "valuing mother tongue education" opens avenues for enhancing Kurdish mother tongue education, aligning with national integrity. Similarly, values like "valuing strong local government" and "valuing nation state" could lead to considering frameworks like the "European Charter of Local Self-Government" (see Himsworth, 2015). This indicates an opportunity for creative, balanced solutions that address the complexities of the conflict, respecting both local governance and national unity.

The discussion in the study aligns with existing literature on the Kurdish-Turkish conflict. Tekdemir (2018) highlights the effectiveness of several approaches in resolving ethnic conflicts like the Kurdish dissent in Turkey, underscoring the role of parties like Halkların Demokratik Partisi (HDP)[4]. in reconciliation. This complements the identified potential for dialogue in the value structures. Kuzu

[4]The Peoples' Democratic Party (HDP) is a left-wing party representing the Kurdish political movement in Turkey.

(2016) delves into the politics of identity and recognition among Kurds, reflecting the diversity within the community, which resonates with the discussion's focus on multifaceted solutions.

Keyman (2012) advocates for inclusive, multicultural approaches to citizenship, aligning with the value tree's emphasis on redefining citizenship. Bezwan (2018) discusses concepts like "democratic confederalism," proposed by the Kurdish movement, which align with the innovative policy approaches suggested in the value tree analysis. These scholarly perspectives support the study's approach in exploring conflict resolution and democratic reconstruction in Turkey.

The transformation from cognitive maps to value trees enhances our understanding of the relationships between values, providing a structured format crucial for policy-making and decision-making. This methodology not only harnesses the qualitative depth of cognitive maps but also structures it into a formal, prescriptive tool. The development of this formal method for constructing value trees marks a advancement in the field, enabling a systematic exploration of innovative and previously unexplored solutions.

The case study on the Kurdish-Turkish conflict exemplifies the utility of our method in a practical conflict scenario. It demonstrates how our approach can uncover common ground and facilitate compromise, fostering collaborative resolution of issues. This methodology shows promise for application in other decision-aiding and policy design contexts.

> **What insights did we receive from the "clients" involved?**
> Both stakeholders accepted the accuracy of the cognitive maps and the resulting value trees. However, neither party fully understood how the transformation from the cognitive maps to the value trees occurred. Interestingly, both stakeholders (who had no prior interaction) acknowledged that the process revealed aspects of the conflict they had not previously considered. They believed that our findings could serve as a starting point for dialogue. Though this experiment was purely theoretical, the feedback was encouraging and positive.

> **How does our approach stand in comparison to others?**
> In contrast to previous studies such as Franco and Montibeller (2010), which also use cognitive mapping to define objectives and establish means-ends relationships, our method is more formalized and structured. We introduce additional layers, including value cognitive maps and ends-means maps, before arriving at the final value tree. The SODA approach (see Ackermann et al., 2001), while helpful in understanding stakeholder motivations,

does not delve into value analysis. Though SODA assists in generating solutions, it often depends on the facilitator, whereas our approach follows a defined, replicable process. Similarly, Soft Systems Methodology (SSM) (see Checkland and Scholes, 1999; Checkland and Poulter, 2020) emphasizes root definitions (see Burge, 2015; Rodriguez-Ulloa and Paucar-Caceres, 2005) but lacks a systematic focus on values. Our approach bridges this gap by incorporating values directly into problem structuring. Through the use of cognitive maps centered around a fundamental node, which connects to all others, we can systematically uncover the core drivers of the conflict. This helps generate new, tailored solutions that directly address the underlying values at stake, differentiating our method from SSM and SODA.

4.4 Conclusion

This research provides a novel contribution to the field of conflict transformation and management by integrating cognitive maps and value trees. The combination of these two established problem structuring tools addresses the gap between descriptive and design-oriented approaches, offering decision-makers a more comprehensive understanding of conflicts. Our approach introduces a formal process to construct value trees from cognitive maps, offering a structured methodology to assist analysts involved in conflict management processes.

A key conclusion from testing our method is that we now have a formal procedure that enhances the understanding and modeling of conflict situations. This approach helps to identify the drivers of conflicting stakeholders and provides a foundation for establishing common ground for discussions, as well as for designing innovative alternatives. The case study on the Kurdish-Turkish conflict demonstrates the practical applicability and replicability of this approach. By identifying areas of potential compromise, our method fosters collaboration and constructive problem-solving, making it applicable not only in conflict scenarios but also in broader decision-aiding and policy design contexts.

From a methodological perspective, the process outlined in this research is the first formalized procedure in the literature to transform a cognitive map into a value tree. This integration merges the descriptive richness of cognitive maps with the prescriptive focus of value-focused thinking. The transformation process offers a deeper analysis of relationships between values, enabling a structured representation that can be used for prescriptive purposes. This approach represents an advancement, facilitating a systematic exploration of creative and previously unknown solutions.

However, there are limitations and open questions that require further research. One challenge involves the scalability of the process when dealing with large cognitive maps. While we hypothesize that the computational complexity of the algorithm remains manageable, further validation is needed to ensure that large value trees can be easily explained to stakeholders. Another area for exploration is the potential influence of the analyst or facilitator on the process. Although the algorithm aims to minimize this influence, additional case studies are required to validate the robustness of the approach.

Moreover, while we propose that our process can generate innovative alternatives, we have not yet formalized a procedure for this purpose. The discussion section suggests that new ideas may emerge by expanding nodes within the value tree, following formal design theory principles (see Hatchuel and Weil, 2009a). By considering cognitive maps and value trees as the knowledge space of a conflict, we can then focus on developing a formal procedure to expand this knowledge space into a concept space, where new "designs" or decision alternatives may emerge. This will be the focus of our next chapters.

Chapter 5

Case Study-2: Tunisia participatory groundwater management

In this case study, the main idea is to validate our proposal in a real-world problem in terms of applicability, versatility, and adaptation to different contexts. This research explores the integration of Problem Structuring Methods (PSMs) with the P-KCP methodology and Concept-Knowledge (CK) theory, focusing on collective groundwater management in Tunisia. By employing cognitive maps and value trees as key tools, this study aims to identify innovative alternatives for groundwater management, combining descriptive methods with theory-driven frameworks for an advancement in the field. The goal is to enhance and innovate policy design in water management by leveraging the strengths of PSMs and CK theory to navigate the complexities of groundwater sustainability and governance.

In conducting this case study [1], we applied our proposed model and validated our transformation process, thus advancing design theory through the incorporation of PSMs. We selected a case study in a water management context where diverse and thread of escalating conflict existed despite the absence of declarated conflict. This choice aims to demonstrate the model's ability to engage diverse stakeholders and its adaptability to complex problems.

Employing the P-KCP method, we utilized cognitive maps to generate a value tree, which subsequently led to the development of a concept tree. This process facilitated the identification of innovative solutions and a diverse categorization of

[1] This case study primarily was the part of paid stage of CNRS and master thesis of Samia Chrii (see Chrii, 2022), during the process we benefited from inputs from her study, like interviewing stakeholders, workshop reports. However, interview guide, theory buiding, cognitive maps, concept tree and expert workshops handled by Berkay Tosunlu.

concepts. The structure of the case study includes an introduction, presentation of the study area, our methodology, and the results, showcasing how our innovative approach can accommodate diverse stakeholders and apply to various complex issues, particularly in enhancing groundwater management policies. A version of this analysis has been submitted for publication (see Tosunlu et al., 2024).

In Tunisia's challenging landscape, managing groundwater resources is a critical endeavor, heightened by the varying interests of involved stakeholders. The arid climate, combined with a substantial dependence on agriculture, emphasizes the pressing need for effective groundwater management strategies. These strategies are essential for maintaining the ecological balance and agricultural productivity of the region, both of which are increasingly endangered by overexploitation and climate uncertainties. The task of managing such a crucial resource is complicated by the diverse needs and viewpoints of local farmers, policymakers, and environmental advocates, underscoring the importance of a sustainable approach to water usage.

As a case study, we selected Limaoua area in Tunisia, The Limaoua area, located on Tunisia's Gabès Sud Jeffara coastal aquifer, boasts fertile soil, accessible groundwater (around 30 meters deep), and excellent road infrastructure, making it attractive to wealthy farmers. However, the influx of newcomers and periodic droughts have spurred the development of both legal and illegal drilling, leading to a decline in the water table. The diverse array of stakeholders further complicates the management of groundwater resources in the Limaoua area of Tunisia, each bringing their unique interests and goals. Years of agricultural intensification have led to environmental degradation, marked by the significant depletion of water tables and deterioration of water quality. These challenges, exacerbated by the differing priorities of local farmers, policymakers, and environmental advocates, underscore the urgent need for a collaborative approach to achieving groundwater sustainability. Inspired by the successful collective management model in the neighboring Bsissi area, this study explores participatory models suited to Limaoua's distinct circumstances. Our aim is to form sustainable and probably new alternatives that effectively tackle the region's critical groundwater challenges.

Soft Operational Research (OR) methods, also known as Problem Structuring Methods (PSMs), play a critical role in navigating the complexities of decision-making in intricate scenarios (see Rosenhead, 1996; Ackoff, 1979a,b). PSMs adeptly handle the ambiguity and subjective elements that typify real-world situations involving multiple stakeholders with varying interests (see Mingers and Rosenhead, 2004). As we use cognitive maps and value trees, we enhance problem structuring in the first place.

The integration of Concepts-Knowledge (C-K) theory into modern design theory represents a pivotal advancement, offering a structured approach for fostering innovative design processes (see Hatchuel and Weil, 2003). This theory facilitates the generation of innovative solutions by leveraging existing knowledge to explore new territories, meeting the growing demand for innovation and the development of new expertise. As we mention before, Ferretti et al. (2019) emphasizes the overlap between decision theory and design theory in decision-making processes, exploring how their integration with policy studies and operational research can enhance policy design methods. Building on these core principles, Pluchinotta et al. (2019b) and Pluchinotta et al. (2020) further our practical understanding of these theories within policy design by introducing the KCP methodology (Knowledge, Concepts, Proposals) and the P-KCP (Policy-Knowledge Concept-Proposal) methodology. These methodologies highlight the co-evolution of concept space (C-space) and knowledge space (K-space), advocating for stakeholder involvement and participatory processes to improve public decision-making. This approach not only promises to bridge gaps across various sectors but also specifically aims to invigorate public policy design with innovative policy alternatives, despite its application in public policy design still being in the exploratory phase.

In this evolving landscape, the Policy-KCP (P-KCP) framework emerges as a novel participatory tool derived from KCP, aimed at the innovative design of policy alternatives. This approach, particularly through the lens of P-KCP, aligns with the current study's focus, illustrating how participatory and innovative policy design can tackle complex issues such as groundwater management in Tunisia's distinct environmental and socio-economic backdrop (see Pluchinotta et al., 2019b). The emphasis on participatory processes to generate novel policy solutions resonates with the critical challenges of managing Tunisia's scarce water resources, paving new pathways for collaborative and sustainable policymaking. The importance of this approach is underscored by the observation that while conventional policy analysis frequently concentrates on assessing existing alternatives, the generation of fresh policy solutions often remains an overlooked dimension. The successful application of P-KCP in the Apulia case study (see Pluchinotta et al., 2019b) not only highlights its capacity to yield innovative policy alternatives but also fosters stakeholder collaboration and encourages a long-term strategic outlook. Furthermore, Pluchinotta et al. (2019b) advocate for ongoing research in this domain, emphasizing the need to broaden case studies, promote interdisciplinary approaches, refine methodologies, and deepen stakeholder engagement, thus enriching the discourse on innovative policy design in complex governance landscapes.

In our research, we adopt an innovative approach akin to that ofPluchinotta et al. (2020) and Pluchinotta et al. (2019b), which synergizes Problem Structuring Methods (PSMs) with Concept-Knowledge (C-K) theory. While Pluchinotta et al. (2020) employed Fuzzy Cognitive Maps for stakeholder analysis in Cyprus, our discussion highlights the limitations of Fuzzy Cognitive Maps due to their restriction of node relationships to causality. Instead, we advocate for the use of cognitive mapping in a more flexible manner, based on influence relations rather than strict causality. Our methodology involves creating cognitive maps for each distinct stakeholder group before merging them. The rationale behind this approach is that, while preserving the uniqueness of each cognitive map, the aggregated map can highlight similarities, enhance discussion, and avoid escalating conflicts. By incorporating the differences between maps into the concept tree we create later, we ensure all information, including disparities, is preserved. Through the aggregated map, we not only facilitate enriched discussions but also utilize all concepts in the development of the concept tree. Our study in Tunisia utilizes aggregated cognitive maps as a descriptive tool and develops value trees derived from these maps, aiming to foster a comprehensive understanding and facilitate discussion among stakeholders in groundwater management.

As a summary, we implement the P-KCP methodology through three workshops. Initially, an internal discussion is conducted where stakeholders are identified and interviewed, leading to the creation of their individual cognitive maps. Following this, we compile these individual maps into an aggregated cognitive map. Utilizing our transformation process, we derive a value tree from this aggregated cognitive map. With the aid of this value tree, the process culminates in the development of a concept tree, which is further refined and enriched by the insights drawn from the value tree. Finally, an expert workshop is convened for a comprehensive analysis. This sequential approach, from stakeholder identification to expert analysis, ensures a holistic and participatory process, fostering the generation of actionable insights and innovative policy alternatives for groundwater management.

5.1 The Area

Tunisia, located in North Africa between the Mediterranean and the Sahara, is characterized by a semi-arid and arid climate. Consequently, its water resources are scarce and subject to significant spatiotemporal variability. On average, Tunisia receives about 230 mm of rainfall annually, translating into approximately 36 billion cubic meters of water per year. However, this figure can plummet to a mere 11 billion cubic meters during drought-afflicted years, while in contrast, during exceptionally wet years, the volume can surge up to 90 billion cubic meters (see Elloumi, 2016; des Etudes Stratégiques , ITES).

In addition to this interannual variation, there is a spatial North-South variation, exceeding 1500 mm/year in the extreme north and not reaching 100 mm/year in the South. Faced with this situation, Tunisia has found it necessary to adopt hydraulic management plans. This good initiative has allowed the country, for the past thirty years, to achieve a commendable level of resource valorization. In 2015, Tunisia's water resources were estimated at 4.8 billion m^3 per year. These main water resources consist of surface water and groundwater

Our case study is set in Limaoua. Geographically, the Limaoua area is strategically positioned within the Gabès governorate in Southern Tunisia, bordered by the city of Gabès, the Zeuss stream, the sea, and the Gabès-Matmata airport (see figure)

Figure 5.1: Gabes area

1.

The Gabès governorate is located in the southeastern part of Tunisia. It is characterized by a coastal plain that extends inward toward the country around El Hamma and a mountainous region primarily centered around the Matmatas. The rainfall in this region is influenced by its proximity to the sea and the surrounding topography, with amounts ranging between 150 and 220 mm/year. The geological formations present are sedimentary, spanning from the Jurassic to the Quaternary periods. This geological diversity has led to a rich lithological variety, which, from a hydrogeological perspective, is evident in the presence of multiple aquifers and water tables. This complex underground water system is vital for the region, supporting both its ecological diversity and the water needs of its inhabitants and agricultural activities.

The study area Limaoua corresponds to the safeguard zone, located in the delegation of South Gabès. In recent years, the Limaoua region has witnessed a remarkable surge in the development of diverse agricultural ventures. This vibrant activity has transformed it into a key economic and agricultural nexus within the governorate, elevating its status significantly. Limaoua now plays a pivotal role in the agricultural landscape, particularly renowned for its substantial contributions to the cultivation of a wide array of vegetable and tree crops. Its strategic focus on these sectors not only underscores its agricultural prowess but also highlights its vital contribution to the region's food security and economic prosperity (see Chrii, 2022).

In pursuit of decentralization (see Jelloul, 2020), a wide range of regional services have local representation, especially within the delegation framework (the Gabès governorate is divided into 10 delegations and 73 sectors). Numerous stakeholders play a important role in managing water resources at the local level (see Chrii, 2022)those are:

-The delegation acts as a crucial administrative layer, bridging the gap between the Governorate and the local community sector (Imada), facilitating streamlined governance and communication.

-The Regional Commission for Agricultural Development (Commissariat Régional au Développement Agricole, CRDA) embodies the regional authority of the Ministry of Agriculture (Ministère de l'Agriculture, MARH). It stands at the forefront of spearheading the development and management of both agricultural resources and water resources, serving as a linchpin in regional development strategies.

-The Territorial Extension Unit (Cellule Territoriale de Vulgarisation, CTV), affiliated with the CRDA, oversees the activities within the Agricultural Extension Centers (Centres de Rayonnement Agricole, CRA) across sector-level agricultural territories. This unit plays a important role in empowering farmers with the necessary guidance and monitoring the implementation of technical activities. Notably, the Limaoua area falls under the purview of the South Gabès extension cell (échelle de délégation), ensuring targeted and effective agricultural support.

-The Agricultural Development Group (Groupement de Développement Agricole, GDA) comprises public utility entities that bring together property owners and users. Entrusted by the state, these groups are charged with the management of water resources. In the Limaoua zone, there exist five GDAs, each committed to fostering sustainable agricultural practices and water resource utilization.

-The Omda or the local sector head (Omda), representing the political authorities at the community level and inheriting the esteemed role of the Sheikh or tribe chief, plays an indispensable role in mediating between the populace and local authorities. In Limaoua, the Omda also leads one of the agricultural development groups, symbolizing the integration of traditional leadership within modern governance frameworks.

Within the division of hydraulics and rural equipment, the seamless collaboration between three key districts underpins the effective management of water resources. The Rural Engineering (GR) district pioneers the formation and support of irrigation associations, equipping them for success. Alongside, the Irrigated Perimeters (PI) district adeptly manages irrigated lands, overseeing everything from water distribution to infrastructure maintenance, ensuring the efficient use of every drop. Meanwhile, the Water Resources district vigilantly manages Hydraulic Property Rights (DPH), issues exploitation permits, and monitors water quality and levels across aquifers, ensuring sustainable water usage. Together, these districts form a cohesive force, safeguarding the region's vital water resources for future generations (see Chrii, 2022).

In response to the overuse of the Gabès South aquifer, where annual withdrawals reached 47 million cubic meters against a recharge of only 36 million cubic meters (CRDA, 2016), the region was designated as a safeguard zone. This measure was necessitated by overexploitation combined with low annual rainfall averaging 180mm, and a notable increase in water points post-2011. A survey conducted in 2021 identified 1,597 water points, encompassing a mix of public, private, legitimate, and illicit wells (CRDA 2016). The proliferation of water points, especially after the 2011 Revolution and the initiation of the safeguard zone, corresponds with drought periods, exacerbating concerns over water scarcity. It is part of the Jeffara aquifer system, incorporating the Gabès North, Gabès South, and El Hamma Henchou aquifers (see Vernoux and Horriche, 2019). The area significantly depends on the Gabès South aquifer's lower Senonian carbonate aquifer, found at depths of 60 to 250 meters. To address water overexploitation, the administration introduced a "safeguard zone" in 2017, aimed at regulating drilling depth to promote sustainable water management. Consequently, no new drilling permits are issued, although surface wells (less than 50m deep) remain eligible for authorization. This policy has sparked tensions between the farming community and administrative bodies as the surge in boreholes, including unauthorized ones, continues unabated, challenging the balance between agricultural needs and sustainable water use.

Agricultural pursuits, particularly arboriculture, are the primary consumers of water in Limaoua. Approximately 630 farmers operate extensive plots, taking advantage of the fertile soil, accessible energy, and infrastructure. Nonetheless, the arrival of new settlers and the resulting well drilling have taxed water resources, leading to apprehensions regarding aquifer depletion. The establishment of the safeguard zone in 2017, during a period of drought, amplified tensions due to a surge in illicit drilling and the challenge of administrative enforcement. The situation faces potential complications from saltwater intrusion and the enactment of stricter regulations if the area transitions into a "prohibited zone" (see Frija et al., 2016b).

In the 2000s, an initiative to establish a Groupement de Développement Agricole (GDA) for collective groundwater management in Limaoua sought to regulate water use through communal, high-capacity wells. GDAs present a solution for administrations to monitor water usage volumes, in contrast to the challenge posed by numerous private wells. The successful implementation of a GDA in Bsissi Oued El Akarit serves as a model, indicating potential advantages for Limaoua despite the hurdles of enforcement and the distinct nature of private irrigation management (see Molle and Closas, 2017). In the Bsisi area, a participatory approach was also used between local stakeholders and policymakers, and it was considered a successful experiment that led to stimulating research motivation among all neighbors.

Drawing inspiration from Bsissi's GDA success, the CRDA of Gabès aspired to replicate this model in Limaoua during the 2000s but faced obstacles due to a lack of leadership and resources. With the escalating demand for water, there's a reconsideration of this initiative. However, the post-revolution context has altered the dynamics between CRDA and farmers, complicating the direct application of past strategies (see Frija et al., 2016b; Molle and Closas, 2017).

The Limaoua area is an agricultural zone comprised of plots of various sizes dedicated to tree cultivation and vegetable farming. These plots are mainly owned by private farmers who depend on groundwater (wells and boreholes) for irrigation. The area boasts several significant advantages, including high soil quality, relatively easy access to the aquifer (30m deep), and road infrastructure that ensures straightforward access from the city of Gabès. Over the past fifteen years, these benefits have drawn numerous newcomers, particularly affluent individuals who have bought land and established themselves there. Currently, the area hosts approximately 300 farmers. Many of these new settlements have prompted the creation of both legal and illegal wells and boreholes, leading to the aquifer's overexploitation. This situation could deteriorate in the coming years, with the risk of saltwater intrusion from the coast and the possible classification of the area as a "prohibition zone," which would lead to much stricter sanctions than are currently in effect (see Chrii, 2022)

In summary, there is an urgent need to review groundwater management policies in Limaoua, as the existing management solutions and tools are no longer capable of ensuring sustainable groundwater management. To tackle this, it is important to adopt a methodology that aids in generating alternatives. Therefore, we recommend the use of a generative participatory process, P-KCP combined with PSMs.

5.2 Method

In our study on groundwater management in Tunisia, we used a similar approach to Pluchinotta et al. (2019b), the Policy-KCP (P-KCP) framework as a participatory tool for designing innovative policy alternatives, The P-KCP framework was aptly applied in our methodological approach, which we structured into three main stages.

First, we introduce our P-KCP process in three stage:

5.2.1 Policy–Concepts Definition Phase (P–D Phase)

During the P-D Phase of our study, we focused on three primary objectives as outlined by Pluchinotta et al. (2019b): (i) to collect and analyze existing knowledge on water management to establish a foundational understanding; (ii) to perform an in-depth analysis of stakeholders, concentrating on their objectives and values; and (iii) to acquire an initial understanding of the problem through various stakeholder perspectives.

5.2.2 Policy–Knowledge Phase (P–K Phase)

In the P-K phases of our study, guided by the framework outlined by Pluchinotta et al. (2019b), our objective was to lay down a collective foundation for policy development. This phase aimed at delivering several important outcomes: (i) providing a comprehensive summary of the state-of-the-art knowledge regarding the case study and the policy issue at hand, (ii) offering an enhanced and detailed analysis of stakeholders, (iii) formulating a common problem statement that integrates individual viewpoints, and (iv) identifying the dominant designs in traditional policy alternatives through the development of a preliminary Concept tree (C-tree) model.

5.2.3 Policy–Concepts Generation Phase (P–C Phase)

The P-C Phase was centered around fostering innovative and practical policy concepts. To facilitate this, a one-day generative workshop was organized. This workshop gathered a diverse group of participants, each representing different stakeholders and viewpoints. The aim was to harness this diversity to collaboratively create actionable and forward-thinking policy concepts.

During the workshop in the P-C Phase, the common problem formulation, as established in the previous phase, was shared and deliberated upon. This step was necessary to ensure that all participants had a unified understanding of the problem at hand. This shared understanding enabled them to collaboratively engage in exploring potential solutions, laying a solid foundation for the collective policy concept development process.

In the workshop, the preliminary Concept Tree (C-tree) model was presented to provide a structured framework for discussions. This model visually represented the dominant designs of traditional policy alternatives, helping participants understand the existing policy landscape. With this knowledge, they could identify key elements within the policy dominant design and propose expansions or modifications to the C-tree model. This approach was instrumental in facilitating a deeper exploration of policy options and encouraging innovative thinking among participants. ....

5.2.4 P-KCP categorization

Here, we summarize the steps of our case study with respect to P-KCP categorization.

Policy–Definition Phase (P–D Phase)	Policy-Knowledge Phase (P–K Phase)	Policy–Concepts Generation Phase (P–C Phase)
Preliminary Interviews and cognitive maps building	Workshop-2	Workshop-3
Workshop-1		

Figure 5.2: Summary of P-KCP process

Policy-Definition Phase (P-D Phase)

- Conducted preliminary interviews with stakeholders to capture a variety of perspectives.
- Held Workshop 1 to exchange and collect insights on water resource management in Limahoa.

Policy-Knowledge Phase (P-K Phase)

- Organized Workshop 2, aimed at identifying common concerns through a participatory method.
- Completed the aggregated cognitive map, incorporating insights from stakeholder engagements.

Policy-Concepts Generation Phase (P-C Phase)

- Hosted Workshop 3, which focused on identifying and prioritizing collective groundwater governance solutions, leading to the development of an "alternatives tree" based on shared concerns.
- Developed a value tree from the cognitive map to serve as a foundation for the concept tree.
- Enhanced the concept tree with outcomes from Workshop 3 and contributions from various stakeholders.
- Conducted an expert workshop to refine and finalize the concept tree, integrating a broad range of policy alternatives.

5.3 Process

Policy-Definition Phase (P-D Phase)

The P-D Phase of our process is marked by the critical components of preliminary interviews and the construction of cognitive maps, together with Workshop-1. This phase establishes the groundwork for a detailed exploration of the pertinent issues, providing a structured basis for the understanding and analysis that follows.

5.3.1 Preliminary Interviews and cognitive maps building (P-D Phase)

The initial phase of our research involved essential preparatory activities to establish a solid foundation. Key among these was engaging in collaborative discussions within the research team, focusing on groundwater management challenges in Limaoua, Tunisia. These discussions offered a deep dive into the region's unique challenges and dynamics. A priority was set on initiating direct dialogue with local stakeholders necessary to groundwater management decisions. We strategically selected stakeholders to ensure a diverse representation of viewpoints and interests, aiming for a comprehensive understanding of the issue. To facilitate meaningful conversations, we developed an interview framework tailored for the cognitive mapping stage.

For cognitive map construction, we adopted the Eden-type map approach (see Eden, 1994), which underscores the importance of pinpointing stakeholders' fundamental values and goals. This method enabled us to capture the specific concerns, objectives, and perspectives of stakeholders engaged in groundwater management, providing a detailed depiction of their varied viewpoints. Employing cognitive maps in this manner was instrumental in enhancing our grasp of stakeholders' perspectives, laying the groundwork for devising practical and sustainable groundwater management strategies and policies.

5.3.2 Interview guide (P-D Phase)

In the development of the interview guide for this study, the aim was to include a representative sample of stakeholders from different sectors relevant to groundwater management. The group consisted of individuals from the state, agricultural sector, research community, and local farmers, each contributing unique insights based on their roles and experiences.
-The state delegation included a director from the CRDA and an administrative personnel from the CTV. Their perspectives were important for understanding the policy and administrative angles of groundwater management.
-Four members from the Agricultural Development Group (GDA) were also part of the stakeholder group. Their involvement provided a direct view into agricultural practices and challenges, especially those related to water usage.
-The Tunisian Union of Agriculture and Fisheries (UTAP) was represented by one member, ensuring that broader agricultural and fisheries perspectives were included.

-The research aspect was covered by a hydrology researcher and an expert in water institutions in Tunisia. Their academic and technical insights were important for understanding the scientific and regulatory aspects of groundwater management.
-Finally, the group included seven farmers, chosen based on their land size and other characteristics, to ensure a diverse representation from the agricultural community. This included farmers with less than 10 hectares, those with 10 to 49 hectares, a farmer owning more than 50 hectares, and two investors from outside the Limahoa area.

This composition of stakeholders was aimed at gathering a broad range of perspectives, which is essential for a comprehensive understanding of the groundwater management situation in the study area.

The purpose of the interview guide in this study was to facilitate the extraction of knowledge and experiences from the stakeholders concerning the issues central to the case study. The guide was designed to enable stakeholders to articulate their expertise and viewpoints, thereby providing valuable insights into the subject matter. The core objective was to capture and evaluate the diverse perspectives of each participant. By doing so, the guide played a critical role in constructing detailed cognitive maps. These maps were intended to accurately represent stakeholders' perceptions of the underlying causes, the resultant consequences, and the intricate interrelationships pertaining to the problems identified in the case study. To probe more deeply into the information provided by the stakeholders, a methodical approach was adopted in the interview process. For each problem identified, follow-up inquiries were made, particularly focusing on the 'why' aspect. This approach aimed to delve into the root causes and consequences of the issues, thereby enriching the data collected and enhancing the depth of understanding of the overall subject matter. Such an in-depth exploration was pivotal in ensuring that the cognitive maps developed were not only comprehensive but also reflective of the multifaceted nature of the stakeholders' perspectives.

The interview guide was structured not only to gather stakeholders' initial ideas for problem resolution but also to examine their perceived connections with broader objectives. This approach was important for exploring potential solutions and understanding how they aligned with the goals of the stakeholders. Such insights were valuable in the early stages of the problem-solving process. Additionally, the guide was focused on identifying a 'shared concern' among the participants. Recognizing a shared concern was pivotal as it facilitated the establishment of a common ground for discussion. This was critical in uncovering 'fundamental values' that underpinned the stakeholders' perspectives. Highlighting these shared concerns and fundamental values was essential for ensuring an inclusive approach in the policy development process, as it accounted for the diverse viewpoints of all stakeholders involved. The role of the interview guide extended beyond information gathering; it was a preparatory tool for the subsequent workshops. It provided a platform for stakeholders to present their knowledge, ideas, and propositions, thereby equipping them to contribute to the collaborative policy-making process. The guide's focus on facilitating thoughtful discussions and information exchange was important for ensuring that participants were well-prepared and ready to engage actively in the workshops that followed.

5.3.3 Workshop-1 (P-D Phase)

In Workshop-1, we strategically segmented farmers based on their landholdings, recognizing that land size often indicates differing priorities within the agricultural community, as detailed by Frija et al. (2016a). This segmentation allowed for focused discussions that adequately addressed the distinct challenges of both small and large landholders. The workshop unfolded in two tailored sessions, the first with large-scale farmers including 19 participants such as facilitators and local agricultural and administrative body representatives, and the second aimed at small-scale farmers, facilitated alongside stakeholders from agricultural associations and administrative bodies. This approach ensured that discussions were specifically tailored to address the unique concerns and perspectives of different farm operators, fostering a dialogue on groundwater management issues.

The goal of both sessions was to encourage knowledge exchange. The workshops began with introductions by project leaders and facilitators, followed by an overview of the workshop's objectives, setting a collaborative tone and aligning participants with the goals of the discussion on groundwater management.

A key part of the workshop was the in-depth dialogue initiated by a presentation on the Bsissi experience, as discussed in the study by Minoia and Guglielmi (2008). This presentation illuminated the agricultural practices and lessons from Bsissi, particularly emphasizing the participatory management of vulnerable aquifers as a successful approach. Key factors such as equitable water distribution, the economic advantages of collective management, trust in shared resource management, and stakeholder commitment to environmental protection were highlighted. It also touched on the regulatory framework for groundwater exploitation in Bsissi, spotlighting the challenges posed by the lack of restrictions for illicit wells and the absence of fees, particularly within designated safeguard zones. This segment not only provided a valuable learning opportunity for workshop participants but also stimulated a lively discussion among them, especially focusing on large-scale farmers. The exchange of ideas and insights underscored the value of collaborative learning and the importance of addressing the complexities of agricultural practices and water management collaboratively.

With the completion of the preliminary interviews, the development of aggregated cognitive maps, and the conduct of Workshop-1, we have successfully wrapped up the P-D Phase. These steps collectively built a strong foundation for understanding the intricate dynamics of groundwater management among diverse stakeholders. Moving forward to the P-K phases, our aim is to deepen our analysis of the insights gathered and construct a knowledge base that will underpin our policy development efforts, leveraging the participatory and collaborative groundwork laid in the initial phase.

Policy-Knowledge Phase (P-K Phase)

Moving into the P-K phases, our study took a strategic approach to deepen our engagement with the complexities surrounding groundwater management in Tunisia. This phase involved two pivotal activities: first, conducting Workshop 2, which was designed to identify common concerns among stakeholders via a participatory method; and second, completing the aggregated cognitive map. These steps were essential in synthesizing diverse perspectives and advancing our understanding of the issues at stake.

5.3.4 Aggregated cognitive map (P-K Phase)

In the P-K phases of our study, we utilized Problem Structuring Methods (PSMs) such as cognitive mapping, following the Eden-type approach(see Eden, 1988, 1994; Eden and Ackermann, 2004; Ackermann et al., 2001); grounded in Kelly's theory of personal constructs (see Kelly, 1955). This method allowed us to capture stakeholders' perspectives accurately, focusing on their analytical views and understanding of groundwater management issues in Tunisia. Initially, individual cognitive maps were developed for each stakeholder to explore their unique viewpoints. Subsequently, these maps were aggregated to form an aggregated cognitive map, aiming to create a holistic view without emphasizing conflicts, thus fostering a shared understanding among stakeholders.

In the previous "Kurdish-Turkish conflict" case study, we used individual cognitive maps to dissect the conflict, highlighting distinct perspectives. This contrasts with the approach for groundwater management in Tunisia, where, instead of separate maps, a unified cognitive map from all stakeholders is created. This method aims to provide a holistic view of the problem, focusing on commonalities and a shared understanding rather than exacerbating any underlying conflicts since there is no declared conflict as we had in the Kurdish-Turkish conflict. The primary objective of this approach is to foster collaboration and consensus among stakeholders, steering clear of potential conflict triggers and concentrating on mutual goals and understandings. In conflict situations, like the Kurdish-Turkish conflict, separate cognitive maps and their derived value trees can reveal common grounds, facilitating dialogue and generating new alternatives. However, in scenarios without a declared conflict, such as the groundwater management issue in Tunisia, unifying cognitive maps from all stakeholders is preferred. This unified approach aims to capture perspectives, focusing on shared understanding and common goals. It's chosen to avoid intensifying any latent conflicts and, instead, foster consensus and collaborative problem-solving among all involved parties. The concept of collective cognitive maps, as discussed in Langfield-Smith (1992), supports our strategy by suggesting that effective decision-making groups can form shared belief systems over time, adaptable to changing circumstances.

The cognitive mapping process in our study unfolded systematically. First we categorize the stakeholders into 8 groups according to their expertise, land size, interest. Then, mapping exercises were conducted for each stakeholder group, capturing their perspectives and concerns regarding groundwater management. These individual maps provided valuable insights into the stakeholders' knowledge and perceptions of the issue. Subsequently, these maps were combined to create aggregated cognitive maps, effectively merging the diverse perspectives. This step was necessary for highlighting both the shared views and the differences among stakeholder groups, offering a insight of the situation. This perspective was pivotal in uncovering key patterns and themes prevalent across the stakeholder spectrum, thereby enriching our understanding of the issue's complexity. Throughout the aggregation phase, we carefully ensured that no detail from the individual maps was lost and documenting each concept. These documented concepts were then leveraged in developing a concept tree, contributing to the refinement of our policy development process.

Stakeholder interviews were conducted using a semi-structured guide, which facilitated the collection of detailed information. This data was then used to create cognitive maps. The stakeholders involved in the study were categorized into eight distinct groups, each representing different viewpoints and interests relevant to the policy issue under study.

1-) State and Administration: This group included representatives from CTV, CRDA-1, and CRDA-2.

2-) Agricultural Development Group (GDA): We had four GDAs represented in this group, namely GDA-A, GDA-B, GDA-C, and GDA-D.

3-) Tunisian Union of Agriculture and Fisheries (UTAP): This group consisted of two stakeholders, UTAP-1 and UTAP-2.

4-) Local Researchers: Two researchers, Researcher-1 and Researcher-2, were part of this group.

5-) AGRI-1: Farmers in the region with agricultural areas of 50 hectares or more. This group included A-1 and A-2.

6-) AGRI-2: Farmers in the region with agricultural areas between 10 and 49 hectares. This group included A-3 and A-4.

7-) AGRI-3: Farmers in the region with agricultural areas of less than 10 hectares. This group included A-5 and A-6.

8-) AGRI-4: Farmers who are not from the region but have invested in the region. This group included A-7 and A-8.

As indicated earlier, the cognitive maps from the eight stakeholder categories were aggregated to form a collective map. This aggregated map was instrumental in identifying shared views, patterns, and areas of consensus among the stakeholders. The process of contrasting individual maps with the aggregated map provided a deeper insight into the similarities and differences in stakeholders' perceptions and priorities, enriching our understanding of the collective viewpoint on the policy issue.

Recent contributions by Colorni and Tsoukiàs (2020), Ferretti et al. (2019), and Pluchinotta et al. (2019b) highlight the importance of shifting from problem description to solution-oriented approaches in decision support activities. This "design-oriented" perspective emphasizes methods that not only describe problems but also guide the development of actionable and innovative solutions. Building on this foundation, Pluchinotta et al. (2019a, 2020) introduced the KCP (Knowledge, Concepts, Proposals) and P-KCP (Policy-Knowledge Concept-Proposal) methodologies to bridge theoretical constructs with practical policymaking.

Our research builds on and extends these methodologies. While Pluchinotta et al. (2020) utilized Fuzzy Cognitive Maps (FCMs) for stakeholder analysis in Cyprus, we address the limitations of FCMs, particularly their restriction of node relationships to causality. Instead, we use cognitive mapping with a more flexible focus on influence relations. This approach enables the creation of cognitive maps for individual stakeholder groups, which are then aggregated to preserve each map's uniqueness while capturing shared elements. The aggregated map facilitates stakeholder discussions and helps avoid conflicts. It also serves as the foundation for constructing value trees, which hierarchically represent stakeholder objectives and guide the design of alternative solutions.

How do we aggregate maps?

We will now explain the process of constructing the aggregated cognitive map by combining 8 groups cognitive maps.

In our interview guide, we initially asked a question to identify the fundamental value, which we verified through follow-up questions. For each stakeholder, the fundamental value was identified as agricultural production. This outcome was predictable given the context of groundwater management and the absence of a declared conflict. Both the administration and farmers primarily approached groundwater management and the issue of water scarcity from the perspective of its importance to agriculture.

This shared fundamental value provided a foundation for creating the aggregated map. Otherwise, if there had been multiple fundamental values, we would not have been able to do this and would have had to work with separate maps.

After identifying the fundamental node, we determined the sub-nodes that stemmed from it and selected the common ones. Additionally, as can be seen in the interview guide, we explicitly asked about consequences and results, which facilitated the creation of the aggregated cognitive map.

5.3.5 Workshop-2 (P-K Phase)

During Workshop 2, facilitated by INAT/CIRAD, 18 stakeholders from diverse backgrounds, including representatives from CRDA, CTV, GDA, along with large and small farmers, came together to delve into the challenges of groundwater management. This gathering aimed to identify common ground, with facilitators emphasizing unity and collaborative solutions over differences. This approach set a cooperative tone right from the welcoming remarks and was reflected throughout the workshop's agenda. The integration of interviews and previous workshops into the discussion underscored the methodology's depth, while the presentation of interview results through cognitive maps offered a clear visualization of stakeholder perspectives. A key activity was the collective identification of a shared concern, which encouraged active participation and aimed at unified problem-solving. The workshop wrapped up with an evaluation, underscoring the importance of collaboration, knowledge exchange, and the pursuit of collective solutions for effective groundwater management in Tunisia. Participants agreed on two common goals, the specifics of which would be detailed later.

The primary goals of this workshop were to share interview insights through cognitive map presentations, reach a consensus on a mutual challenge to address, and identify committed individuals for collaborative groundwater resource management in the south Gabès area.

The presentation of the aggregated cognitive map was a key moment, highlighting the collective insights and viewpoints of stakeholders. While the value tree, a more detailed analytical tool, was kept internal to maintain focus, it played a important role in the research team's evaluations. The consensus reached on a core concept from the aggregated cognitive map confirmed its accuracy and the identified shared concern, showcasing the cognitive mapping process's effectiveness in capturing a collective understanding of groundwater management challenges.

Policy-Concepts Generation Phase Transitioning into the P-C Phase, our approach included several key activities aimed at developing actionable strategies for groundwater management. We began with Workshop-3, which was structured to identify and prioritize potential solutions by constructing an "alternatives tree" based on collective concerns. Following this, we created a value tree from the cognitive map, which acted as a benchmark for the development of the concept tree. This tree was then enhanced with insights gathered from Workshop 3 and additional stakeholder input, culminating in an expert workshop dedicated to refining and completing the concept tree by incorporating a broad range of policy alternatives. This phase marked a critical step in translating collaborative insights into concrete, implementable strategies for managing groundwater resources effectively.

5.3.6 Workshop-3 (P-C Phase)

Workshop-3 brought together 33 participants, including facilitators, authors of this study, various sector stakeholders, and 18 farmers, to focus on identifying and prioritizing solutions for unified groundwater governance. The central task was to create an "alternatives tree" to visually organize potential solutions derived from shared concerns, aiming to identify actionable strategies for sustainable groundwater management through collaborative effort.

The workshop's agenda was carefully structured to enhance collaboration and in-depth discussion, starting with opening remarks that recapped progress and set the stage for the day's activities. Participants were split into two groups to stimulate creativity and innovation in proposing solutions, emphasizing the freedom to suggest ideas beyond the constraints of current realities.

During this session, each group developed its alternative tree, categorizing proposed actions into a structured visual format. This participatory approach yielded a variety of proposals, which will be detailed in the results section. A coffee break facilitated informal networking, followed by focused group work on defining actionable alternatives, leading to a collective decision on specific groundwater management actions.

A democratic voting process using stickers allowed participants to visually express their preferences for the proposed actions, facilitating consensus on priorities for implementation. This method underscored the workshop's goal of achieving a democratic and visual consensus on future actions.

The workshop materials presented an important process: transforming cognitive maps into value trees, as proposed in our proposal. This step, transitioning directly from cognitive maps to value trees, played a pivotal role in establishing the structure of the concept tree. It's a key integration point for Problem Structuring Methods with Concept-Knowledge theory, boosting the P-KCP process's participatory nature. Cognitive maps, by design, are descriptive, pinpointing problems without suggesting direct solutions. In contrast, value trees act as prescriptive tools, aiming to identify potential solution pathways and encourage the generation of novel alternatives. This methodology is based on value-focused thinking, which suggests that emphasizing values over specific solutions can unleash creative potential, thus paving the way for innovative solutions to complex challenges (see Keeney, 1996a). The synergy between cognitive maps' detailed problem descriptions and value trees' clarity in solution pathways provides a thorough framework for constructing concept trees. This approach not only makes the concept tree development more efficient by reducing the reliance on facilitator interpretation but also ensures a rich array of innovative solutions for groundwater management are explored.

In summary, Workshop-3 was pivotal in the P-C Phase, advancing collaborative decision-making and the exploration of actionable groundwater governance strategies. It marked a step in developing concrete plans for sustainable groundwater resource management, blending the descriptive insights of cognitive maps with the analytical clarity of value trees to foster innovative solutions. The outcomes and details of this phase will be further elaborated in the results section.

5.3.7 Initial Concept tree to the Expert workshop

Merging the detailed insights from cognitive maps with the analytical precision of the value tree has refined our methodology. Typically, the creation of a concept tree is time-consuming and heavily dependent on the facilitator's personal insight. However, by combining the extensive perspectives captured in cognitive maps with the solution-oriented approach of value trees, we've streamlined the development of the concept tree. This integration not only enhances efficiency but also encourages the generation of innovative groundwater management solutions. Initiating the concept tree with the structured, actionable insights derived from the value tree ensures a solid foundation.

Utilizing the structural similarities between the concept tree and the value tree, both arranged as graph trees, allowed us to use all nodes from the value tree as the basis for the concept tree. To explore unconsidered solutions and promote creative thinking, we adopted a novel approach by inverting the combination of nodes from the value tree. This method of creative provocation was key in introducing new concepts into the concept tree, broadening our ability to devise effective groundwater management solutions.

For instance, by using negated combinations of nodes in value tree, let us consider a value 'happiness' and its subvalues 'success in social life' and 'wealth', we explored all theoretical possibilities— 'success in social life but not wealth', 'success in social life and wealth' 'wealth but not success in social life' and 'not success in social life nor welath', encompassing both presence and absence of these values with their combinations. This method allowed us to partition and evaluate every scenario more distinctly, leading to the discovery of unconventional alternatives. In the 'none' category, considering moving to a small village, emerged as a a solution, which can make you happy without improving your wealth nor social life, demonstrating how negated combinations can reveal overlooked opportunities for achieving overarching values like happiness

5.4 Self-evaluation

In this section, we evaluate the interview guide used in our study. The interview process was designed with several objectives: to extract participants' knowledge and experiences relevant to the case study, to assess their diverse viewpoints on the central issue, and to facilitate the creation of cognitive maps for each stakeholder group. These maps were important in visualizing the perceived causes and effects related to the issue, based on stakeholders' initial insights.

This evaluation will focus on how effectively the interview guide helped achieve these goals and its role in the research process. Additionally, the interviews aimed to gather participants' initial suggestions for resolving identified issues, playing a key role in identifying a "shared concern" that became foundational for the study's generative phase. The interviews also prepared participants for upcoming workshops by collecting essential knowledge, ideas, and proposals, ensuring productive and in-depth participation in subsequent sessions.

#	Question	Objective
1	Name and Surname	Stakeholder identification
2	(if relevant) What is your job title and for what organization do you work?	Stakeholder identification
3	(if relevant) What is the main mission/goal of your organization with regards to the *case study topic?*	Organization's objectives
4	What is your role with regards to the *case study topic?*	Stakeholder's role and objectives
5	What are your interests in the *case study topic?*	Stakeholder's values
6	According to your experience, what are the main environmental/water related problems faced by the *case study*? (prompt: Could you briefly describe them?)	Case study problems
7	For each of the above-mentioned/numbered problems, what are their causes? (prompt: Why?)	Causes
8	For each of the above-mentioned/ numbered problems, what are the main consequences? (prompt: Why?)	Consequences
9	Are there any relations between the problems mentioned above that is worth mentioning?	Relationships
10	Why do you care about this *conflict*? What is your fundamental concern on this *conflict*?	Stakeholder's values follow-up (this is a deeper version of question 5. on purpose it is formulated differently and after the problems)
11	What is your fundamental/ final goal for resolution of the *conflict*?	Fundamental value
12	According to your best knowledge, what are the existing main strategies/policies/plans that are (or will be soon) implemented in order to deal with the above-mentioned problems?	Identify the main strategies available, K-space building
13	(if appropriate) What could you personally do to contribute to the resolution of these problems? For each resolution of the problems what is your idea of possible solutions? (we should explicitly ask: 'Why do you think this idea will be successful?')	Initial ideas for resolution actions (future scenarios, individual actions) C-space building
14	Given those consequences of greatest concern, which of the strategies/actions do you feel are most important? Given what you've previously said about your fundamental concerns/the consequences you are most concerned about, which of the strategies/actions do you feel are most important?	Eliciting means-ends relationships
15	(if appropriate) For each of the above-mentioned problems, who has this problem? And who is responsible for it?	Contribution to stakeholder analysis
16	All in all, what is the fundamental outcome you would like to achieve?	Fundamental value-follow up
17	Is there anyone else you think we could usefully speak to?	Stakeholder snowballing

The interview guide, comprising 18 questions, is designed to extract stakeholder perspectives and insights relevant to the case study. The initial questions focus on identifying stakeholders and understanding their organizational affiliations. Questions 1 and 2 are aimed at clarifying the identity, roles, and positions of the interviewees. Question 3 then delves deeper, exploring the objectives and missions of their respective organizations, adding valuable context to their involvement in the case study. This structured approach ensures knowledge of each participant's background and their organization's role.

Questions 4 and 5 in the interview guide are specifically crafted to elucidate the interviewee's role and interests in relation to the case study topic. Understanding their roles provides valuable insights into each stakeholder's objectives and what they might contribute to the study. Similarly, exploring their interests helps to reveal their values and perceptions of what is significant within the context of the case study, offering a deeper understanding of their perspectives and motivations.

Questions 6 through 9 in the interview guide are vital for addressing the environmental and water-related challenges in the case study. Question 6 seeks a broad overview of these problems, with detailed notes taken to capture all issues mentioned. Questions 7 and 8 delve into the causes and consequences of the identified problems, fostering a thorough understanding of their origins and impacts. This section is integral in constructing a picture of the environmental challenges being examined.

Question 9 in the interview guide focuses on understanding how the various identified problems are interrelated, highlighting the interconnected nature of the challenges within the case study.

Question 10 then revisits the interviewee's personal values in the context of the case study conflict. This question is designed to provide a deeper insight into what the interviewees prioritize and care about most, offering a clearer understanding of their motivations and concerns within the context of the case study.

Question 11 in the interview guide is designed to elicit the fundamental goals that the interviewee has for resolving the conflict, focusing on their core values and ideal outcomes.

Question 12 then shifts to inquire about the existing strategies, policies, and plans either currently in place or proposed to address the identified problems. This question is key in mapping out the available strategic approaches and understanding the broader policy landscape surrounding the issues.

Question 13 explores the personal involvement of the interviewee in resolving these problems. It aims to gain insights into their individual contributions and potential roles in mitigating the issues, adding a personal dimension to the broader strategic context.

Questions 14 to 16 are focused on the interviewees' initial ideas for resolving the identified problems, contributing to the development of future scenarios and individual action plans. These questions aim to capture the interviewees' perspectives on effective strategies and actions, centered around their core concerns and the impact on stakeholders directly affected by the issues. This line of inquiry is necessary for establishing means-ends relationships and enriching the stakeholder analysis, thereby providing insights for the formulation of targeted and effective solutions.

Question 17 is strategically designed for stakeholder snowballing, aimed at identifying additional individuals or organizations that could provide further insights into the case study. This question is essential for expanding the scope of the study and ensuring a more comprehensive understanding by including a wider range of perspectives and experiences.

This interview guide is a important tool for gathering diverse stakeholder perspectives, understanding the root causes and effects of identified problems, and exploring potential solutions and contributions towards resolving the challenges of the case study. Its aim is to foster a holistic understanding of the case study context by involving key stakeholders and integrating their valuable insights into the research framework.

5.5 Results

Policy–Definition Phase (P–D Phase)

P-D Phase of the P-KCP process set the stage for our study by aiming to fulfill several critical objectives: analyzing existing knowledge on water management, conducting detailed stakeholder identification and analysis, and synthesizing the diverse perspectives of stakeholders to establish a foundational understanding of the water management challenges. Workshop 1 played a pivotal role in achieving these objectives by collecting and integrating inputs from various stakeholders. This initial phase effectively laid a foundation for the subsequent phases of the P-KCP process, ensuring a well-informed and broad approach to addressing the complexities of water management.

5.5.1 Workshop-1

The workshop for big farmers in the Limahoua-Tanestli region focused on sharing knowledge and addressing challenges in water resource management. Discussions centered on critical issues like water wastage, the proliferation of illegal well drilling, the need for infrastructure such as dams, and the utilization of rainwater. Participants exchanged insights on water conservation techniques and emphasized the importance of organizing farmers, raising awareness, and navigating bureaucratic hurdles to effectively manage water resources and support sustainable agricultural practices in the region.

Similarly, the workshop for small farmers aimed to facilitate knowledge exchange and collective efforts to tackle water management challenges in the Limahoupa-Tanestrial region. This session brought together farmers and representatives from GDAs, CRDA, and CTV, who deliberated on concerns including the widespread use of private boreholes, water scarcity, high costs of inputs, and the lack of governmental supervision. A highlight of this workshop was the discussion on the successful establishment of a GDA in the Bsissi region, showcasing the advantages of organized collective action in efficiently confronting these water management. challenges.

Workshop-1 provided insights into the P-D Phase of the P-KCP process, uncovering key challenges and stakeholder perspectives in the Limahoua-Tanestli region's water management scenario. The analysis pointed to an increase in farming activities and water resource exploitation, contributing to water scarcity. This issue is compounded by the presence of illegal wells, water wastage, and inadequate infrastructure. A wide array of stakeholders was identified, spanning small to large farmers and average-sized farms. The suggested intervention strategies include the state's implementation of safeguard zones for water and agricultural protection, highlighting the significance of collective water management and farmer organization.

Both large and small farmers share concerns over water scarcity, stressing the necessity for better water management infrastructure and collective action strategies, such as forming GDAs. Commonalities include acknowledging the issues of illegal wells and the critical role of organized efforts. While both groups recognize the need for farmer organization and state support, their focal points diverge; large farmers call for infrastructure improvements and bureaucratic navigation, whereas small farmers emphasize the challenges of high input costs and seek more state support, including subsidies and efforts to include rural women in agriculture.

Summarizing, the P-D Phase is built around analyzing water management knowledge, detailed stakeholder analysis, and initial problem understanding from multiple viewpoints. Our findings from Workshop 1 address these objectives by shedding light on water management issues like illegal wells and scarcity, highlighting diverse stakeholder values from infrastructure needs to collective action, and presenting varied perspectives on tackling water management challenges. This phase sets a participatory groundwork for exploring sustainable agricultural practices and developing a comprehensive approach to water management.

Policy-knowledge Phase (P-K Phase)

The P-K phases is strategically segmented between developing an aggregated cognitive map and conducting Workshop 2, focusing on achieving four key objectives. Initially, the cognitive map serves to encapsulate existing knowledge on water management and perform a thorough stakeholder analysis, addressing the first two goals. Following this, Workshop 2 takes the lead in accomplishing the latter objectives by fostering a shared problem formulation among participants and laying the groundwork for a preliminary Concept Tree model. This model is instrumental in pinpointing the dominant designs within policy alternatives, thus guiding the direction of potential solutions. This methodical approach not only ensures a cooperative progression towards addressing the water management challenges in the south Gabès area but also exemplifies the effective implementation of the P-KCP framework in a practical setting.

5.5.2 Aggregated Cognitive Map

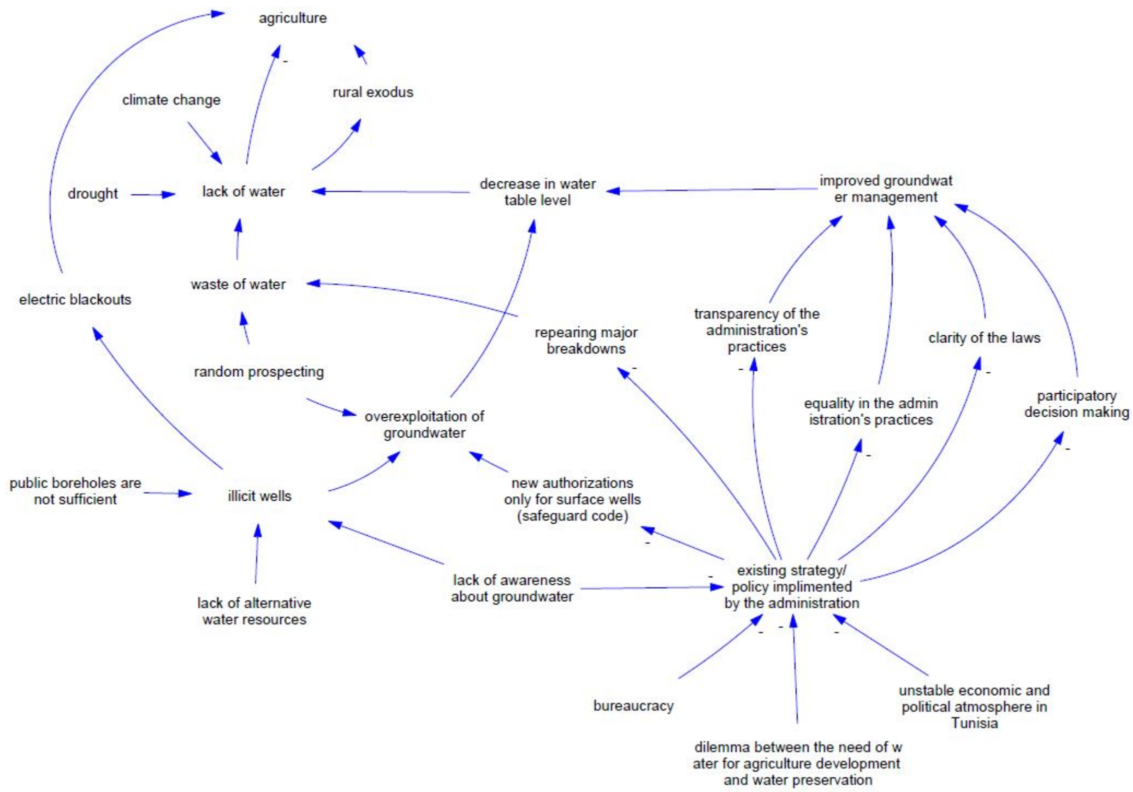

Figure 5.3: Aggregated cognitive map

General description The aggregated cognitive map identifies agriculture as the fundamental value common across all stakeholder groups. The primary issue is water scarcity and its detrimental effects on agriculture, attributed to factors like drought, climate change, and overuse lowering the water table. Illicit wells are noted as a key factor in groundwater overuse. Stakeholders stress the need for better groundwater management and stricter regulation enforcement. They also observe that the existing administration's strategies are hindered by bureaucracy and Tunisia's unstable political and economic climate. For improved management, transparency, equality, and clarity in administrative processes are considered crucial.

Similarities and diffirences The common cognitive map highlights key similarities among stakeholder groups. The safeguard zone, recognized as a response to the depleted water table, faces enforcement challenges. The consensus identifies illicit wells as a major cause of overexploitation, reducing the water table and adversely affecting agriculture. The map suggests that enhanced groundwater management and revising administrative policies could be effective in mitigating overexploitation and reducing the prevalence of illicit wells.

The common map reflects a consensus on climate change and drought as key factors for water scarcity. One group also points to population growth as exacerbating illicit wells and overexploitation. There's a call from one group to reduce new well authorizations, while others suggest using the safeguard zone code for controlling deep well permissions. The unstable economic and political climate in Tunisia, along with the development-preservation dilemma and bureaucracy, are concerns shared by almost all stakeholder groups, highlighting the complexity of the situation.

The cognitive map displays varying viewpoints. Small farmers primarily blame administrative policies for the declining water table levels, diverging from the general focus on groundwater overexploitation. Additionally, 'waste of water' emerges as a concern in some maps, influencing water scarcity. The maps also reveal differences in awareness levels among stakeholders. To bridge this gap, fostering solidarity among farmers is suggested as a strategy to enhance awareness and jointly address these water management issues.

The cognitive map effectively structured stakeholder ideas and aided in building consensus. While it primarily highlighted similarities, differences, especially between small and large farmers, surfaced during discussions. These differences, however, didn't hinder the overall agreement process. Stakeholders valued the map for its role in consolidating their ideas and clarifying the interconnections of the issues at hand, demonstrating its utility in facilitating a shared understanding among the diverse groups.

The cognitive map played an important role in fulfilling the objectives of the P-K phases, effectively organizing stakeholder insights and cultivating a shared comprehension of water management challenges. It was pivotal in identifying stakeholders and clarifying a collective understanding of current knowledge, aligning with the goals of the P-KCP process. This organized depiction aided in building consensus among varied stakeholder groups and underscored the interrelated nature of water management issues.

5.5.3 Workshop-2: Shared concern

Workshop 2 aimed to convene all stakeholders to discuss findings from previous interviews, identify shared concerns, and assess the commitment to collective groundwater management in the south Gabès area.

During the discussions, farmers responded to the information shared, adding their own experiences and viewpoints. The dialogue covered various topics, including the need for collective authorization for small farmers, the social aspects of collective management, and challenges such as support, subsidies, financial concerns, and farmer mobilization. Additionally, the importance of organization, the role of groundwater district managers, livestock farming, and drilling permits emerged as critical areas, suggesting a strategy for tackling groundwater management challenges.

Prior to group activities in Workshop 2, the aggregated cognitive map, summarizing results from interviews, was presented. This presentation provided a structured view of water management challenges, and cognitive map validated by farmers. The cognitive map laid a solid groundwork for discussions, effectively setting the stage for stakeholders to collectively pinpoint a shared concern and deliberate on solutions, thus fulfilling the workshop's goal of fostering collaborative exploration of groundwater management solutions within a collective framework.

Following the presentation of the aggregated cognitive map, participants were divided into two groups to explore specific themes. The first group focused on the financial state of farmers, the need for increased administrative awareness, the adoption of modern agricultural techniques, and organizational strategies. They formulated a goal to develop strategies enhancing farmer organization under supportive authorities, aiming to promote sustainable agriculture, improve incomes, manage water resources effectively, and facilitate access to subsidies.

The second group concentrated on fostering positive stakeholder relationships, advocating for equity water management, and implementing efficient irrigation practices. Their goal was to establish water management strategies within a participatory framework.

After discussions, both groups presented their summarizing statements to all participants. Following a thorough review, the statement from the second group was selected as it better represented the shared aspirations for sustainable water management and stakeholder collaboration

Incorporating an aggregated cognitive map within the P-KCP process greatly enhanced the effectiveness of Workshop 2. The use of cognitive maps, especially the aggregated map, provided a structured view of the water management issue, facilitating focused discussions. This structured approach not only made the exchange of ideas more productive by highlighting the relationships between different concepts but also played a pivotal role in identifying shared concerns. It paved the way for collaborative exploration of viable solutions for sustainable groundwater management, underscoring the importance of these methods in fostering stakeholder collaboration.

The workshop ended on a high note, with participants expressing their appreciation for the session and showing keen interest in future collaborations. It succeeded in bringing together stakeholders from various backgrounds, promoting the exchange of valuable insights and laying the groundwork for addressing common challenges and finding collective solutions to water management issues in the region

Policy-Concepts Generation Phase

During the P-C Phase, our aim shifted towards creating innovative and actionable policy concepts collaboratively, leveraging the groundwork established in the P-D phase and P-K phases. This phase was marked by the strategic use of a preliminary Concept Tree (C-tree) model, which provided a structured method for exploring and refining policy alternatives, thus aiding stakeholders in the concept generation process. Additionally, a value tree was developed from the aggregated cognitive map, serving as a guide for the concept tree's construction. This transition from descriptive analysis to prescriptive solutions was instrumental in the phase's success. The employment of problem-structuring methods such as cognitive maps and value trees not only enriched the P-KCP process but also played a crucial role in formulating the concept tree. This approach demonstrated the effectiveness of these tools in the intricate process of policy development, showing how they contribute to shaping feasible policy strategies.

5.5.4 Workshop-3: Generation of alternatives

The third workshop was dedicated to generating a range of alternatives for the collective management of groundwater, with the goal of exploring and prioritizing solutions that align with concerted local groundwater governance efforts, drawing on shared concerns. The outcomes of Workshop-3 revealed a broad array of proposed solutions—39 diverse solutions in total, with participants distributing votes across these options to signify their preferences

During the workshop, participants highlighted several critical areas for improving groundwater management:
-Groundwater Management: There were important concerns regarding the current groundwater management state, with issues like illegal drilling, water scarcity, and inadequate monitoring and control by authorities being highlighted. The need for improved management practices to ensure sustainable use of groundwater was underscored.
-Creation of a Groundwater Development Association (GDA): A key proposal was the formation of a GDA to tackle groundwater management issues collectively. The discussion covered the association's objectives, functions, and governance, stressing the need for qualified personnel and democratic elections for its executive office.
-Training and Awareness: The importance of educating farmers on various agricultural aspects, such as irrigation techniques, marketing, and crop selection, was recognized. Awareness campaigns to inform farmers about the importance of conserving groundwater resources were also deemed essential.
-Funding Sources: Funding the GDA's activities was a major topic, with discussions on potential funding sources and the idea of establishing a revolving fund contributed by farmers. The GDA's role in marketing agricultural products and selling inputs at fixed prices was also explored.
-Collaboration with Other Stakeholders: The necessity of including other stakeholders in groundwater management decisions was emphasized. This includes agricultural development groups and the Société Tunisienne de l'Électricité et du Gaz (STEG). Regular meetings with CRDA, APIA, and other relevant organizations were suggested to collaboratively address challenges.
-Alternative Water Sources: The exploration of alternative water sources, such as seawater desalination, was proposed as a solution to augment the available water resources for irrigation, highlighting the workshop's comprehensive approach to identifying solutions for sustainable groundwater management.

The workshop discussions were organized around two main themes: 'Generation of Alternatives and Solutions', which concentrated on brainstorming and suggesting innovative approaches to tackle water management challenges, and 'Shared Concerns and Prioritization', where participants collaboratively identified and ranked the most urgent issues. This structure enabled the development of a cohesive strategy for addressing groundwater management effectively.

Generation of Alternatives and Solutions:

The workshop focused on uncovering innovative solutions for the Limaoua territory's water management challenges. Of the 30 participants, 14 cast their votes for options they considered innovative, though some showed a preference for practicality over innovation. Seven solutions stood out: five already implemented elsewhere but new to Limaoua, such as non-corruption measures, regulation of illegal drilling, financial support for farmers in debt, training programs, and clarity on GDA financing sources. Two solutions—granting collective authorizations for small farmers and amending laws for GDA operations—are distinctive to the region. This selection process highlighted the importance of integrating both innovative and established solutions to address local water management challenges effectively.

-Institutional Component/Laws: Creation of a Groundwater Development Association (GDA) was proposed to bridge the gap between farmers and administration, enforcing laws against illegal drilling and fostering sustainable agriculture. The GDA would offer agricultural training, ensuring active farmer involvement, regular evaluations, and unique membership fees. Additional suggestions included establishing a specialized water resources department within the GDA, hiring skilled personnel, facilitating national and international meetings for farmer experience exchange, involving agricultural development groups in decision-making, and supporting GDAs in adopting water-efficient systems. Transparency and strategic financial management within the GDA were underscored as essential.

-Technical Component: Installation of meters on boreholes for water monitoring, promotion of solar energy in agriculture to lessen dependency on electrical energy, and adoption of advanced irrigation techniques to conserve water were recommended. Proposals also included subsidies for farmers utilizing electrical or solar energy, maintenance of public wells, and exploration of desalination options, aiming for a important strategy for sustainable water and agricultural management.

-Subsidies Component: Enhancing subsidy management was suggested, offering debt subsidies for farmers with private boreholes using electric or solar energy, alongside subsidies for maintaining public boreholes in irrigated areas using electrical energy.

-Farmer Support and Extension: The importance of farmer support and extension services was highlighted, focusing on groundwater conservation awareness and the adoption of water-saving irrigation techniques.

-Revision of Existing Laws: Revising laws to improve groundwater management regulation and address farmers' challenges was discussed.

-Involvement of Agricultural Development Groups and Collectivity: The crucial role of agricultural development groups in decision-making and development within irrigated areas was noted, along with the emphasis on collectivity and collaboration. This approach advocates for collective action among small farmers to efficiently navigate administrative processes and access necessary resources for sustainable water management, signaling a move towards a more integrated and cooperative strategy in tackling water resource challenges.

Shared Concerns and Prioritization:

One of the workshop's main aims was to bring participants together to identify common challenges and determine priorities for managing groundwater as a collective. Participants voiced concerns over water scarcity, the prevalence of illegal drilling, insufficient monitoring, and obstacles to achieving sustainable agriculture. There was strong support for the idea of setting up a Groundwater Development Association (GDA) to tackle these issues together.

In the group discussion, facilitators led a debate on the next steps for establishing the GDA effectively, with a focus on overcoming the hurdles identified. Discussions pointed towards organizing additional meetings and workshops to fine-tune the GDA's goals and rules. Highlighting the importance of farmer awareness and engagement, as well as the need for working together with other stakeholders, was also part of the conversation.

The workshop played a critical role in sketching out alternatives and drawing up a plan for forming and implementing the GDA, which aims to collaboratively manage groundwater and tackle the region's shared challenges.

The aggregated cognitive map was important in this phase, offering a clear picture of the situation, shedding light on different stakeholder perspectives, and supporting an evaluation. It helped make stakeholders aware of each other's views, creating a conducive environment for collaborative crafting of policy alternatives.

Figure 5.4: Workshop-3: first group

Figure 5.5: Workshop-3: second group

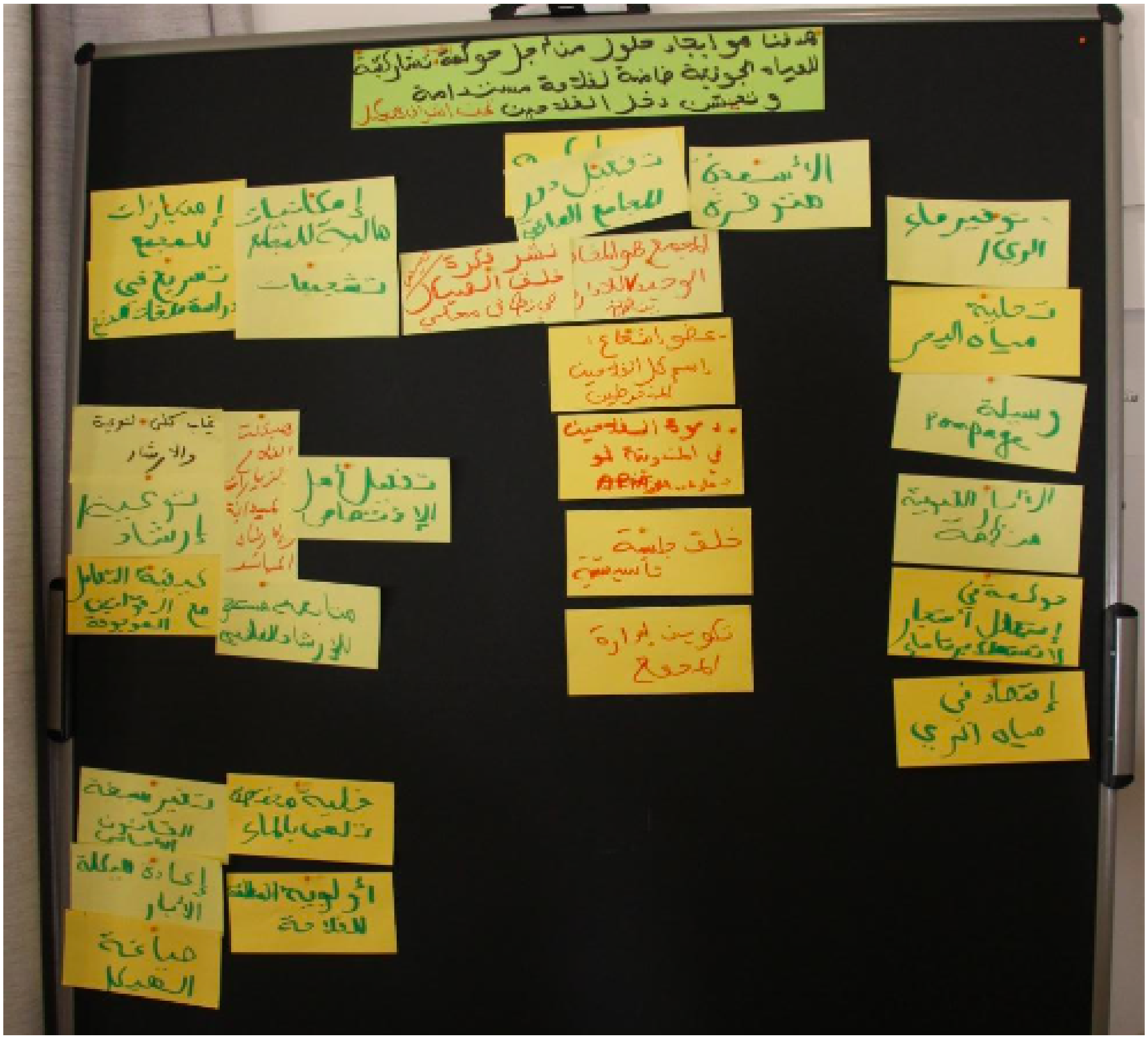

Figure 5.6: Workshop-3: some outputs from stakeholders

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5.5.5 Value tree

Transforming cognitive maps into value trees was a key move, revealing new solutions post-workshop and laying the foundation for future action. This step takes the diverse perspectives and solutions identified through cognitive mapping and organizes them into a structured value tree, focusing on evaluating priorities and potential impacts. The value tree, derived from the aggregated cognitive map, serves as an essential base for the concept tree, guiding the development of practical and strategic policy initiatives, which we'll delve into in the next section.

Creating a value tree from the aggregated cognitive map plays a strategic role in our policy-generation framework. First, it serves as an essential validation tool for the innovative solutions proposed during Workshop-3, ensuring these ideas are not just new but are also firmly aligned with the collective insights and priorities gathered from extensive stakeholder engagement. The value tree, crafted from the detailed information provided by stakeholder interviews and cognitive maps, wasn't shown in Workshop 3 to keep discussions straightforward and unbiased, promoting clarity and an objective basis for building consensus.

Second, the value tree highlights the benefits of using structured problem-solving methods, especially in moving from the broad perspectives of stakeholders to specific, actionable policy outlines. By using the value tree as a foundation for the concept tree, we adopt a systematic approach that boosts the P-KCP process's ability to produce detailed and effective policy alternatives. This choice is a conscious step towards linking descriptive analysis with prescriptive policy innovation, laying groundwork for future efforts and emphasizing the importance of structured analytical models in the development of environmental policies.

By using our algorithm, we end up the value tree out of aggregated cognitive map:

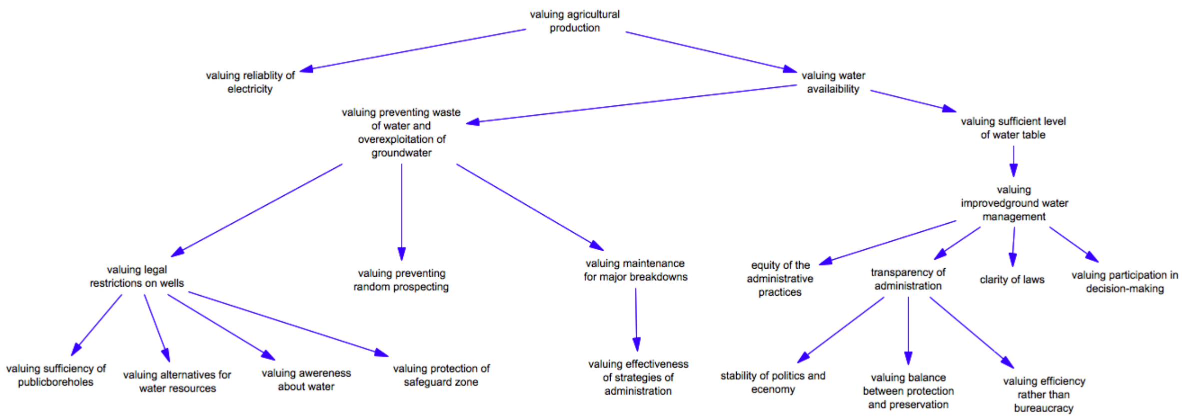


Figure 5.7: Value tree of aggregated cognitive map

In the constructed value tree from the aggregated cognitive map, the fundamental value identified is 'valuing agricultural production,' which is supported by two predecessor values: 'valuing reliability of electricity' and 'valuing water availability.' The value tree illustrates an ends-means relationship among these values. For instance, 'valuing water availability' serves as an end goal, which is supported by means such as 'valuing a sufficient level of water table' and 'valuing the prevention of water waste and overexploitation of groundwater.' This structure reflects the interconnectedness and hierarchy of values related to agricultural sustainability and resource management.

The value tree's narrative illustrates the interconnection of agricultural value with essential resources like water and electricity. To uphold 'valuing agriculture,' it's crucial to maintain 'water availability' and 'reliability of electricity.' The aspect of 'water availability' integrates critical facets like 'preventing water waste and overexploitation of groundwater.' This necessitates concrete actions against 'illicit wells' and 'random prospecting,' along with 'maintaining major breakdowns.' Furthermore, maintaining an 'efficient water table level' is vital, which requires the implementation of 'improved groundwater management' strategies.

The realization of 'efficient groundwater management' hinges on key factors like 'equity,' 'transparency in administration,' 'clarity of laws,' and 'participatory decision-making.' These elements are crucial at the foundational level of the value tree. The tree uses arrows to illustrate ends-means relationships, effectively narrating how each value contributes to the overarching goal. This representation helps in understanding how various components synergistically work together to fulfill the primary objective of the value tree.

The transformation from the aggregated cognitive map of stakeholders to the value tree is a pivotal aspect, ensuring the applicability of our process outlined in section 3. The successful application of this approach in the Kurdish-Turkish conflict and its adaptation to a broader case study context in the current research reinforces confidence in the robustness and versatility of our process. This demonstrates the method's effectiveness in diverse scenarios and its potential for wide-ranging applications in policy development and conflict resolution.

The analysis highlights the value tree's effectiveness in capturing the innovative solutions proposed by stakeholders, illustrating that each solution is either explicitly included or can be inferred within the value tree's framework:
-Non-corruption is represented through the notions of "equity in administrative process" and "transparency of administration," offering a strategy for tackling corruption.
-Regulating illicit drilling finds its place in "valuing preventing random prospect-

ing" and "valuing legal restrictions on wells," encapsulating the regulatory aspects within the value tree.
-Debt support for farmers is seen as contributing to "valuing efficiency over bureaucracy," connecting financial aid to overarching efficiency goals.
-Training is acknowledged in "valuing awareness about water," underlining the importance of education in sustainable water management.
-Understanding GDA financing resources falls under "clarity of laws" within the value tree, stressing the need for transparent and accessible financial regulations.
-Collective authorization for small farmers, a new concept, aligns with "valuing alternatives for water resources," suggesting a wider inclusivity in accessing water resources.
-Revising laws for GDA operations connects with "valuing participation in decision-making" and "transparency of administration," advocating for more open and inclusive governance frameworks. The transformation from a cognitive map to a value tree represents a move towards a more prescriptive/ design oriented understanding of the water management issues previously outlined in a descriptive manner. This progression is instrumental in generating out-of-box alternatives and establishes the value tree as an essential step towards creating a concept tree. Highlighting the capacity of structured analytical methods to connect descriptive analysis with strategic, solution-focused frameworks, this approach improved the policy development process. The implications of this transition for policy innovation and its role in crafting effective solutions will be further examined in the subsequent section.

5.5.6 Initial concept tree

Creating a concept tree, as highlighted in the literature, is a time-intensive process that requires considerable intellectual effort and is influenced by the subjective interpretation of the facilitator. The development of a concept tree begins with a phase of knowledge expansion ((see Hatchuel and Weil, 2003; Kazakçi et al., 2009), which then sets the foundation for the initial construction of the concept tree. Additionally, the notion of a 'knowledge tree' has been proposed. However, we argue that given the description of situations provided by the cognitive map from which our value tree is derived, our value tree can effectively function as a 'knowledge tree.'

The suggestion to use a value tree as the starting point for creating a concept tree is rooted in the shift from descriptive to prescriptive analysis. A value tree, emerging from a cognitive map—which in turn is based on in-depth interviews—captures a fundamental understanding of the issue. This means the process already fulfills the requirement for K-space expansion. The value tree, as a prescriptive tool evolved from the descriptive insights of a cognitive map, utilizes detailed stakeholder perspectives to steer the creation of actionable and strategic policy frameworks. This provides a systematic pathway from understanding the problem to generating solutions.

Leveraging the tree structure common to both value trees and concept trees facilitates the integration of semantics of nodes for systematic policy development. This approach intertwines the two structures, enhancing the efficacy and clarity of policy formulation by drawing on a method that aligns descriptive analyses with prescriptive, solution-oriented outcomes.

To uncover innovative and previously unexplored solutions, our approach employs negated combinations of nodes from the value tree, offering a method that can be adapted selectively based on the situation at hand. The choice of specific negated combinations to enrich the concept tree involves a level of subjectivity and depends on the particular challenges being addressed.

Integrating the concept of disruption, as emphasized by Considine (2018), into the process of utilizing inverse node combinations in a value tree, can boost the potential for innovative design outcomes. Design theory posits that creativity flourishes when conventional practices and norms are challenged and redefined. By deliberately seeking departures from established patterns, the negated combinations of nodes in a value tree can uncover hidden opportunities and alternatives. This approach encourages the emergence of creative solutions that diverge from traditional pathways, contributing to the evolution of design practices and pushing the boundaries of what is conventionally considered possible. Here is the initial concept tree, out of the value tree:

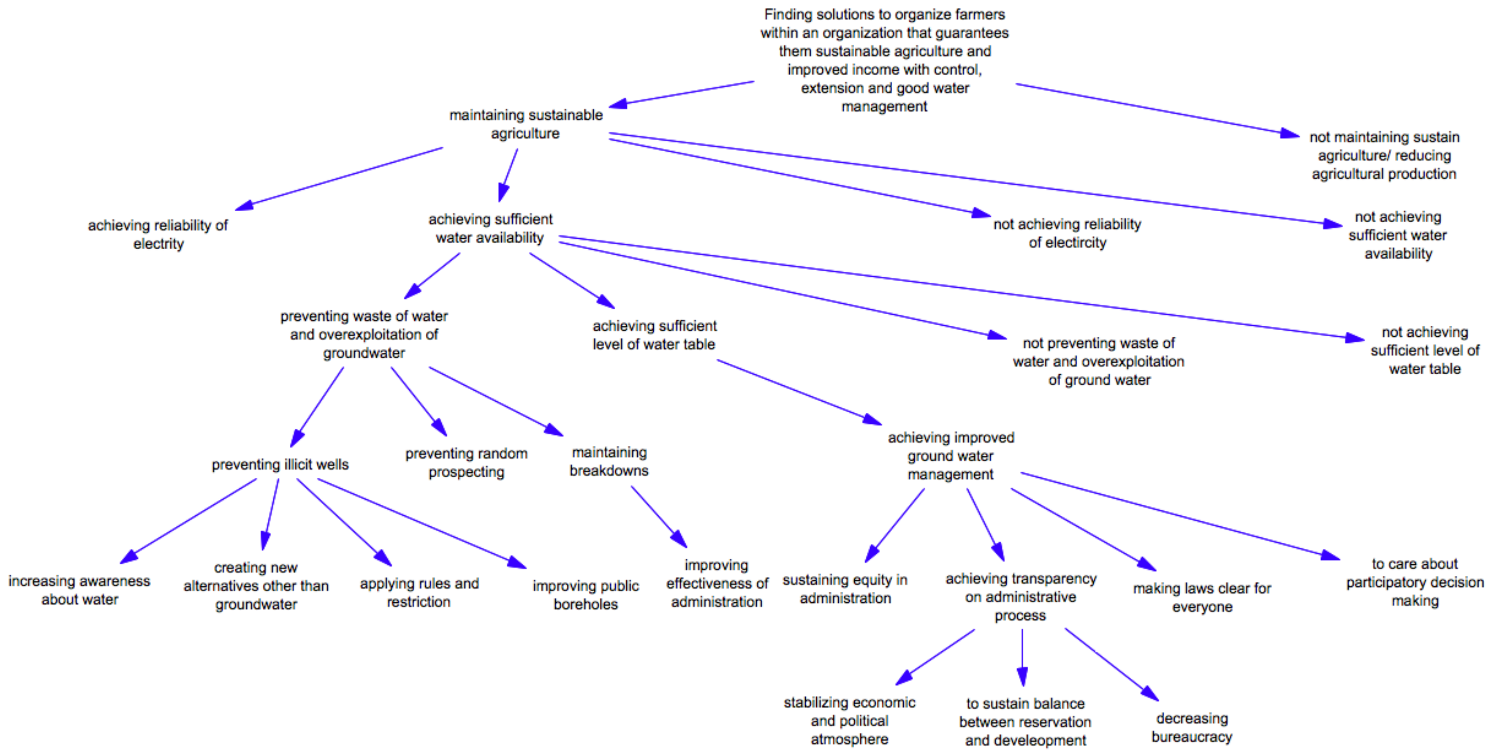


Figure 5.8: Initial concept tree

The initial concept tree, leveraging a hierarchical structure, starts with the shared goal of developing strategies to organize farmers under a system that ensures sustainable agriculture and improves incomes through effective water control and optimal management. This objective is rooted in the core value of "valuing agricultural production" identified within the value tree. The concept tree begins by examining "sustainable agriculture" and its opposite, aiming to stimulate ideas that could enhance farmer income beyond traditional agricultural dependence.

From "sustainable agriculture," the tree branches into "reliability of electricity" and "sufficient water availability." The "reliability of electricity" branch isn't explored in its negated form due to its less direct influence on agricultural productivity, as perceived by stakeholders. This decision reflects the itterative ability of the process while to developing the concept tree. Conversely, aspects like "preventing waste of water" and "maintaining a sufficient level of the water table" are considered alongside their negations, focusing on direct actions for water management.

After these considerations, the selective negation process concludes, resulting in a concept tree that integrates all pertinent nodes from the value tree. Given the value tree's foundation in stakeholders' cognitive maps—which captures the innovative solutions identified in Workshop 3—the concept tree is anticipated to encompass the necessary knowledge expansion. As the value tree acts as a stepping stone to the concept tree, it facilitates a smoother shift from descriptive to prescriptive analysis, enhancing efficiency. The subsequent phase will incorporate insights from the interview guides not previously covered, as the aggregated cognitive map concentrated on shared insights, and the value tree derived from it addressed the risk of oversimplifying complex systems, a concern noted by von Winterfeldt (1987) due to the tree structure's inherent limitations, aiming for a thorough policy development approach.

5.6 Final concept tree

In the development of the final concept tree, our objective was to incorporate concepts that might have been missed initially due to the focus on shared insights within the aggregated cognitive map and the inherent limitations of the value tree's structure. This expansion step is crucial for bridging the gap and acknowledging that while the value tree is effective in surfacing common concerns and values, it might inadvertently exclude specific concepts important to certain stakeholders.

By weaving in these overlooked concepts, we substantially enhance the depth and breadth of the concept tree, ensuring it encompasses a more comprehensive range of stakeholder perspectives and insights. This approach effectively addresses the risk of losing valuable insights during the aggregation and filtering stages, thereby enriching the final policy design framework with a wider array of considerations and alternatives.

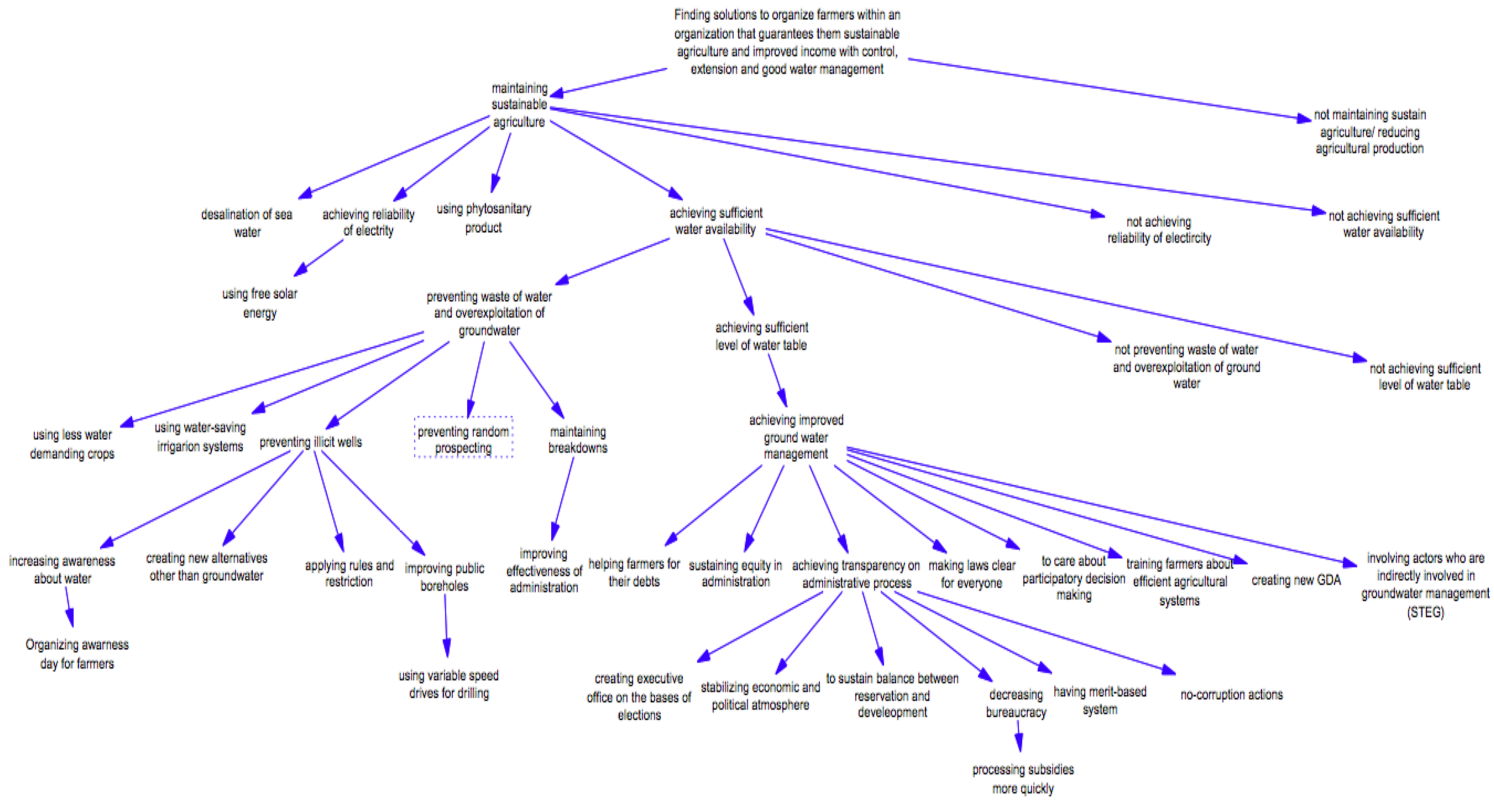


Figure 5.9: Final concept tree

The concept tree underwent expansion to integrate new concepts unearthed during Workshop-3, thereby capturing a wider range of stakeholder insights and priorities. It now encompasses considerations on phytosanitary products, seawater desalination, the introduction of innovative crops, and a transition to more water-efficient cropping practices. A distinct difference emerged between small-scale and large-scale farmers concerning the issuance of new well authorizations, illustrating the complexities inherent in groundwater management. This variation in perspectives emphasizes the necessity of acknowledging the diverse interests and concerns of different stakeholder groups in crafting sustainable management solutions.

5.7 Final concept tree with experts expansion

Following the internal analysis using the value tree, a supplementary workshop was convened that brought together experts in environmental science familiar with the regional context. During this workshop, the concepts previously discussed were methodically arranged into specific categories within the concept tree, facilitating a structured approach to integrating expert insights with the case study already completed.

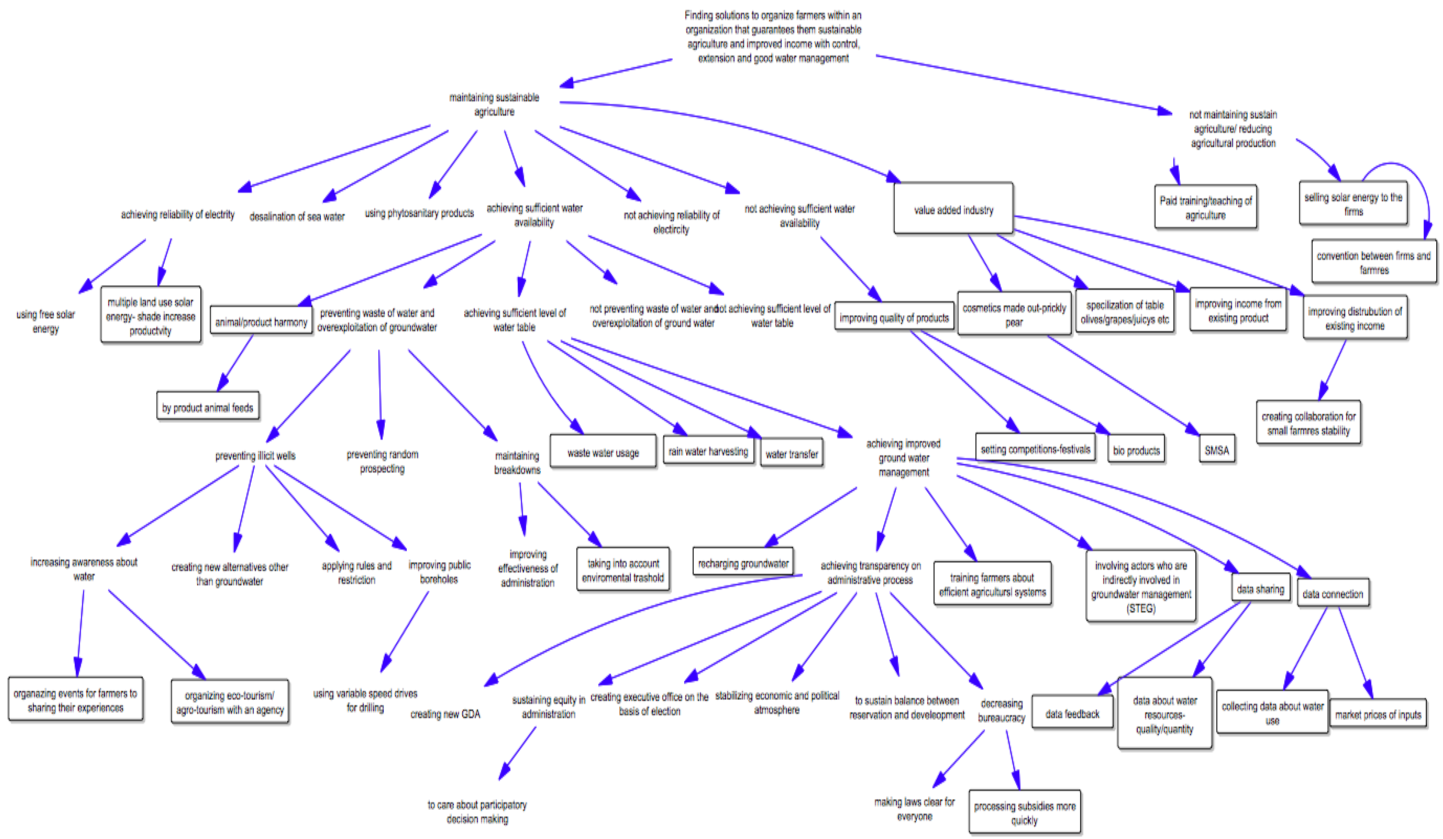


Figure 5.10: Final concept tree with expert expansion

This collaborative effort with experts, enhanced by the strategic use of the value tree, contributed to forming a detailed narrative. The existing concepts mapped out provided a comprehensive context for the experts, enabling the infusion of various new elements into the established branches of the value tree, which is an integral part of the broader concept tree, affecting both its higher and lower tiers.

The progression from the value tree to the concept tree, marked by the introduction of innovative concept pairings, dynamically involved the experts. For instance, in addressing the complex issue of 'not maintaining agriculture,' fresh ideas such as 'paid training' and 'selling solar energy to firms' were introduced, broadening the scope of solutions beyond the initial set. Additionally, in tackling 'not achieving sufficient water availability,' the conversation enriched the 'improving quality of products' node with new insights.

The flexibility afforded by the value tree in the developmental phase allowed experts to effortlessly incorporate new concepts at various levels of the concept tree. This led to the introduction of the 'value-added industry' node, marking a substantial and inventive extension of the concept tree's framework. This instance underscored the value tree's role in fostering expansive and creative thought processes, facilitating an open environment for idea generation rather than constraining the exploration of potential solutions.

5.7.1 Typology

Our project aligns with the seven typologies identified by Hassenforder (2023), serving as the foundation for water management strategies. These typologies are:
-Supply Management: Focuses on securing water availability for various uses. Demand Management: Aims at optimizing the utilization of water resources to ensure efficiency.
-Alternative Resources: Explores the use of sustainable energy sources in water management practices.
-Aquifer Recharge: Involves techniques to replenish groundwater sources. Water Accounting: Implements precise tracking mechanisms for water usage and allocation.
-Management of Drilling Operations: Establishes regulations for water extraction activities to prevent illegal drilling.
-Energy Management in Water Pumping: Concentrates on efficient energy use in water pumping systems.
-These categories guide our integrated approach to water resource management,

ensuring sustainability and thoroughness.

Our concept tree encapsulates a diverse typology of water management strategies, highlighting innovative solutions for sustainable resource utilization in Tunisia. It integrates:
-Supply Management through initiatives such as rainwater harvesting and desalination of seawater.
-Demand Management by addressing water waste prevention and overexploitation.
-Alternative Resources through the adoption of solar energy.
-Aquifer Recharge with techniques ensuring long-term water sustainability.
-Water Accounting reflected in data sharing and connections for efficient resource allocation.
-Drilling Operations Management evident in efforts to combat illegal wells.
-Energy Management optimizing water pumping operations.
-Aligning with these recognized typologies directs us towards a holistic approach to water management in Tunisia.
By adapting comprehensive measures from the Groundwater Catalogue

(https://www.groundwatercatalogue.org/measures) to our framework, we can integrate management solutions corresponding to the innovative approaches outlined in our concept tree. The inclusion of 'rainwater harvesting' and 'desalination of seawater' resonates with supply measures from the Catalogue. Additionally, 'preventing waste of water' and 'improving public administration effectiveness' reflect demand and protection measures, emphasizing the importance of stakeholder involvement and policy dialogue. This synergy underscores our dedication to a multi-dimensional strategy for water management in Tunisia.

5.7.2 Novelty and Taboo

In the realm of water resource management, exploring the concepts of novelty and taboo is crucial for unleashing innovative solutions as every complex situation with diverse interests. The application of a value tree extends beyond merely organizing established perspectives; it acts as a catalyst for creativity. This is particularly evident when we engage in the negation of nodes within the value tree, which serves as a method to unlock new ideas and approaches.

For example, the node 'achieving water availability' alongside its negation 'not achieving sufficient water availability' illustrates this principle. The negation of this node inspires the innovative concept of 'increasing quality of products,' highlighting how engaging with taboo subjects can lead to creative breakthroughs. Similarly, the introduction of a thought-provoking negation such as 'not maintaining agriculture' pushes the boundaries of traditional thought, yielding unconventional solutions like 'paid training for farmers' and 'selling solar energy to firms.' This approach underlines the significance of negation of nodes in the value tree as a powerful tool for generating novel ideas and solutions in water resource management.

The addition of nodes by experts to the concept tree enhances the idea generation process. For instance, the introduction of the 'value-added industry' node leads to the development of distinct sub-nodes like 'cosmetics made from prickly pear' and 'specialization in table olives/grapes'. This showcases the concept tree's capacity to encourage a broad range of ideas, underscoring the critical role of expert contributions in uncovering new solutions.

Another notable example is the development of 'increasing awareness about water,' which paves the way for the idea of 'eco-tourism.' This progression demonstrates the concept tree's effectiveness in facilitating the exploration of diverse and innovative approaches within water resource management. Such instances highlight the importance of integrating taboo and novelty in policy design, urging stakeholders to venture beyond traditional confines and contemplate an extensive spectrum of inventive solutions.

In conclusion, the dynamic interaction between taboo and novelty, enabled by the use of value trees and the deliberate inclusion of inverse nodes, plays a pivotal role in promoting innovation in water resource management. This methodology not only deepens stakeholder involvement but also expands the range of possible policy solutions. It encourages a more flexible and imaginative strategy towards the management of water resources, illustrating the importance of embracing unconventional ideas to address complex environmental challenges.

5.7.3 Overcoming Challenges and Strategic Adaptations

Regarding the integration of CK theory methodology in generating alternatives, it was noted that no groundbreaking solutions emerged, although some of alternative considered innovative by stakeholders as discussed in section-5. However, the context of the workshop, where participants were primarily oriented towards establishing a GDA, played a role in the kinds of suggestions put forth. Most proposed options revolved around the activities the GDA could undertake, with some innovation related to the management of not just water but also agricultural production and sales.

The facilitators admitted that they didn't extensively apply CK theory principles during the session. Instead, they collected participants' proposals on post-its and organized them into thematic groups collaboratively. The group dynamics and collection of ideas were similar in both groups.

Regarding stakeholders' freedom to express opinions, it was affirmed that they had the liberty to do so, which occasionally led to tensions, particularly between those advocating immediate action and those emphasizing the importance of a comprehensive approach. This conflict was skillfully managed by the facilitators, emphasizing the complexity of the issue and the need for multiple solutions rather than a single, rushed approach. For instance, in Workshop-3, disagreements among participants regarding the urgency and approach to establishing the GDA. Some participants expressed frustration with the pace of progress, suggesting a desire for immediate action. In contrast, others defended the importance of the methodological process, emphasizing the need for agreement on a common concern and the benefits of a step-by-step approach to developing solutions.

The workshop participants were divided into mixed groups, and the decision to split them into two groups was made during the workshop, leading to a well-balanced distribution of participants.

During the conclusion of the workshop, participants were asked to vote on action alternatives. These actions were created based on previously identified options, including those designated for the GDA. Some participants may have voted based on importance rather than innovativeness. One of the actions mentioned was 'collective permission,' which entails farmers uniting to request administrative authorization for a new well, a collective approach diverging from the usual individual requests.

The collaborative workshops conducted in the Limaoua region revealed the influence of both cultural context and team composition on the overall process. The spoken culture in Tunisia played a pivotal role in shaping the communication styles and interactions among the specific stakeholders involved. Notably, strong personalities sometimes introduced ad hoc interventions, impacting the workshop dynamics. It was also evident that not everyone had fully embraced the complexity of the problem at hand or the necessity of a systematic problem-solving process.

Tensions emerged between those advocating for immediate action and those emphasizing the importance of a comprehensive, step-by-step process. Facilitators played a critical role in managing these tensions, emphasizing the complexity of the problem and the need for diverse solutions. A farmer with expertise in philosophy contributed to conflict management and consensus-building.

Team composition brought its own set of dynamics, with participants representing diverse scientific backgrounds and speaking multiple languages. Facilitator training in CK theory and related methodologies was instrumental in guiding the workshops effectively. The division of tasks and roles among team members influenced how information flowed within the group. Overall, these factors underscore the importance of considering cultural context, team composition, and facilitator training in collaborative workshops, with an emphasis on managing tensions and recognizing the value of the process itself, in addition to the outcomes achieved.

The use of multiple languages (English, French, Arabic) increased complexity, with translators and multilingual participants playing crucial roles. The choice of language affected the quality of discussion and the understanding of narratives, with participants preferring their mother tongue for freedom of expression. This aspect also influenced the connotations of language used in discussions, impacting the framing of concepts within the discourse.

The diverse scientific backgrounds of participants, ranging from operations research to environmental science and stakeholder engagement, enriched the knowledge acquisition process. The integration of various methods (graph-theoretical tools, decision/design-based tools, participatory methods) and the adaptation of theory to practice were pivotal. Facilitators, trained in theory but with discretion in application, prioritized meeting the participants' needs, sometimes at the expense of theoretical principles.

Practical challenges included poor internet connections, timezone differences, and the need for a local presence. The division of tasks between organizing, conducting interviews, and adapting theory to practice was important. The style of building workshops, the importance of venue selection, and the ability to adjust to new inputs (like expert views) were also important in shaping the process.

The non-utilization of value trees during the workshops stems from two primary reasons. Firstly, we made a conscious decision not to use value trees to avoid complexity. Workshops can be constrained by time and resources, and introducing the value tree might demand a certain level of complexity that could potentially complicate the workshop process. Secondly, we used value trees for internal purposes in a separate specialized workshop. As mentioned in the introduction, such a specialized workshop aimed to delve deeper into theoretical approaches and provide participants with more in-depth knowledge on the subject. Therefore, the absence of value trees during the workshops is a deliberate strategy and a result of using these theoretical tools in different platforms where they might be more suitable or effective.

Another important aspect of the second case study is the opportunity it provides to examine the potential of using the value tree as the top structure for a concept tree. In this context, the value tree serves as a clear representation of stakeholder values and objectives, offering a solid foundation for the development of innovative solutions. This provokes further exploration into methodologies that could transform a value tree into a concept tree, expanding the knowledge space and generating new, creative policy alternatives.

5.7.4 Discussion

This study examined the integration of the P-KCP methodology with cognitive mapping and value trees to address the complexities of groundwater management in Tunisia. The methodology focused on enhancing stakeholders' problem-solving capacities by conducting a series of participatory workshops.

The initial phase involved creating individual cognitive maps for each stakeholder group, which were then aggregated into a single map to provide a comprehensive overview of the problem situation. From this, we derived a value tree that served two important functions:

1. Ensuring that all proposed solutions were consistent with the values shared by the stakeholders.

2. Providing a knowledge space that acted as the foundation for generating innovative solutions during the participatory process.

The value tree, as a structured representation of the stakeholders' collective values, not only simplified the tasks for participants but also fostered creativity when developing the concept tree. This approach ensured that the concept tree incorporated all critical issues identified during the workshops, including water management strategies such as rainwater harvesting, desalination of seawater, and preventing overexploitation of groundwater resources.

Furthermore, the concept tree encapsulated innovative policy alternatives for sustainable groundwater use, including aquifer recharge techniques and measures for efficient water accounting. By adapting existing frameworks like the Groundwater Catalogue (https://www.groundwatercatalogue.org/measure) to the context of Tunisia, we were able to propose comprehensive, multi-dimensional solutions.

Feedback and Key Insights

The feedback received throughout the participatory process highlighted the effectiveness of the different steps involved in constructing the concept tree. Several key insights emerged during this phase:

1. Contrasting the nodes of the value tree stimulated stakeholders' reactions, particularly in understanding why "not supporting agriculture" is not a viable option. This clarified the fundamental reasons for pursuing a sustainable groundwater management policy aimed at agricultural development.

2. The incorporation of expert opinions and specific suggestions contributed to uncovering alternative solutions that were not initially identified through the consensus-driven discussions during the workshops.

3. Involving stakeholders' individual experiences brought critical insights that were otherwise difficult to grasp. For instance, the widespread adoption of solar panels for electricity production, while offering cheap energy, also encouraged excessive water pumping and exacerbated the overexploitation of the aquifer. This highlighted the need for regulations governing the use of renewable energy sources to ensure they align with the broader goals of sustainable water management.

Multimethodology and Integration of Cognitive Mapping

Multimethodology, as defined by Mingers and Brocklesby (1997), involves integrating multiple methodologies or their components to address the complexity of real-world problems. They outline several forms of methodological integration, including:

1. **Methodological isolationism**, which relies solely on one methodology.

2. **Methodology enhancement**, where techniques such as cognitive mapping are incorporated into existing methodologies.

3. **Methodology combination**, applying entire methodologies complementarily.

4. **Partitioning and recombining methodologies**, forming hybrid approaches.

Cognitive mapping, as a flexible tool for eliciting and structuring stakeholder perspectives, has been utilized in various methodologies to enhance both the analytical and participatory dimensions of problem-solving. For instance, Gains and

Rosenhead (1993) integrated cognitive mapping with *Soft Systems Methodology (SSM)* to improve medical quality assurance, enriching the problem structuring process and fostering deeper stakeholder engagement. Similarly, Eden (1994) demonstrated its compatibility with *systems dynamics*, bridging individual perspectives with systemic modeling.

Our work extends this tradition by integrating cognitive mapping into the processes of the *P-KCP methodology*, aligning with Mingers and Brocklesby (1997)'s multimethodology framework, specifically the "partitioning and recombining methodologies" approach. Just as Eden (1994) employed cognitive mapping to inform systems dynamics modeling, we use cognitive mapping to define problems and understand stakeholder values, thereby supporting the systematic processes of *P-KCP*. This integration exemplifies multimethodology in practice, where different methodologies are combined in a coherent and context-specific manner to address complex decision-making scenarios.

Summary of Limitations

Despite the overall success of the participatory process, several limitations were encountered:

- The innovation potential of the third workshop was limited by the stakeholders' commitment to the establishment of the Groundwater Development Association (GDA). This led to a focus on its implementation rather than exploring alternative solutions. [2]
- The cultural, scientific, and linguistic diversity of the participants presented challenges to the innovation process. The workshop facilitators were native Arabic speakers, while the research team, experts in design theory, did not speak Arabic, which created communication barriers. [3]
- Due to time and resource constraints, a dedicated workshop for the construction of the concept space could not be held. Although the expert workshop helped, it could not fully substitute for the participatory workshop that was planned.
- The formalization and development of the generative process for solutions derived from the concept space require further work, as does the construction of the concept space itself.

[2]The unstable political situation in Tunisia did not allow to have further knowledge about the practical implementation of the GDA in Limaoua.

[3]The reader should note that the entire experiment and the workshops were conducted during the COVID-19 pandemic, which imposed well-known restrictions.

5.7.5 Conclusion

This research highlighted the critical role of integrating cognitive mapping and value trees with the P-KCP methodology in designing innovative groundwater management policies in Tunisia. Through a series of participatory workshops, we gained insights into stakeholder perspectives and were able to develop actionable, consensus-driven policy solutions. The methodology offers a promising approach to participatory groundwater management, contributing to both theoretical frameworks and practical applications. Further research is needed to assess its adaptability in different contexts and to refine the tools used for generating policy alternatives. The next chapter will focus on that benchmark, especially how to use a value tree for a concept tree.

Chapter 6

Incorporating design theory with policy design

Building upon the integration of Problem-Structuring Methods (PSMs) into design theory, our theoretical contribution further extends by incorporating design theory into the realm of policy design. This integration brings a new dimension to policy development by applying design thinking principles to complex policy issues, enhancing both the creativity and effectiveness of policy solutions. By embedding design theory into policy design, we advocate for a formal method that structures a concept tree through the use of a value tree derived from a cognitive map. This approach not only provides a systematic framework for organizing concepts but also facilitates the expansion of the knowledge space (K-space).

Utilizing a value tree out of a cognitive map enables policymakers to capture a wide range of stakeholder values and perspectives, which are essential for comprehensive policy analysis and design. The process allows for a more nuanced understanding of the problem space and encourages the exploration of innovative solutions that may not emerge through traditional policy analysis methods. By structuring the concept tree in this way, we provide a strategic pathway for translating descriptive insights into prescriptive action, thereby bridging the gap between theoretical analysis and practical policy-making.

6.1 Using value tree to structure concept tree: Tunisia case

Creating a concept tree in this study involves a process that requires effective dialogue, creativity, and considerable time. To streamline this process, the study proposes the use of a value tree as a more focused approach. This value tree, derived from cognitive maps built through detailed interviews with stakeholders, captures their creativity and critical thinking. By starting with this foundation, the time and effort invested in these interviews can be effectively utilized to construct a concept tree, reducing randomness and addressing potential challenges more efficiently. This approach leverages the rich input gathered to create a well-informed and robust concept tree.

In the case of Tunisia, employing negated nodes of the value tree during its creation has set a foundational method for developing the concept tree in subsequent stages. The concept tree incorporates two types of 'partition' (see Kazakçi et al., 2009): restrictive and expansive, with the addition of a hybrid partition observed in our case.

Restrictive Partition originates from the existing knowledge encapsulated within the value tree. Since the value tree is derived from the cognitive map, this partition is deemed restrictive. It encompasses concepts directly taken from the value tree, reflecting established understanding and insights.

Here are the restrictive partitions:

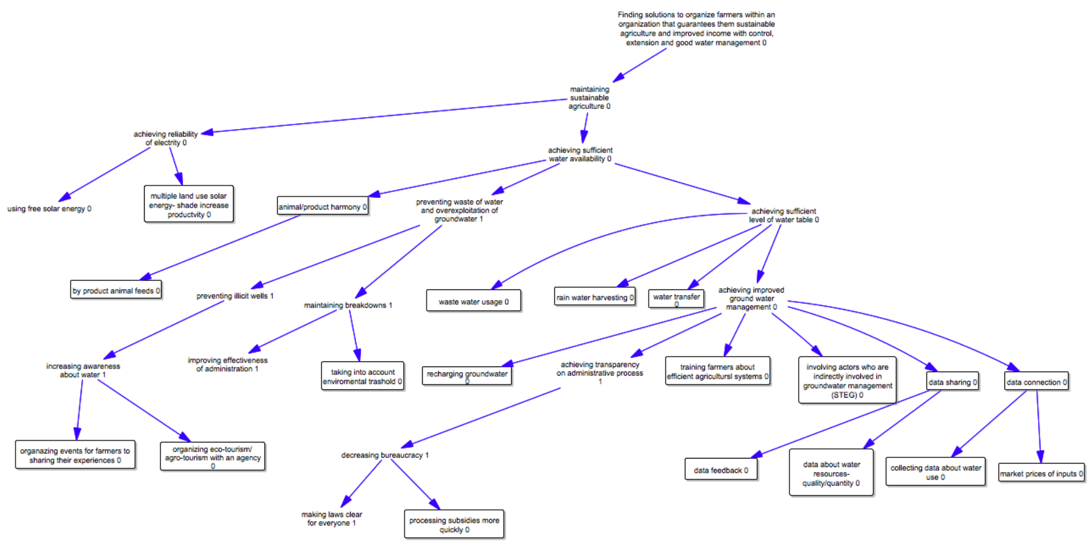


Figure 6.1: Restrictive partitions

Expansive Partition emerges from the application of inverse node combinations, drawing upon novel properties to ignite discussions and provoke new ideas. This partition represents the introduction of innovative concepts that extend beyond the traditional boundaries defined by the existing knowledge in the value tree.

Here are the expansive partitions:

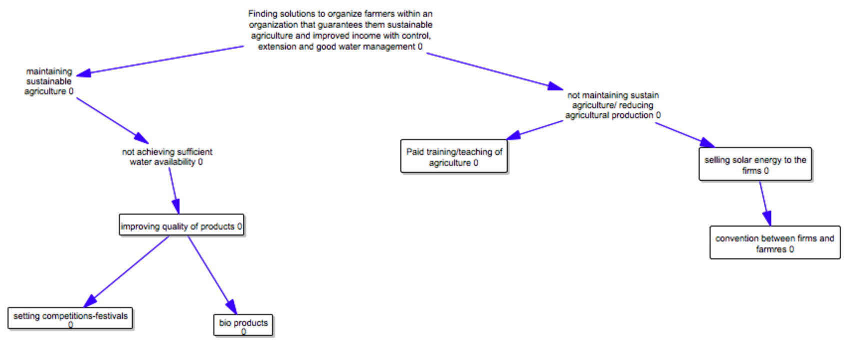


Figure 6.2: Expansive partitions

Hybrid Partition involves concepts that do not directly originate from the value tree nodes or their negated combinations. Instead, this partition allows for the inclusion of entirely new concepts during the iterative development process. An example from our work is the addition of the 'value-added industry' node during the expert workshop. This node wasn't initially present or directly derivable from the value tree but was introduced as a new high-level concept, demonstrating the concept tree's flexibility to incorporate new insights.

Here are the hybrid partitions:

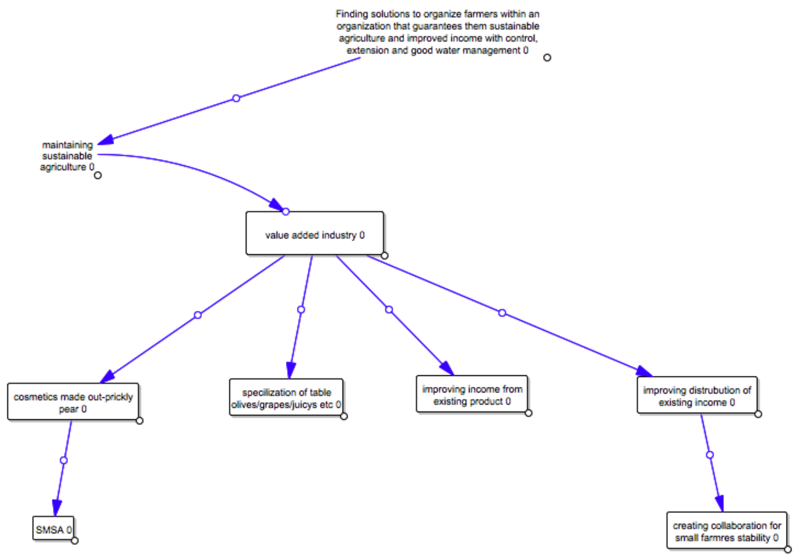


Figure 6.3: Hybrid partitions

This method of creating the concept tree, incorporating restrictive, expansive, and hybrid partitions, highlights a comprehensive approach to policy development.

Together with insights we got from the Tunisia case study in terms of using a value tree to construct a concept tree, we designed a procedure for how to use a value tree to get a concept tree Section 3.6 Now we will use our proposal in a popular problem situation. It is important to note that, as we described in the introduction, we deliberately chose a decision problem to test our results' generalizability beyond conflict transformation and management.

6.2 Example of Alice

Alice is an individual striving for academic success. However, her department operates with a limited budget, and it does not cover conference fees that exceed a certain amount. Alice is eager to submit a paper she has written to a prestigious academic conference. Unfortunately, due to the prestige of the conference, it has a low acceptance rate.

Alice faces a dilemma. If she purchases her flight tickets now, before knowing whether her paper will be accepted, she can attend the conference without exceeding the department's budget. However, if she waits to find out whether her paper is accepted, the price of the flight tickets will increase, and even if her paper is accepted, she will not be able to attend because the higher ticket price will exceed the department's budget.

In the first scenario, if Alice buys the tickets now for a conference with a low rate of acceptance, there is a significant risk that her money will be wasted if her paper is not accepted. On the other hand, if she doesn't purchase the tickets in advance and waits to see if her paper is accepted, even if it is accepted, the increased ticket prices will exceed the department's budget, preventing her from attending the conference.

In Alice's case, a decision analysis would suggest that not submitting the paper is the rational choice, as reflected in the decision tree () However, this option is unsatisfactory for Alice, as it does not align with her goals of academic success and conference participation.

Therefore, we view Alice's situation as an opportunity to test our algorithm. By applying the transformation from a Value Tree (VT) to a Concept Tree (CT) in this case, we can explore creative alternatives and potential solutions that might otherwise be overlooked in a traditional decision analysis framework. This allows us to move beyond purely rational decisions and account for more nuanced stakeholder perspectives, which is precisely what our algorithm aims to achieve.

We begin by illustrating Alice's situation using her **Cognitive Map**, which visually represents the relationships between key factors influencing her decision.

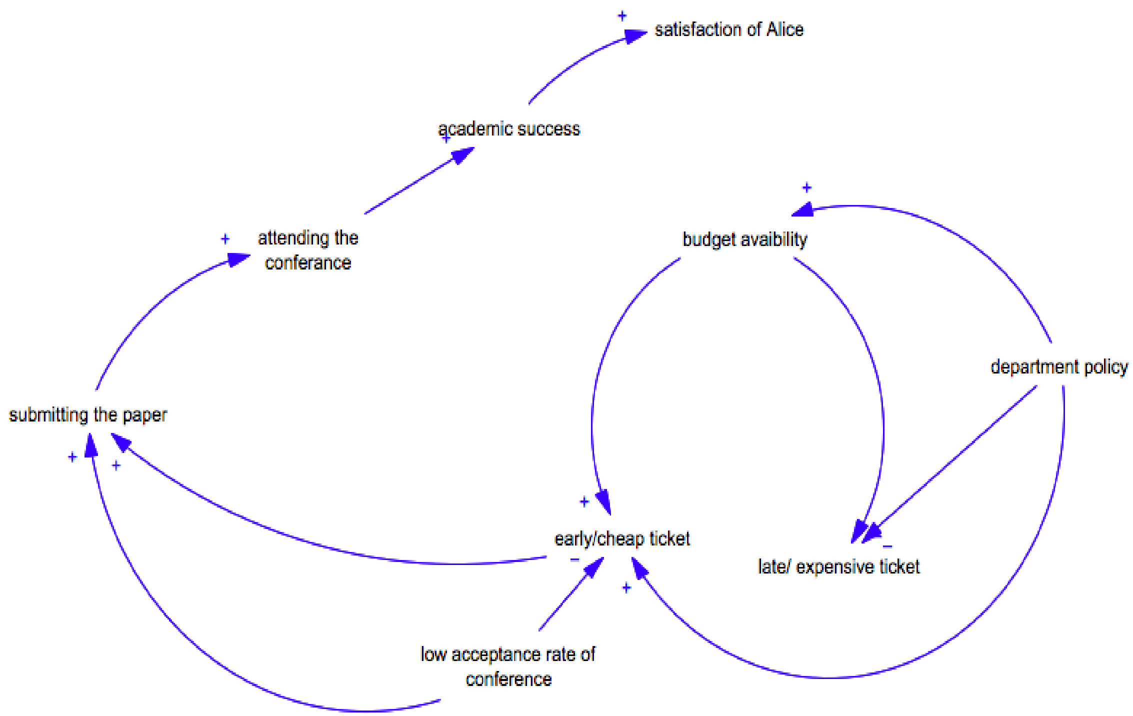


Figure 6.4: Alice's cognitive map

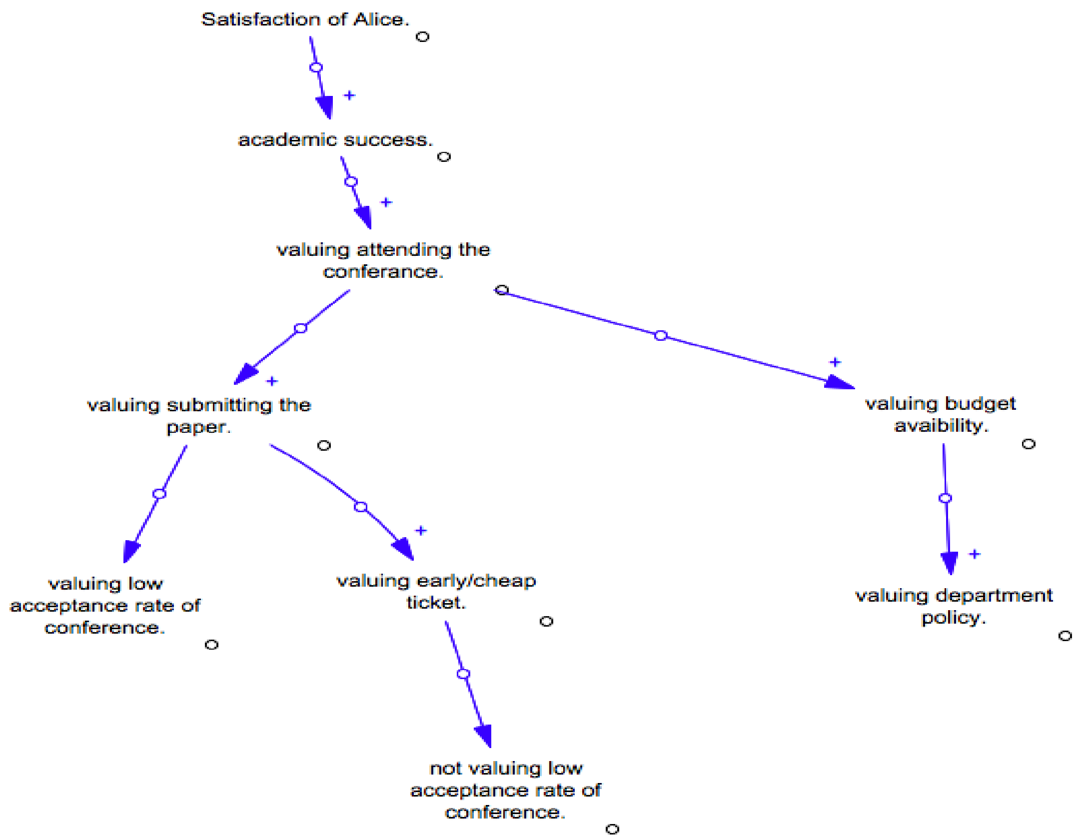
In the cognitive map:

- **Satisfaction of Alice**: This is Alice's fundamental value, linked to *academic success*.
- **Attending the conference** is a key contributor to Alice's academic success. However, attending the conference depends on several interconnected factors.
- **Budget availability** and **department policy** are constraints. Alice's department has limited funds, and the policy restricts covering costs beyond a certain amount, which affects Alice's decision-making.
- **Low acceptance rate of the conference** complicates Alice's decision. While she wants to submit her paper, the low likelihood of acceptance makes early action risky.
- **Ticket pricing** plays a crucial role. Alice faces the dilemma of either purchasing an *early/cheap ticket* before knowing if her paper will be accepted or waiting until later, which could result in *late/expensive tickets* that might exceed the department's budget, even if her paper is accepted.

This cognitive map highlights the complexities of Alice's decision-making, with various feedback loops and constraints (budget, timing, paper submission) affecting her goal of attending the conference and achieving academic success.

Next, we will apply the transformation from this cognitive map into a **Value Tree** and eventually a **Concept Tree** using our algorithm, to explore potential solutions for Alice's problem.

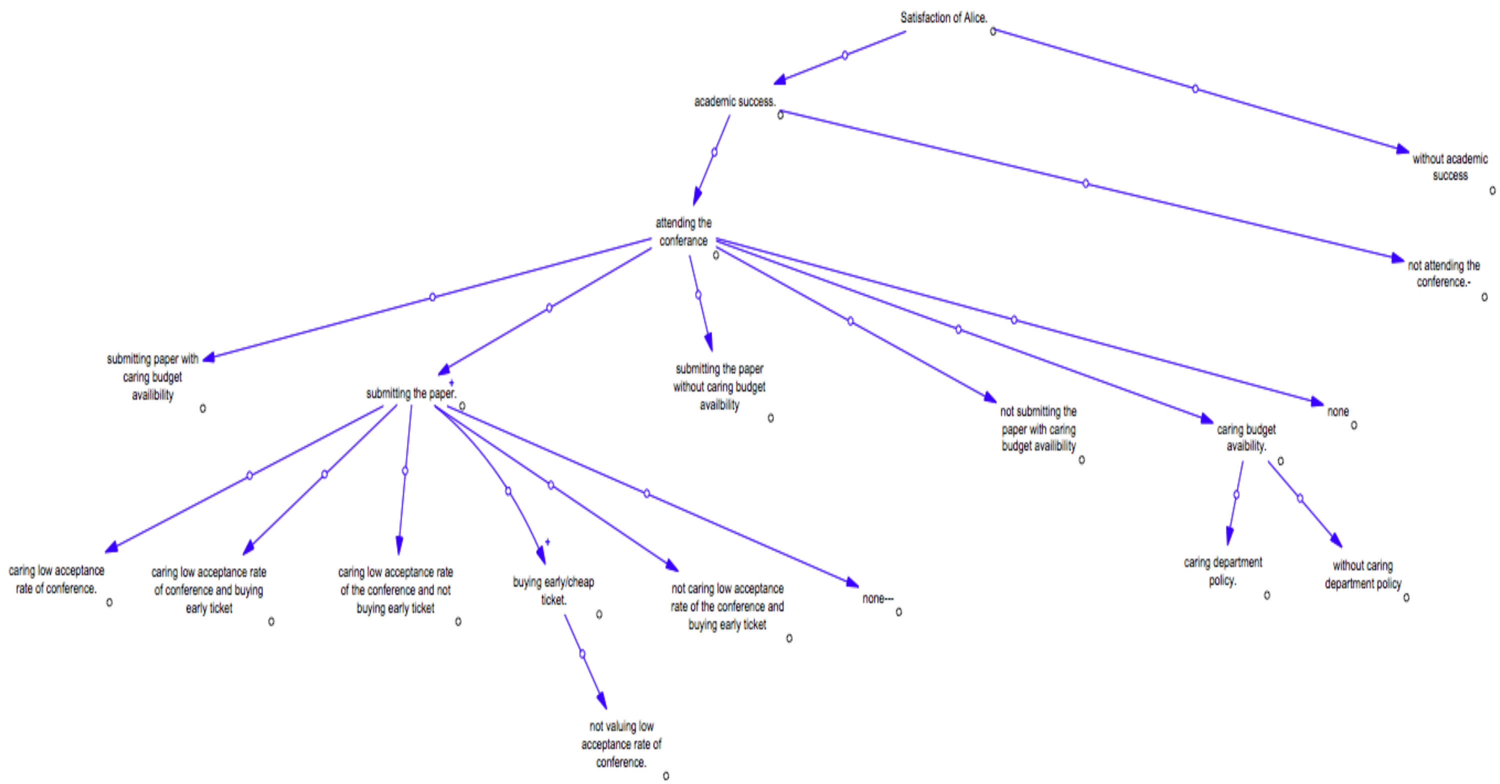
Using the algorithm from the first part of the thesis, we have constructed the Value Tree (VT) for Alice based on her Cognitive Map. This transformation follows the steps outlined in the algorithm by converting key elements from the cognitive map into value nodes and establishing their hierarchical relationships. Each value is aligned with Alice's goals and constraints, such as academic success, budget availability, low acceptance rate, and other important decision factors.



Alice’s Value Tree

Next, we will apply the second part of the algorithm to transform this Value Tree into a Concept Tree, which will explore creative alternatives and potential solutions for Alice's decision-making process. This step will incorporate negations and binary combinations to account for all possible scenarios and identify satisfactory solutions.

Using our algorithm to transform the Value Tree (VT) into a Concept Tree (CT), we have generated Alice's Concept Tree based on her decision-making scenario.



captionAlice's Concep tree

Alice's fundamental value is her Satisfaction, which is primarily tied to her academic success. There are two main paths that lead to this satisfaction: achieving academic success or finding satisfaction in other ways. If Alice attains academic success, it will come largely from attending conferences and presenting her work. However, even if she doesn't achieve traditional academic success, such as publishing papers or gaining recognition, she might still find satisfaction through alternative routes, such as building a strong professional network at the conference. On the other hand, if Alice doesn't achieve academic success, she may still find personal satisfaction through career development opportunities, such as exploring job prospects or collaborating with potential partners she meets at the conference.

One of the primary steps toward academic success is attending the conference. However, attending the conference is contingent on several factors, each of which introduces new decision points. The most important factor is whether or not Alice submits her paper. If she submits the paper while caring about budget availability, her decisions will be influenced by the department's financial constraints. In this case, Alice might consider applying for external funding or scholarships to cover her conference costs. Alternatively, if Alice submits the paper without worrying about the budget, she may need to explore self-funding options, such as using her personal savings or taking out a loan to attend the conference.

If Alice decides not to submit the paper, this might seem like a dead-end, but it could still open up other alternatives. For example, she could attend the conference as a participant rather than a presenter, which would allow her to network and explore potential job opportunities. Even if Alice doesn't submit the paper but remains concerned about the budget, she could still consider attending a different conference that aligns better with her financial constraints or academic goals.

Another major factor influencing Alice's decision is her concern about the low acceptance rate of the conference. This could lead her to further explore alternatives. For example, if she chooses to buy an early ticket despite the low acceptance rate, Alice can reduce her financial risk by purchasing a refundable or flexible ticket, which would allow her to change her plans if her paper is not accepted. If Alice decides not to worry about the low acceptance rate and buys a ticket anyway, she could explore other ways of presenting her work, such as poster sessions or less formal workshops that do not require full paper acceptance.

Budget availability is also a critical factor. If Alice strictly follows the department's budget policies, this could limit her options. However, if she chooses to ignore budget constraints, this opens up additional possibilities, such as self-funding or seeking alternative financial support. Ignoring department policy altogether could provide Alice with the flexibility she needs to attend the conference, albeit at personal financial risk.

Finally, the concept of not attending the conference is always present as an outcome if Alice decides not to submit her paper, misses the acceptance deadline, or can't afford the ticket. This is the least desirable outcome, as it would result in Alice failing to meet her academic goals, leading to dissatisfaction. However, each of these nodes offers a potential pathway for Alice, whether by seeking out alternative opportunities, navigating financial constraints, or making strategic decisions about submitting her paper.

Now we will see how can we expand our concept tree:

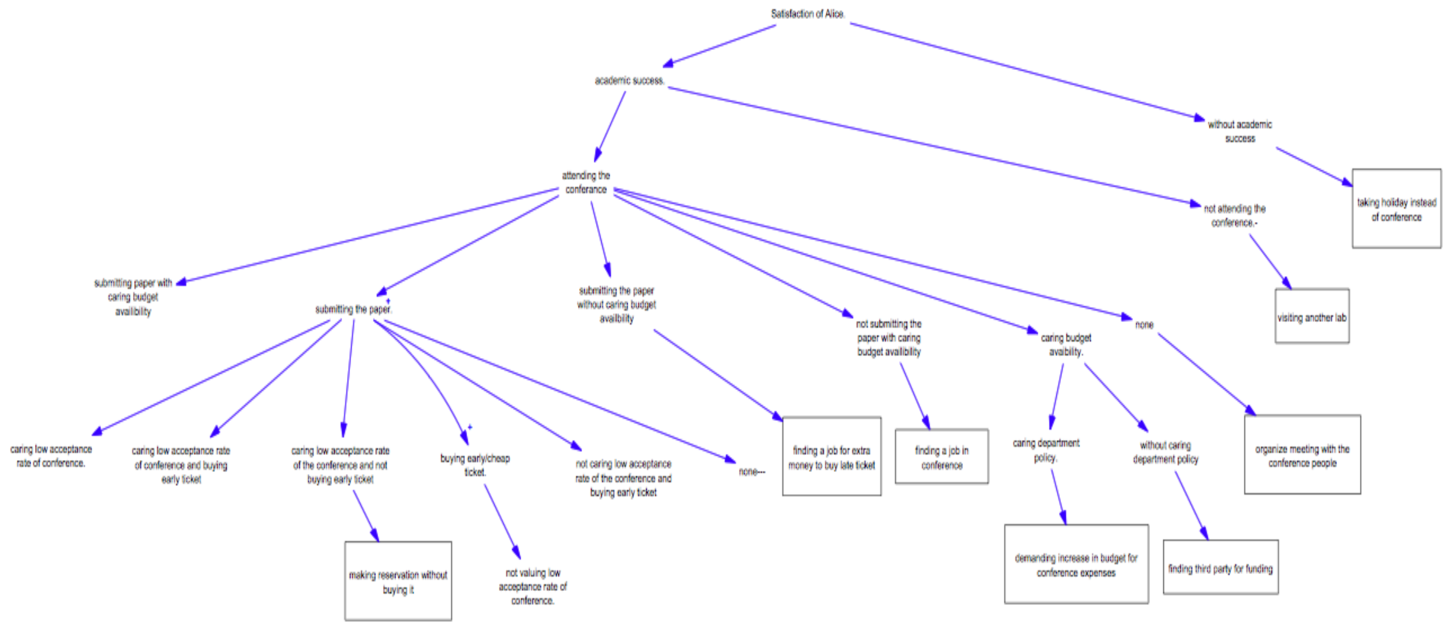


Figure 6.5: Alice's expanded concept tree

In Alice's situation, as depicted in the Extended Concept Tree, we can clearly see how generating a Concept Tree increases the range of alternatives available to her. Each node leads to new possibilities and encourages the exploration of options that may not have been considered initially.

For instance, when Alice submits her paper while considering budget constraints, creative solutions such as finding a third party for funding or demanding an increase in the department's conference budget emerge as viable alternatives. Similarly, by not submitting the paper, instead of losing all options, Alice can pursue other opportunities like finding a job at the conference or visiting another lab, turning what might have seemed like a dead-end into new opportunities.

This process of transforming a Value Tree into a Concept Tree not only broadens the set of choices but also sparks creativity by presenting alternatives that involve collaboration, funding, or even entirely different goals (like taking a holiday instead of attending the conference). The Concept Tree framework encourages Alice to think beyond the obvious and take a more holistic, imaginative approach to decision-making. By using this approach, Alice is more likely to find a solution that aligns with her personal and academic goals, even within her constraints.

6.3 Disscussion

6.4 Discussion

In this chapter, we explored how design theory, particularly the integration of value trees into concept trees, can enhance policy design processes in complex decision-making scenarios. Using the Tunisia case study as a starting point, we demonstrated that value trees not only provide a structured way to understand stakeholder values but can also act as a foundation for constructing concept trees, which are essential for generating innovative solutions. The case study showed the utility of transforming the top structure of the value tree into a concept tree, yielding creative and actionable policy alternatives in participatory groundwater management.

We extended this approach further by formalizing a second algorithm for systematically transforming the entire value tree into a concept tree. This process was validated using the Alice example, highlighting the general applicability of the methodology beyond conflict transformation. The successful application of this algorithm in the Alice example indicates that the integration of value trees and concept trees can be applied to broader complex decision problems, not just conflicts.

The ability of this methodology to bridge descriptive and prescriptive approaches offers a new dimension in policy design. By formalizing the transformation from cognitive maps to value trees, and from value trees to concept trees, the framework allows decision-makers to navigate between the knowledge space (what is known) and the concept space (what could be known), fostering innovation and more comprehensive decision-making processes.

While this approach has shown promise, there are limitations that need to be addressed. The process of transforming a value tree into a concept tree is inherently complex, and future research should explore the intermediate steps, such as value cognitive maps (VCMs) and ends-means maps (EMMs), to better understand where grouping or refinement should occur. Additionally, further studies should investigate how the knowledge space can be represented and demonstrated in parallel to the concept space, offering a fuller picture of the problem-solving process.

In conclusion, this chapter demonstrates that incorporating design theory with policy design, through the integration of value trees and concept trees, is not only feasible but offers a structured and replicable framework for addressing complex decision problems. This methodology has potential applications beyond conflict transformation, offering new avenues for innovative policy design in diverse contexts.

Chapter 7

Conclusion

This thesis has developed a comprehensive framework for conflict transformation and innovative policy design by integrating Problem Structuring Methods (PSMs) with formal design theory such as Concept-Knowledge (C-K) theory. Through the use of both case studies — the Kurdish-Turkish conflict and groundwater management in Tunisia — this work demonstrates the versatility and utility of this approach in addressing complex, multi-stakeholder problems.

In the first case study on the Kurdish-Turkish conflict, we tested the proposed methodology by identifying shared values between conflicting parties and uncovering areas for potential compromise. This process facilitated constructive dialogue, showcasing the method's effectiveness in conflict resolution. In the second case study on groundwater management in Tunisia, we moved beyond testing and validated the framework by applying the transformation process of a value tree out of a cognitive map and the use of the top structure of the value tree as the foundation for a concept tree.

Having found the value tree's top structure useful for guiding the construction of the concept tree in the Tunisia case study, we developed a second algorithm that formally uses the value tree for the generation of concept trees. We tested this additional step using the Alice example, which allowed us to generalize the applicability of our methodology beyond conflict transformation to more complex decision problems, expanding the scope to include diverse public policy challenges.

The key contribution of this thesis lies in the formalization of a process for transforming cognitive maps into value trees providing a structured and replicable approach for decision-makers. The integration of this process with design theory, with value tree to concept tree opens new avenues for innovative policy design, particularly in generating creative alternatives in situations of conflict and complex decision-making.

Despite these contributions, there are several limitations and directions for future research. In the Kurdish-Turkish conflict, since there is a declared conflict, we chose to work on each part of cognitive mapping separately. In the Tunisia case study, since there was no declared conflict, and to avoid spark conflict, we prefer to have group cognitive mapping. Since we have steps CM to VT (VCM and EMM), it would be beneficial to study at which point in these steps grouping should occur, and future studies could investigate the optimal timing and methodology for these groupings. Additionally, since this research focused on the concept space, it would be valuable to explore how the knowledge space can be demonstrated, providing a fuller picture of the interplay between known and potential solutions in decision-making processes. Lastly, in our research, we did not use fuzzy cognitive mapping, which typically assigns weights to nodes. In our framework, we assigned weights as well, but they were identical, with a value of 1. A potential direction for future research could involve exploring the use of different weights for the arrows, allowing for a more nuanced representation of relationships between nodes.

In summary, this thesis has advanced the fields of conflict transformation, decision support, and policy design by proposing a novel and adaptable framework. Future research should focus on refining the tools for generating alternatives, exploring the intermediate steps in cognitive map to value tree transformation, and expanding the applicability of the framework to different contexts and sectors. With additional validation, this methodology has the potential to foster innovation in decision-making, not only in conflict scenarios but also in addressing complex public policy challenges.

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Théorie de la Décision, Théorie du Design et Conception Innovante de Politiques pour la Transformation et la Gestion des Conflits

Motivations

La thèse commence par aborder la nature inhérente des conflits dans les interactions entre individus, organisations et États. Bien que les conflits puissent servir de catalyseurs pour l'innovation, leur escalade violente entraîne destruction et pertes. Les méthodes traditionnelles de résolution des conflits échouent souvent à gérer la complexité et la multifacette des conflits contemporains, ce qui souligne la nécessité d'approches interdisciplinaires innovantes.

Cette recherche vise à développer des méthodologies intégrant la théorie de la décision, les méthodes de structuration de problèmes (*Problem Structuring Methods* ou PSMs) et la théorie du design pour transformer les conflits en opportunités de dialogue constructif et de solutions durables. Elle va au-delà de la gestion des conflits pour aborder des défis plus larges de POLITIQUES PUBLIQUES, en mettant l'accent sur l'innovation, l'adaptabilité et la conception participative dans l'élaboration des politiques.

Perspective théorique

Cette thèse explore trois dimensions principales :

1. **Amélioration des PSMs** : Combiner les cartes cognitives et les arbres de valeurs pour la transformation des conflits et la prise de décision complexe, en passant des applications descriptives à des applications orientées design.

2. **Fusion de la théorie de la décision avec la théorie du design** : S'appuyant sur la théorie Concept-Connaissance (*Concept-Knowledge* ou C-K), cette dimension se concentre sur la génération d'alternatives innovantes.

3. **Intégration de la théorie du design dans la conception des politiques publiques** : En introduisant un cadre participatif, la thèse innove dans la formulation de politiques pour la transformation des conflits et les défis des politiques publiques plus larges.

La recherche souligne les limites des PSMs traditionnels, qui sont uniquement descriptifs, et insiste sur le besoin de méthodes permettant de concevoir des solutions innovantes et exploitables. L'intégration des cartes cognitives et des arbres de valeurs vise à combler l'écart entre la compréhension des problèmes complexes et la création d'alternatives viables.

Études de cas

Deux études de cas démontrent l'application pratique des méthodologies proposées :

1. **Le conflit kurdo-turc** : *Focus* : Un scénario de conflit déclaré où des cartes cognitives ont été créées séparément pour chaque partie. *Résultat* : En intégrant les cartes cognitives avec les arbres de valeurs, des alternatives innovantes de résolution de conflit ont été générées, mettant en avant des terrains d'entente et des zones de compromis.

2. **Gestion des eaux souterraines en Tunisie** : *Focus* : Un conflit non déclaré où les intérêts de diverses parties prenantes ont été représentés. *Résultat* : Des cartes cognitives agrégées ont été utilisées pour éviter d'exacerber les tensions, et un arbre de valeurs a été développé pour proposer des politiques innovantes. Cette approche a validé l'applicabilité de la méthodologie dans un contexte collaboratif et non conflictuel.

Enfin, la thèse formalise la transformation des arbres de valeurs en arbres conceptuels pour démontrer leur utilité au-delà de la transformation des conflits. Cette méthodologie a été testée avec l'exemple d'ALICE afin de généraliser son application aux problèmes complexes de prise de décision.

Revue de littérature

La revue de littérature commence par une exploration de la transformation et de la gestion des conflits, en positionnant les conflits comme inhérents aux interactions humaines, résultant d'intérêts et de perspectives divergents. Bien que le conflit puisse stimuler l'innovation et la créativité, son escalade violente mène souvent à la destruction et échoue à résoudre les causes profondes. Les contributions fondamentales, telles que les travaux de Galtung sur la recherche de la paix (1969, 1976, 2007), mettent en évidence la nécessité de dépasser la « paix négative » — définie comme la simple absence de violence — pour atteindre une « paix positive », favorisant la coopération et l'intégration. Galtung introduit également les concepts de violence structurelle et personnelle, soulignant la nécessité de traiter les injustices structurelles sous-jacentes qui alimentent les conflits. En s'appuyant sur ces bases, Rogers et Ramsbotham (1999) soulignent l'importance des approches interdisciplinaires, combinant les perspectives de la sociologie, de la psychologie et de l'anthropologie pour comprendre la nature multifacette des conflits. Cette approche met également en lumière la valeur des méthodes non violentes de transformation des conflits, visant à créer des relations équitables et des solutions durables.

Les défis de gestion des conflits complexes ont conduit au développement de méthodologies innovantes telles que les *Problem Structuring Methods* (PSMs). Ces méthodes sont apparues comme une alternative à la recherche opérationnelle traditionnelle (*Operational Research*, OR), qui suppose que les problèmes sont bien structurés et déterministes (Rosenhead, 1996). Les PSMs permettent de traiter la complexité des situations réelles impliquant de multiples parties prenantes, de l'incertitude et des intérêts divergents. Parmi ces méthodes, la cartographie cognitive et les arbres de valeurs se distinguent par leur capacité à structurer et analyser les problèmes complexes. La cartographie cognitive, inspirée à l'origine de la *Theory of Personal Constructs* de Kelly (1955), capture les perceptions des parties prenantes à travers des représentations visuelles de leur compréhension du problème. Eden (1988) a adapté cette approche à la structuration des problèmes, en mettant l'accent sur son pouvoir descriptif pour articuler les valeurs, les croyances et les objectifs des parties prenantes. Cette méthode s'est révélée particulièrement utile pour révéler les perspectives des parties prenantes et faciliter le dialogue, ce qui en fait un outil clé dans la transformation et la gestion des conflits.

Cependant, bien que la cartographie cognitive soit efficace sur le plan descriptif, elle est limitée dans ses capacités prescriptives, car elle ne propose pas intrinsèquement de solutions ou de stratégies d'action. Cette lacune est comblée par les arbres de valeurs, qui sont ancrés dans la pensée orientée sur les valeurs de Keeney (1992). Les arbres de valeurs priorisent les valeurs des parties prenantes par rapport aux alternatives existantes, structurant les objectifs de manière hiérarchique pour encourager des solutions innovantes et axées sur les valeurs. Cette approche déplace l'attention de la résolution de problèmes vers l'exploration des valeurs, permettant aux parties prenantes d'identifier de nouvelles opportunités et stratégies. Malgré leurs points forts, les arbres de valeurs rencontrent des défis dans leur application pratique en raison du manque de méthodologie standardisée pour leur construction. Des problèmes tels que la perte d'information, l'asymétrie et la difficulté à capturer toute la complexité du problème ont été relevés (Jacobi et Hobbs, 2007 ; Pöyhönen et Hämäläinen, 1998).

La littérature met en évidence la synergie potentielle entre la cartographie cognitive et les arbres de valeurs, suggérant que leur intégration peut combler l'écart entre la compréhension des problèmes et la conception de solutions. Marttunen et al. (2017) insistent sur la nécessité de combiner ces méthodes pour créer un cadre global qui exploite la richesse descriptive des cartes cognitives avec l'orientation prescriptive structurée des arbres de valeurs. Cette intégration s'aligne également sur des appels plus larges en faveur d'une approche orientée design pour la prise de décision, qui met l'accent sur la création de solutions exploitables plutôt que sur une simple analyse des problèmes (Ferretti et al., 2019). Une telle approche est particulièrement pertinente dans la transformation des conflits, où des solutions innovantes et adaptées au contexte sont souvent nécessaires.

En plus de discuter des bases théoriques de la cartographie cognitive et des arbres de valeurs, la revue de littérature examine leurs applications pratiques dans divers domaines. La cartographie cognitive a été largement utilisée dans la gestion stratégique, l'analyse des politiques publiques et la prise de décision environnementale. Par exemple, Ackermann et Eden (2005) démontrent son utilité dans l'identification des risques des projets, tandis que Silva et al. (2019) l'appliquent pour évaluer l'ouverture à l'innovation dans les petites et moyennes entreprises. En matière de politiques publiques, la cartographie cognitive a été employée pour structurer les perspectives complexes des parties prenantes et faciliter la prise de décision collaborative (Pluchinotta et al., 2019a). Les applications environnementales incluent des études sur la gestion agroforestière (Isaac et al., 2009) et la gestion participative des ressources naturelles (Hjortsø, 2004), où les cartes cognitives ont été utilisées pour capturer les points de vue diversifiés des parties prenantes et promouvoir des pratiques durables.

La cartographie cognitive floue (*Fuzzy Cognitive Mapping*, FCM), une variante de la cartographie cognitive introduite par Kosko (1986), étend la méthode en incorporant des relations causales et des poids numériques pour représenter la force des influences entre concepts. La FCM a été appliquée dans des évaluations d'impact socio-économique, la modélisation écologique et l'analyse des politiques, offrant une approche plus dynamique et quantitative pour comprendre les systèmes complexes (Çoban et Seçme, 2005 ; Gupta et Gupta, 2017). Cependant, la thèse critique la FCM pour sa dépendance aux relations causales, qui ne s'alignent pas toujours avec les perspectives subjectives des parties prenantes. Elle privilégie plutôt la cartographie cognitive de type Eden, qui met l'accent sur la structuration descriptive des problèmes basée sur les perceptions des parties prenantes, ce qui la rend plus adaptée à la transformation des conflits.

Les arbres de valeurs, quant à eux, ont été appliqués dans l'analyse multicritère (*Multi-Criteria Decision Analysis*, MCDA) pour évaluer et prioriser les alternatives sur la base des valeurs des parties prenantes (Keeney et McDaniels, 1992). Mendoza et Prabhu (2009) intègrent la cartographie cognitive avec l'analyse des arbres de valeurs pour améliorer la prise de décision participative, tandis que Ferretti (2016) combine les arbres de valeurs avec la MAVT (*Multi-Attribute Value Theory*) pour l'évaluation des politiques publiques. Ces applications démontrent la polyvalence des arbres de valeurs dans la structuration des problèmes de décision complexes et le renforcement de l'engagement des parties prenantes.

Malgré ces avancées, la littérature identifie un manque crucial de formalisation dans la transition des cartes cognitives aux arbres de valeurs. Les approches actuelles manquent d'un cadre systématique pour intégrer les idées descriptives des cartes cognitives avec la structure hiérarchique des arbres de valeurs. Cette thèse s'attaque à cette lacune en proposant une méthode algorithmique pour transformer les cartes cognitives en arbres de valeurs, assurant un processus fluide et reproductible. Cette formalisation est jugée améliorer l'utilité pratique des PSMs tant dans la transformation des conflits que dans des contextes décisionnels plus larges.

La revue de littérature conclut en soulignant l'importance d'intégrer les PSMs avec la théorie du design pour innover dans la conception des politiques publiques. La théorie du design, en particulier la théorie Concept-Connaissance (*Concept-Knowledge* ou C-K) introduite par Hatchuel et Weil (2003), offre un cadre structuré pour générer des solutions nouvelles en explorant l'interaction entre concepts et connaissances. La thèse s'appuie sur ces fondations en proposant une méthodologie qui combine cartographie cognitive, arbres de valeurs et théorie C-K pour élargir l'éventail des alternatives politiques et favoriser la résolution collaborative des problèmes. En appliquant cette approche intégrée à la transformation des conflits et aux politiques publiques, la recherche vise à contribuer à des pratiques décisionnelles plus efficaces et durables.

Notre proposition

Introduction

La proposition centrale de cette thèse consiste à formaliser la transition entre les cartes cognitives et les arbres de valeurs, en introduisant des étapes intermédiaires pour préserver la richesse des données tout en structurant les objectifs de manière hiérarchique. Cette approche est soutenue par des définitions formelles et des algorithmes qui assurent un processus systématique et reproductible.

Définitions formelles

Définition 1 : Carte cognitive
Une *carte cognitive* est un graphe orienté $G = (A, R)$, où A est l'ensemble des nœuds représentant des concepts et R est l'ensemble des arcs décrivant les relations entre ces concepts. Chaque relation $r \in R$ peut être positive (r^+) ou négative (r^-), représentant respectivement une influence positive ou négative.

Définition 2 : Carte cognitive de valeurs (VCM)
Une *carte cognitive de valeurs* (VCM) est une extension de la carte cognitive, où chaque concept $x \in A$ est associé à une valeur $v(x)$ représentant son importance pour les parties prenantes. Cette structure intermédiaire permet de réorganiser les relations en fonction des priorités et des objectifs des acteurs.

Définition 3 : Carte des fins et des moyens (EMM)
Une *carte des fins et des moyens* (EMM) est un graphe orienté $G' = (A', R')$, dérivé de la VCM, où A' est l'ensemble des nœuds représentant les fins et les moyens, et R' est l'ensemble des arcs indiquant les relations hiérarchiques entre eux. Les nœuds de A' sont classifiés en deux catégories : - *Fins* : objectifs finaux souhaités. - *Moyens* : actions ou étapes nécessaires pour atteindre ces fins.

Définition 4 : Arbre des valeurs
Un *arbre des valeurs* est une représentation hiérarchique dérivée de l'EMM, où les objectifs sont organisés en niveaux, les objectifs finaux apparaissant au sommet et les moyens à la base. Chaque nœud de l'arbre est relié à ses descendants par des arcs représentant des relations de dépendance.

Algorithme pour la construction d'une EMM

Construction d'une EMM (Carte des Fins et des Moyens) 1. Importer A
2. Importer R^+ et R^-
3. Créer $\bar{A}$
4. Étiqueter x_o
5. $\forall x \in A : \exists r^+(x, x_o) \rightarrow \pi(x_o, x)$ et éliminer $r^+(x, x_o)$
6. $\forall x \in A : \exists r^-(x, x_o) \rightarrow \pi(x_o, \neg x)$ et éliminer $r^-(x, x_o)$
7. Étiqueter tous les x pour lesquels $\pi(x_o, x)$
8. Étiqueter tous les $\neg x$ pour lesquels $\pi(x_o, \neg x)$
9. $\forall x$ étiqueté : $\exists r^+(y, x) \rightarrow \pi(x, y)$ et éliminer $r^+(y, x)$

10. $\forall x$ étiqueté : $\exists r^-(y,x) \to \pi(x,\neg y)$ et éliminer $r^-(y,x)$
11. $\forall \neg x$ étiqueté et x non étiqueté : $\exists r^+(y,x) \to \pi(\neg x,\neg y)$ et éliminer $r^+(y,x)$
12. $\forall \neg x$ étiqueté et x non étiqueté : $\exists r^-(y,x) \to \pi(\neg x,y)$ et éliminer $r^-(y,x)$
13. Étiqueter tous les y pour lesquels $\pi(x,y)$ ou $\pi(\neg x,y)$
14. Étiqueter tous les $\neg y$ pour lesquels $\pi(x,\neg y)$ ou $\pi(\neg x,\neg y)$
15. Si aucun $r^+(x,y)$ ou $r^-(x,y)$ n'existe, arrêter
16. Éliminer tous les nœuds non étiquetés.
17. Pour tous les cycles, s'il existe un chemin le plus long unique, éliminer le dernier arc.
18. S'il y a plusieurs chemins les plus longs de la même longueur, soumettre au client le choix de l'arc à éliminer.
19. Sinon, éliminer un arc du cycle arbitrairement.
20. Fin.

De l'EMM à l'Arbre des Valeurs (VT)

La transformation de la Carte des Fins et des Moyens (EMM) vers un Arbre des Valeurs (VT) constitue une étape cruciale pour structurer les objectifs identifiés dans une hiérarchie claire. À partir des relations définies dans l'EMM, les fins et les moyens sont réorganisés pour représenter les dépendances et priorités sous une forme arborescente.

Tout d'abord, les objectifs finaux identifiés dans l'EMM sont placés au sommet de la hiérarchie en tant que *fins principales*. Ensuite, les moyens nécessaires pour atteindre chaque objectif sont connectés comme branches descendantes. Chaque relation dans l'EMM est analysée pour garantir qu'elle reflète correctement la dépendance fonctionnelle entre les éléments. Enfin, des regroupements peuvent être réalisés pour simplifier la structure, notamment en fusionnant des objectifs similaires ou interdépendants.

Cette transformation donne naissance à un Arbre des Valeurs qui permet de clarifier les priorités, tout en conservant la richesse des données initiales issues de l'EMM.

De l'Arbre des Valeurs (VT) à l'Arbre Conceptuel (CT)

L'étape suivante consiste à utiliser l'Arbre des Valeurs (VT) comme base pour générer un Arbre Conceptuel (CT) à l'aide de la théorie Concept-Connaissance (C-K). Cette transformation ne se limite pas à structurer des relations hiérarchiques existantes, mais vise également à explorer des alternatives innovantes à travers la création de nouveaux concepts.

Pour effectuer cette transformation, chaque nœud de l'Arbre des Valeurs est examiné sous l'angle des connaissances disponibles (*base de connaissances*). À partir de ces connaissances, des idées nouvelles sont générées en explorant des relations inédites ou des combinaisons innovantes entre les objectifs et moyens identifiés. L'arbre est alors enrichi par l'ajout de branches représentant ces nouveaux concepts. Ce processus s'appuie sur les principes de la théorie C-K, qui permettent de naviguer entre les espaces conceptuel et de connaissances pour proposer des solutions innovantes.

Enfin, l'Arbre Conceptuel résultant est validé avec les parties prenantes afin de garantir sa pertinence et son applicabilité dans le contexte du problème étudié. Cette validation permet également d'identifier les concepts les plus prometteurs pour une mise en œuvre effective.

Exemple d'application et généralisation

Cette méthodologie a été testée dans plusieurs contextes, notamment avec l'exemple d'Alice, où l'Arbre des Valeurs a servi de base pour explorer des alternatives décisionnelles dans un problème complexe. Cet exemple a permis de démontrer que la méthodologie peut être généralisée au-delà de la transformation des conflits pour inclure des problématiques plus larges, telles que la gestion de problèmes complexes et la prise de décision collaborative.

Conclusion

La transformation de l'EMM vers un VT, puis d'un VT vers un CT, constitue une avancée méthodologique majeure pour passer de la compréhension descriptive d'un problème à la conception de solutions innovantes et applicables. Ce cadre propose une approche systématique qui s'applique aussi bien à la transformation des conflits qu'à d'autres contextes décisionnels complexes.

Validation de la proposition

Les méthodologies proposées ont été testées à travers deux études de cas distinctes :

1. **Conflit kurdo-turc** : La construction de cartes cognitives pour chaque partie a permis de révéler des terrains d'entente et de générer des alternatives de résolution innovantes grâce à l'arbre des valeurs.

2. **Gestion des eaux souterraines en Tunisie** : Une carte cognitive agrégée a été utilisée pour éviter l'escalade des tensions et proposer des poli-

tiques durables, validant l'applicabilité du cadre dans des contextes collaboratifs.

En conclusion, cette proposition formalise une méthode innovante pour structurer des problèmes complexes, en combinant cartes cognitives, arbres de valeurs, et design participatif.

Étude de cas 1 : Le conflit turco-kurde

Résumé

Le conflit turco-kurde constitue l'un des conflits les plus anciens et les plus complexes de la région. Marqué par des décennies de tensions politiques, culturelles et socio-économiques, il oppose l'État turc à la population kurde, une communauté réclamant des droits culturels, linguistiques et politiques. Ce conflit déclaré est souvent exacerbé par des divergences idéologiques et des perceptions mutuelles négatives, ce qui en fait un terrain propice à la mise en œuvre de méthodologies innovantes pour la transformation des conflits.

Méthodologie

Afin de mieux comprendre les dynamiques du conflit, des cartes cognitives distinctes ont été créées pour chaque partie impliquée : l'État turc et les représentants kurdes. Ces cartes cognitives capturent les perceptions, objectifs et obstacles perçus par chaque groupe, offrant une représentation visuelle et explicite de leurs priorités respectives.

Le processus de création des cartes cognitives s'est déroulé de manière itérative et participative. Chaque étape a impliqué la collecte d'informations qualitatives provenant de discours politiques, de documents officiels et de publications académiques, ainsi que l'analyse de points de vue issus des médias et des déclarations publiques. Cette approche a permis d'assurer que les perspectives des deux parties étaient représentées de manière équilibrée et que leurs préoccupations fondamentales étaient prises en compte.

Processus de transformation

Les cartes cognitives créées pour chaque partie ont ensuite été transformées en arbres de valeurs. Cette transformation s'est effectuée en plusieurs étapes :

— **Identification des valeurs fondamentales** : Les concepts-clés présents dans les cartes cognitives ont été analysés pour extraire les valeurs sous-jacentes. Ces valeurs incluent des notions comme la "paix", la "sécurité culturelle" pour les Kurdes et la "préservation de l'intégrité territoriale" pour l'État turc.

— **Hiérarchisation des objectifs** : Les relations entre les concepts ont été organisées sous forme d'une hiérarchie, distinguant les objectifs finaux (fins) des moyens nécessaires pour les atteindre. Par exemple, le "développement économique" a été identifié comme un moyen partagé pour favoriser une coexistence pacifique.

— **Analyse des divergences et convergences** : Les arbres de valeurs ont révélé à la fois des zones de convergence, comme l'intérêt pour la stabilité économique, et des divergences profondes, notamment sur la reconnaissance des droits linguistiques.

Cette transformation a permis de clarifier les priorités des deux parties tout en identifiant les points de friction spécifiques nécessitant une attention particulière lors des négociations.

Résultats

L'intégration des cartes cognitives et des arbres de valeurs a permis de générer de nouvelles alternatives pour la résolution du conflit. Les résultats incluent :

— **Identification de valeurs communes** : Des éléments comme le "développement économique", la "sécurité" et la "réduction des tensions" ont émergé comme valeurs partagées, offrant une base pour le dialogue.

— **Propositions innovantes** : Par exemple, l'idée de mettre en place des politiques de décentralisation a été explorée comme un compromis possible pour répondre aux besoins des Kurdes sans compromettre l'unité de l'État turc.

— **Réduction des tensions** : En clarifiant les objectifs et en mettant en évidence les convergences, la méthodologie a contribué à réduire les malentendus entre les parties, créant un espace plus propice à la négociation.

Importance et implications

Cette étude de cas démontre la capacité de la méthodologie proposée à aborder des conflits complexes et profondément enracinés. En combinant cartes cognitives et arbres de valeurs, elle offre un cadre structuré pour transformer des relations conflictuelles en opportunités de dialogue et de coopération. Cette approche montre également comment des méthodologies innovantes peuvent être appliquées pour explorer des solutions viables dans des contextes où les approches traditionnelles de résolution des conflits ont échoué.

Enfin, le conflit turco-kurde met en lumière la nécessité de solutions participatives et contextuelles, où chaque partie peut exprimer ses préoccupations et voir ses priorités reflétées dans le processus de négociation.

Étude de cas 2 : La gestion des eaux souterraines en Tunisie

Résumé

La gestion des ressources en eaux souterraines en Tunisie représente un exemple typique de conflit latent, où des intérêts divergents entre les parties prenantes – agriculteurs, autorités locales, gouvernements et organisations environnementales – exacerbent les tensions autour de l'utilisation et de la préservation des ressources hydriques limitées. Contrairement au conflit turco-kurde, ce conflit n'est pas explicitement déclaré mais repose sur des déséquilibres systémiques. Cette étude de cas illustre l'applicabilité de la méthodologie proposée dans un contexte de conflit non déclaré, mettant en évidence son utilité pour structurer les enjeux et proposer des politiques durables.

Méthodologie

La méthodologie adoptée pour cette étude se concentre sur l'identification et la structuration des perspectives des différentes parties prenantes impliquées dans la gestion des eaux souterraines. Le processus a été mené en trois étapes principales :

- **Cartes cognitives agrégées** : Contrairement au cas turco-kurde, où des cartes distinctes ont été élaborées pour chaque partie, une carte cognitive unique a été construite pour représenter l'ensemble des perspectives des parties prenantes. Cette carte capture les objectifs communs, les préoccupations spécifiques et les relations conflictuelles entre les acteurs.
- **Collecte des données** : Les données ont été obtenues à partir d'entretiens, de documents officiels sur la politique de gestion de l'eau et d'études académiques sur la région tunisienne. Cela a permis de représenter les intérêts des petits exploitants agricoles, des autorités

gouvernementales, et des organisations environnementales de manière équilibrée.

— **Analyse des priorités et des tensions** : Les objectifs des différentes parties, tels que l'augmentation des rendements agricoles, la conservation des ressources naturelles et la prévention de la surexploitation des nappes phréatiques, ont été identifiés et cartographiés.

Transformation vers un Arbre des Valeurs (VT)

À partir de la carte cognitive agrégée, un Arbre des Valeurs a été construit pour structurer les objectifs identifiés et révéler les dépendances entre les moyens et les fins. Le processus s'est déroulé comme suit :

— Les objectifs finaux, tels que la "durabilité des ressources en eau" et la "sécurité alimentaire", ont été placés au sommet de l'arbre.

— Les moyens nécessaires pour atteindre ces fins, comme "l'introduction de techniques d'irrigation efficaces" ou "la réglementation stricte de l'extraction des eaux souterraines", ont été classés sous ces objectifs finaux.

— Les relations entre les objectifs ont été hiérarchisées, mettant en évidence des dépendances critiques et des synergies potentielles entre les différentes parties prenantes.

— L'arbre final a été validé avec les parties prenantes pour garantir qu'il reflétait leurs priorités et préoccupations.

Résultats

L'intégration des cartes cognitives agrégées et des arbres de valeurs a permis de produire plusieurs résultats significatifs :

— **Mise en évidence des objectifs communs** : Des objectifs tels que la "préservation des nappes phréatiques" et la "résolution des conflits entre agriculteurs et autorités" ont été identifiés comme des priorités partagées par les acteurs.

— **Solutions politiques innovantes** : La création d'un fonds de compensation pour les agriculteurs réduisant leur consommation d'eau et l'encouragement des cultures moins consommatrices d'eau ont été proposées comme solutions viables.

— **Réduction des tensions** : La méthodologie a permis de clarifier les divergences perçues et de mettre en avant des zones de convergence, contribuant à une meilleure collaboration entre les acteurs.

Importance et implications

Cette étude de cas démontre l'efficacité de la méthodologie proposée dans un contexte où les conflits sont latents mais systémiques. L'approche adoptée a permis non seulement de structurer les problématiques complexes mais également de fournir un cadre pour explorer des solutions durables et innovantes.

En outre, l'utilisation d'une carte cognitive agrégée montre que la méthodologie peut s'adapter à des contextes où les tensions ne sont pas explicitement déclarées. Cela élargit la portée des applications potentielles de cette méthodologie, rendant son utilisation pertinente dans des domaines tels que la gestion des ressources naturelles, les politiques environnementales et la gouvernance participative.

1 Intégration de la théorie du design dans la conception des politiques publiques

Ce chapitre explore l'intégration de la théorie du design, en particulier la théorie Concept-Connaissance (C-K), dans la conception des politiques publiques. L'objectif est de proposer une méthodologie innovante pour structurer et générer des alternatives en matière de conception des politiques, tout en abordant des problématiques complexes. En associant les cartes cognitives et les arbres de valeurs à la théorie du design, nous démontrons comment ces outils peuvent enrichir la prise de décision.

1.1 Utilisation de l'arbre de valeurs pour structurer l'arbre conceptuel : Le cas de la Tunisie

Dans le cadre de l'étude de cas sur la gestion participative des eaux souterraines en Tunisie, l'arbre de valeurs a été utilisé pour structurer un arbre conceptuel. Ce processus s'est appuyé sur la méthodologie P-KCP (Politiques, Connaissances, Concepts, Propositions) basée sur la théorie C-K. Voici les étapes clés :

1. **Construction de la carte cognitive agrégée** : Une carte cognitive regroupant les perspectives des parties prenantes a été construite pour identifier les valeurs partagées et les tensions spécifiques.
2. **Transformation en arbre de valeurs** : À partir des concepts identifiés dans la carte cognitive, un arbre de valeurs hiérarchique a été

créé pour structurer les objectifs en fonction des valeurs des parties prenantes.

3. **Passage de l'arbre de valeurs à l'arbre conceptuel** : L'arbre conceptuel a été développé en enrichissant les branches de l'arbre de valeurs à travers des itérations entre l'espace des connaissances (K) et l'espace conceptuel (C). Cela a permis de générer des alternatives politiques innovantes tout en validant leur faisabilité dans l'espace K.

Cette méthodologie a permis d'identifier des solutions novatrices et adaptées aux enjeux de gestion des eaux souterraines, tout en favorisant une collaboration renforcée entre les parties prenantes.

2 Exemple d'Alice

L'exemple d'Alice illustre l'application de la méthodologie pour résoudre un problème fictif. Cet exemple ne relève pas directement de la transformation des conflits, mais il permet de tester la généralité de notre approche. Voici le déroulement :

1. **Définition du problème dans l'espace K** : Alice est confrontée à un obstacle à franchir (par exemple, un ravin). Les solutions traditionnelles incluent des ponts ou des échelles.
2. **Exploration dans l'espace C** : De nouveaux concepts émergent, tels que "Alice peut voler" ou "Alice peut construire un passage temporaire". Ces idées sont explorées comme des alternatives créatives.
3. **Validation dans l'espace K** : Les concepts sont testés pour leur faisabilité, par exemple en utilisant un planeur ou des matériaux légers.
4. **Génération de l'arbre conceptuel** : Un arbre conceptuel est construit pour organiser les solutions possibles de manière hiérarchique, en intégrant les relations entre les concepts et les connaissances.

Cet exemple montre comment la théorie C-K, combinée à un arbre de valeurs, permet de structurer et de valider des alternatives innovantes dans des contextes variés.

3 Discussion

L'intégration de la théorie C-K avec les méthodes de structuration des problèmes (PSMs) offre des avantages significatifs :

— Elle favorise une exploration approfondie de l'espace conceptuel, stimulant la créativité.

— Elle fournit un cadre systématique pour valider les solutions dans l'espace des connaissances.
— Elle s'adapte à des contextes complexes, allant de la gestion des conflits à la conception de politiques publiques.

Conclusion

En combinant les cartes cognitives, les arbres de valeurs et la théorie C-K, ce chapitre propose une méthodologie robuste pour concevoir des politiques publiques novatrices et adaptées aux défis contemporains. Les études de cas, y compris l'exemple d'Alice, démontrent la flexibilité et l'efficacité de cette approche dans des contextes variés.

Exemple d'Alice : Transformation en Arbre Conceptuel (CT)

Cet exemple illustre comment un **Arbre de Valeurs (VT)** peut être transformé en un **Arbre Conceptuel (CT)** en utilisant une approche méthodologique innovante. L'objectif est de générer des alternatives créatives et adaptées aux contraintes spécifiques, dépassant les limites des analyses décisionnelles traditionnelles. Alice, une doctorante, est confrontée à des contraintes budgétaires pour assister à une conférence prestigieuse, avec un faible taux d'acceptation des articles. Son objectif principal est la **satisfaction personnelle**, étroitement liée à son succès académique.

Carte Cognitive Initiale (CM)

La carte cognitive identifie les principaux facteurs influençant les décisions d'Alice :
— **Satisfaction personnelle** : Valeur fondamentale et objectif final.
— **Succès académique** : Étroitement lié à la participation à des conférences et à la présentation de travaux.
— **Contraintes budgétaires et politiques du département** : Restrictions financières qui limitent ses options.
— **Reconnaissance académique** : Obtenir des opportunités futures grâce à une présence visible.

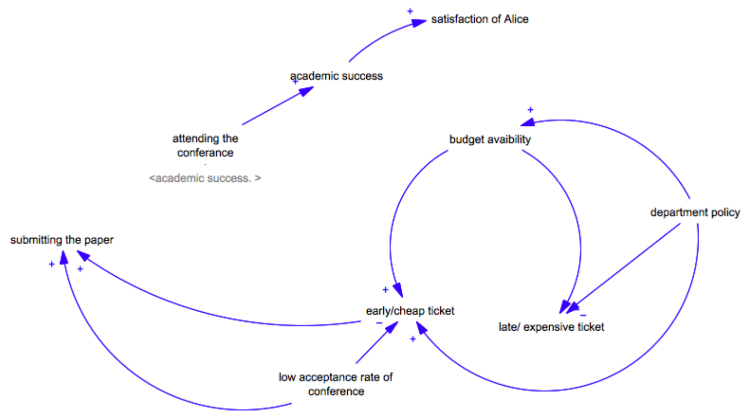

FIGURE 1 – Carte Cognitive (CM) initiale pour l'exemple d'Alice.

Transformation en Arbre de Valeurs (VT)

L'Arbre de Valeurs est créé à partir de la Carte Cognitive pour structurer les objectifs et moyens. Tous les éléments du VT sont utilisés dans la construction de l'Arbre Conceptuel (CT). Les relations dans le VT incluent :

— **Objectif final** : Satisfaction personnelle.
— **Succès académique** : Atteint par la participation à des conférences ou la publication d'articles.
— **Moyens associés** : Obtenir un financement, trouver des conférences alternatives, ou optimiser les ressources existantes.

Passage à l'Arbre Conceptuel (CT)

L'Arbre Conceptuel est généré à partir de l'Arbre de Valeurs en appliquant la théorie Concept-Connaissance (C-K). Tous les éléments de l'Arbre de Valeurs sont exploités dans l'Arbre Conceptuel, en explorant des alternatives innovantes dans l'espace conceptuel et en validant leur faisabilité dans l'espace des connaissances.

Les concepts dans l'Arbre Conceptuel incluent :

— **Alternatives pour participer à la conférence** :
  — Demander un financement au département ou à une organisation externe.
  — Publier un article dans une revue liée à la conférence, en cas de non-acceptation.

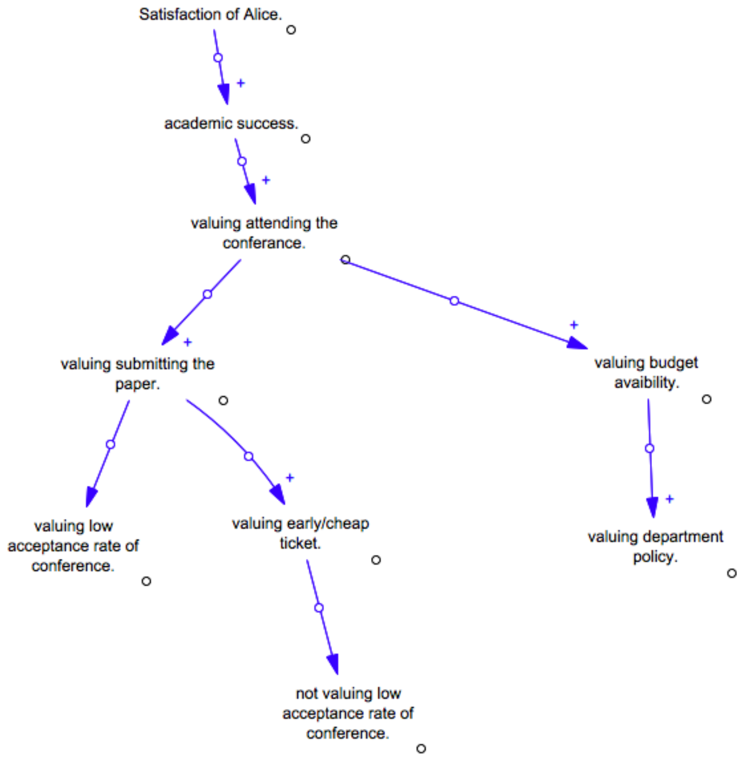

FIGURE 2 – Arbre de Valeurs (VT) pour l'exemple d'Alice.

  - Présenter dans une conférence régionale pour réduire les coûts tout en augmentant la visibilité.
- **Alternatives créatives** :
  - Trouver une collaboration pour partager les frais.
  - Explorer des options de présentation virtuelle (par exemple, via une plateforme en ligne).

Synthèse et utilisation complète des éléments du VT

Dans cet exemple, tous les éléments de l'Arbre de Valeurs ont été utilisés pour construire l'Arbre Conceptuel. Cela inclut les objectifs finaux, les moyens associés, ainsi que les relations identifiées dans le VT. Le processus démontre la capacité de la théorie C-K à générer des solutions innovantes et pratiques à partir d'une base bien structurée.

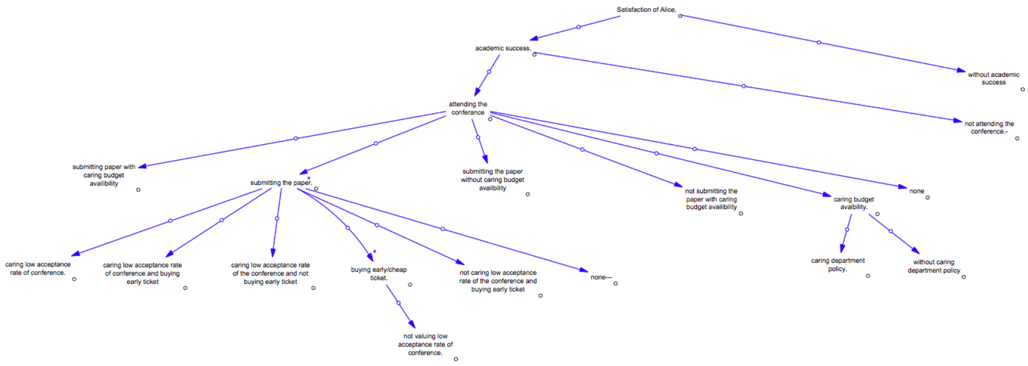

Figure 3 – Arbre Conceptuel (CT) final pour l'exemple d'Alice.

Conclusion

L'exemple d'Alice illustre la transformation réussie d'un problème complexe en opportunités créatives grâce à l'intégration des Cartes Cognitives, des Arbres de Valeurs et de la théorie Concept-Connaissance. Cette méthodologie montre son utilité pour résoudre des problématiques complexes, tant dans des contextes académiques que dans des scénarios plus larges.

Conclusion

Cette thèse propose un cadre méthodologique novateur pour la transformation des conflits et la conception des politiques publiques, en intégrant les **méthodes de structuration des problèmes (PSMs)** avec des théories formelles de design, telles que la **théorie Concept-Connaissance (C-K)**. En mobilisant deux études de cas — le conflit kurdo-turc et la gestion des eaux souterraines en Tunisie —, ce travail démontre la polyvalence et l'utilité de cette approche pour résoudre des problèmes complexes impliquant de multiples parties prenantes.

Contributions clés

Étude de cas 1 : Conflit kurdo-turc

Cette étude de cas a mis en évidence :

— L'identification des **valeurs partagées** entre les parties opposées, telles que la paix, le développement économique et la stabilité régionale.
— La détection de **zones de compromis potentiel**, facilitant un dialogue constructif entre les parties.

— L'efficacité de la méthodologie pour la résolution de **conflits déclarés**, en utilisant les cartes cognitives et les arbres de valeurs pour structurer les enjeux.

Étude de cas 2 : Gestion des eaux souterraines en Tunisie

Cette étude a validé la méthodologie dans un contexte de **conflit latent**. Les contributions incluent :

— L'identification des **priorités communes**, comme la préservation des ressources hydriques et la sécurité alimentaire.

— L'exploration de **solutions politiques innovantes**, telles que les fonds de compensation pour les agriculteurs et les systèmes d'irrigation efficaces.

— La démonstration de l'adaptabilité du cadre dans des contextes collaboratifs impliquant des tensions implicites.

Implications plus larges

Les implications de ce travail sont significatives pour plusieurs domaines :

— **Transformation des conflits** : Cette approche offre un cadre structuré pour explorer des solutions novatrices dans des situations conflictuelles complexes.

— **Conception des politiques publiques** : L'intégration de la théorie C-K permet de dépasser les cadres traditionnels et d'enrichir la prise de décision par des alternatives innovantes.

— **Prise de décision complexe** : La méthodologie contribue à une meilleure structuration des problèmes et à l'exploration systématique des espaces conceptuels et des connaissances.

Perspectives pour les recherches futures

Cette recherche ouvre des pistes pour des travaux futurs :

— **Élargissement de la méthodologie** : Appliquer le cadre proposé à d'autres types de conflits ou contextes décisionnels, tels que la gouvernance environnementale ou la gestion de crises globales.

— **Amélioration des étapes intermédiaires** : Formaliser davantage les transitions entre les cartes cognitives, les arbres de valeurs et les arbres conceptuels.

— **Intégration de nouvelles techniques** : Explorer l'utilisation de la cartographie cognitive floue ou d'autres outils pour capturer des relations pondérées et des dynamiques plus complexes.

Conclusion finale

Cette thèse démontre que l'intégration des PSMs et de la théorie C-K constitue une avancée méthodologique importante pour la transformation des conflits et la conception des politiques publiques. Les études de cas montrent que cette approche est capable de générer des solutions novatrices et durables dans des contextes variés, tout en favorisant un dialogue constructif entre les parties prenantes.

RÉSUMÉ

Cette thèse propose une approche novatrice pour la transformation des conflits et la conception des politiques, en intégrant les Méthodes de Structuration des Problèmes (PSM), les cartes cognitives et les arbres de valeurs avec la théorie du design, notamment la théorie Concept-Connaissance (C-K). La recherche vise à combler le fossé entre les méthodologies descriptives et prescriptives, offrant aux décideurs un cadre structuré pour comprendre les conflits et générer des solutions innovantes. Deux études de cas ont été utilisées pour tester et valider cette approche : le conflit kurdo-turc et la gestion des eaux souterraines en Tunisie. Dans le premier cas, la méthode a été testée en identifiant des valeurs partagées entre les parties en conflit et en mettant en lumière des compromis potentiels. La deuxième étude a validé l'approche en utilisant la structure supérieure de l'arbre de valeurs pour construire un arbre de concepts, aboutissant à des solutions politiques consensuelles et actionnables. De plus, un deuxième algorithme a été développé pour formaliser la transformation des arbres de valeurs en arbres de concepts, testé dans l'exemple d'Alice afin de généraliser l'applicabilité de la méthode au-delà de la résolution de conflits vers des problèmes décisionnels complexes. La contribution clé de cette thèse réside dans la formalisation d'un processus qui transforme les cartes cognitives en arbres de valeurs, offrant aux décideurs une méthode reproductible pour identifier un terrain d'entente et concevoir des alternatives innovantes. L'intégration des arbres de valeurs avec la théorie C-K permet de générer de nouvelles solutions en reliant l'espace de connaissances et l'espace de concepts. Avec un développement supplémentaire, cette méthodologie pourrait apporter une contribution significative à la résolution des conflits et à la conception des politiques publiques dans divers scénarios complexes et multi-acteurs.

MOTS CLÉS

La prise de décision, Transformation et gestion des conflits, Conception de la politique, Recherche opérationnelle

ABSTRACT

This thesis presents a novel approach to conflict transformation and policy design by integrating Problem Structuring Methods (PSMs), cognitive maps, and value trees with design theory, particularly Concept-Knowledge (C-K) theory. The research aims to bridge the gap between descriptive and prescriptive methodologies, offering decision-makers a structured framework to understand conflicts and generate innovative solutions. Two case studies are used to test and validate this approach: the Kurdish-Turkish conflict and groundwater management in Tunisia. In the first case study, the method was tested by identifying shared values between conflicting parties and highlighting areas of potential compromise. The second case study validated the approach by using the top structure of the value tree to construct a concept tree, resulting in actionable and consensus-driven policy solutions. Additionally, a second algorithm was developed to formalize the transformation of value trees into concept trees, and this was applied in the Alice example to generalize the method's applicability beyond conflict resolution to complex decision problems. The key contribution of this thesis is the formalization of a process that transforms cognitive maps into value trees, offering decision-makers a replicable method for identifying common ground and designing innovative alternatives. The integration of value trees with C-K theory allows for the generation of new solutions by bridging the gap between the knowledge space and the concept space. With further development, this methodology has the potential to significantly contribute to both conflict resolution and public policy design in a variety of complex, multi-stakeholder scenarios.

KEYWORDS

Decision making, Conflict Transformation and Management, Policy design, Operational research