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Integrating Problem Structuring Methods And Concept-Knowledge Theory For An Advanced Policy Design: Lessons From A Case Study In Cyprus

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Abstract. Evidence suggests that policies largely fail, due, on the one side, to a simplification of the uncertainty and complexity associated with stakeholders' problem understanding and, on the other side, to the lack of methodologies for the innovative generation of policy alternatives. This work describes a methodology based on the integration between Problem Structuring Methods and Concept-Knowledge Theory, as mean to transform ambiguity in problem framing from barrier to enabling factor in collaborative settings. This supports the generative design process for innovative and consensual policies. The methodology was implemented for the design of water management policy in the Republic of Cyprus

Keywords: Policy analysis, Multi-stakeholder decision making, Policy analytics, Design theory, Policy Co-design, Fuzzy Cognitive Maps

1. Introduction

Policy design is an intricate challenge for policy makers as future policy outcomes are inherently uncertain (Nair & Howlett 2016). Within a decision aiding perspective (see Tsoukias 2007), policy design can be considered the result of a collective decision-making process involving multiple stakeholders for the generation of a set of policy alternatives (Pluchinotta et al. 2019a). Alternatives tend to be few and similar when the policy design process is constrained (Alexander 1982). When designing policy alternatives, a decision aiding process can bring novelty through the expansion of the solutions space (Colomi and Tsoukiàs 2018).

Especially the presence of ambiguity in problem framing among different decision- and policy-makers, as one type of uncertainty, indicates confusion among decision makers regarding which are the problems for which the policy is expected to be designed (Weick 1995). Ambiguity reflects the multiplicity of interpretations that different actors bring to a collective process (Giordano et al. 2017). Ambiguity, which can be considered as a form of uncertainty and indeterminacy (Brugnach et al. 2012; Van den Hoek et al. 2012) is ineradicable in complex decision-making processes (Jasanoff, 2007).

On the other side, the set of alternatives can be expanded also through the evolution (or integration) of problem formulations, such that stakeholders may enrich their perspectives, and establish reciprocity (Ferretti et al. 2019), recognizing the presence of ambiguity. It has been suggested that divergent frames can still yield organized collective action when the interaction frames are sufficiently aligned (Brugnach et al. 2011; Dewulf and Bouwen 2012). Though interaction mechanisms, different decision-actors tend to align their problem frames, overcoming the barriers due to the presence of ambiguity.

The problem of an advanced policy design process is shared by several research fields (i.e. policy studies, design theory, decision theory and operational research), although their intersection has not been properly investigated (see Ferretti et al., 2019). Some preliminary attempts have been proposed. For instance, Pluchinotta et al. (2019a) experimentally used one of the Design Theory

methodologies to support a formal process for the design of policy alternatives. The pilot case study created new insights and evidence, bringing together stakeholders, experts, institutional and non-institutional actors.

Within this context, this paper proposes an upgraded methodology, integrating Design Theory, specifically Concept-Knowledge (C-K) theory, and Problem structuring Methods (PSMs) for an advanced design of policy alternatives. PSMs (Rosenhead and Mingers 2001) build individual models of situations (Franco, 2013), where a model is an integrated representation of a situation that supports negotiation or develops new understanding (Smith et al. 2019). PSMs contribute to shape shared understanding and commitment across stakeholders (Ackermann, 2012) through facilitation (Franco & Montibeller, 2010), participation (Rosenhead, 1996) and stimulating dialogue (Mingers & White, 2010).

On the other side, C-K theory defines the design process as the co-evolution of two expandable spaces, a space of Concepts (C-space) and a space of Knowledge (K-space) (see Hatchuel et al. 2003, Agogu e et al. 2014b, Le Masson et al. 2017). Within a given design process, every C-space has a strong dependency on the related K-space, i.e. every element in the C-space relies on the structure and content of the Knowledge base (Hatchuel et al. 2007). In multi-stakeholder settings, developing the K-space starting from different, often conflictual problem framings, is challenging. Therefore, PSMs can support the analysis of ambiguities in problem framing, detecting similarities and differences, and therefore enhance the C-K theory effectiveness in policy design. When integrating PSMs and C-K theory, PSMs need to be adapted to the design of policy alternatives, a field of application they have not originally been developed for, and C-K theory driven tools need improved knowledge elicitation and structuring methods to account for the complexity of the K-space in policy making situations (e.g. De Marchi et al. 2016) and the ambiguity in problem framing arising in multi-stakeholders settings (Giordano et al. 2017).

The integrated and participatory policy design tool was implemented for the design of environmental policies for groundwater protection in Kokkinochoria area (Republic of Cyprus)

Within the case study, PSMs, specifically Fuzzy Cognitive Maps (FCM), were implemented to elicit and structure individual problem understandings in the area, specifically detecting and analysing differences in stakeholder concerns and interests. The C-K theory driven tool was then used to align the different problem understandings and available knowledge and enable creative development of innovative and consensual environmental policies. Building on a previous application of the C-K theory framework by Pluchinotta et al. (2019a), in the present work, the K-space expansion phase was enhanced by making decision-makers aware of the main reasons of ambiguity, while the C-space expansion was realized by accounting for the alternatives that could be implemented in order to overcome the main differences in problem framing (Giordano et al. in press).

The remainder of this paper is structured as follows. Section 2 reviews the concept of policy design. Section 3 describes the case study, while Section 4 describes and discusses the methodology and its application. Lastly section 5 discusses lessons learned.

2. Policy design

Policy design is a specific form of policy formulation based on the gathering and application of knowledge about policy tools to the development and implementation of strategies aimed at the attainment of policy ambitions (Howlett 2011). In a time when policymakers are often tasked with developing innovative solutions to increasingly complex policy problems, the need for intelligent design of policies and a better understanding of the policy formulation processes they involve has never been greater.

The concept of policy design is controversial in the field of research. Some academics suggest that policies cannot be “designed” as one would design a physical object (Dryzek et al. 1988, DeLeon 1988). Other scholars state that policies are designed and can be systematically studied and improved, similar to the way one would improve urban planning or product creation (e.g. Shon 1992, Howlett 2011). Research on policy design often responded to 1970s implementation studies

that held institutional systems responsible for policy failures (Sidney 2007). This involved answering a set of key questions such as: determining what constitutes a design process, what makes one successful, and what makes one design better than another (Howlett 2014). However, a design-oriented policy formulation contributes to the awareness of the “boundaries” of rationality (Simon 1947) of the policymaking process, in order to expand the set of policy alternatives, hoping to improve the outcome (Pluchinotta et al. 2019a).

Fields such as political science, economics, decision analysis and operational research, have developed methods aimed at addressing also the policy design, e.g. best practice analysis, consensus building activities (Bailey et al. 2016), ex-ante and ex-post evaluation (Dollery et al. 1996), public sector operational research (e.g. Larson 1981, Pollock et al. 1994, Keeney 1996), problem structuring methods (e.g. Eden 2004, Rosenhead 2006), soft system methodologies (Checkland 2000), group facilitation and participatory modelling (e.g. Vennix 1996, Voinov et al. 2016, Pagano et al. 2019), system thinking (Sterman 2000) and Multi Criteria Decision Analysis for public sector (Belton et al. 2002, Marttunen et al 2013) (for further details see Ferretti et al. 2019).

The existing formal methodologies of policy design were not originally conceived for it (Ferretti et al. 2019, Pluchinotta et al. 2019a). Researchers and practitioners use adapted methodologies without considering the emerging problems connected to the design of policy alternatives.

Firstly, policy design is context-based, and the policy transfer does not provide always satisfying outcomes. Policy design takes place within a specific historical and institutional framework that largely determines its content (e.g. May 2003). The exact processes through which policies are articulated vary by domain and reflect the differences between forms of government as well as the particular configuration of issues, actors and problems (Ingraham 1987, Howlett 2009). For instance, Bobrow and Dryzek (1987) advocate for contextual designs that explicitly incorporate values, and Weimer (1992) points out that developing truly innovative policy alternatives involves crafting designs that reflect substantive, organizational, and political contexts.

Secondly, policy design is not a linear practice. Some policies emerge from processes such as logrolling (i.e. the practice of exchanging favours), patronage or bargaining and cannot be thought of as having been formally "designed" (Howlett 2011). In some circumstances, policy design outcomes will seem highly contingent and "less rational", driven by situational logics and opportunism rather than careful deliberation and assessment (e.g. Cohen 1979, Dryzek 1983, Kingdon 1984).

Lastly, Linder and Peters (1988) argued that the abstract concept of policy design can be separated from the practical process of decision-making, in the same way as abstract architectural concept can be separated from its final spatial embodiment. In this view, policy design involves a systematic development of a set of policy alternatives by using knowledge about policy means gained from experience, and reason. This is followed by the development and adoption of a possible set of actions that are likely to succeed in attaining the predetermined policy goals (Bobrow 2006). Such a distinction allowed to orientate policy studies towards policy design, by arguing that policies can be conceptually separated from the process of policy design. Central to the policy design perspective is the notion that public policy contains a design framework of ideas and instruments to be identified and analysed (Sidney 2007).

Thus, the design orientation of policy studies allows to explore how policy design can improve the policymaking practice and to support the analysts. Specifically, policy scholars seek to reduce "randomness" of policy making by structuring the process. For example, Alexander (1982) recommended a "deliberate design stage" in which policy analysts search for policy alternatives, in order to improve policy outcomes. He argued that the systematic design of policy alternatives involves creativity, in addition to rational processes of search and discovery. Linder and Peters (1988) proposed a framework that policy analysts can use to generate, compare and match policy alternatives, resulting in a less random process of policy design. Bobrow and Dryzek (1987) proposed to search for alternatives from a wide range of policy designs (e.g. welfare economics, public choice, political philosophy), while Fischer and Forester (1993) suggested that looking at

policy dialogue could unlock policy innovation and creativity. As such, the inclusion of marginalized populations and local knowledge in the design process could potentially play an important role in policy improvement.

In conclusion, existing mainstream literature on policymaking seems to underestimate attempts to solve policy problems through policy design (Ferretti et al 2019) and, instead, focuses on design as part of the political process, something that happens in a black box (e.g. Birkland 2011), experimenting and transferring approaches e.g. derived from best practice analysis, participation and consensus building activities (Bailey et al 2016). Nevertheless, Dryzek (1983) argues, public policy's capacity to respond effectively to complex social problems could be significantly enriched by a shift in policy analysis from methods emphasising the assessment of pre-ordained and well-defined policy alternatives towards a formal policy design (Considine 2014).

This idea encourages reflection on the role of Design Theory as a new approach for the definition of innovative policy alternatives (Pluchinotta et al. 2019). In recent years there has been a growing interest in Design Theory by governments, seeking to innovate policy practices (Bailey et al 2016, Kimbell 2016). Examples of attempts made in public policy context within design-based approaches, are detectable in "policy labs" appearing in the past years: the New York Public Design Commission¹, the European Policy Lab², the UNESCO Inclusive Policy Lab³, the Dutch Mind Lab⁴, the PoliMi DESIS Lab⁵ supporting a design-driven innovation. Furthermore, the UK Policy Lab⁶ is an example of collaborative space where innovative policymaking processes are experimented. It claims to bring new policy tools and techniques to the UK government departments, helping design policies around people's experience, using data analytics and new

¹ <http://www1.nyc.gov/site/designcommission/index.page>

² <http://blogs.ec.europa.eu/eupolicylab/>

³ <http://en.unesco.org/inclusivepolicylab/>

⁴ <http://mind-lab.dk/en/>

⁵ <http://www.desisnetwork.org/>

⁶ <https://openpolicy.blog.gov.uk/category/policy-lab/>

digital tools (i.e. Open Policy Making Toolkit⁷). Lastly the European funding campaign Design for Europe⁸ introduced design thinking concepts to explore policy solutions. Several projects have been developed such as Design Policy Lab in partnership with Deep Initiative⁹, promoting European innovation policies.

However, the identified processes of policy design lack a formal approach, which limits the process of generating sets of policy alternatives. In lack of a formal description, the complex processes of building policy alternatives remain obscure. Within this context, we are interested in exploring how Design Theory can be combined with a Decision Aiding approach, in order to assist the innovative design of public policies.

3. The case study

The participative multi-methodology was implemented for supporting the design of environmental policies for groundwater (GW) protection in Kokkinochoria area (Republic of Cyprus).

3.1. The context

Similarly to all Mediterranean countries, GW resources play a major role in the water economy of Cyprus and constitute the main supply for all applications (MED-EUWI, 2007). Although in recent years the introduction of non-conventional resources has considerably reduced the GW pressure (ibid.), Cyprus remains the most water scarce country in Europe (EEA, 2007). Water is essential not only for sustaining the agricultural sector (accounting for ca. 70% of total water demand) but also for the booming tourism sector (according to some estimations 10% of total water consumption).

⁷ <https://www.gov.uk/guidance/open-policy-making-toolkit>

⁸ <http://www.designforeurope.eu/>

⁹ <http://www.designpolicy.eu/> and <http://www.deepinitiative.eu/>

The study region Kokkinochoria is situated at the South-eastern tip of the island and mostly coincides with the Kokkinochoria aquifer. The aquifer crosses all four self-administrative entities of Cyprus (the Republic, the occupied North Cyprus, the British Sovereign Territory and the UN Buffer Zone), which complicates the management of GW (Zikos and Roggero, 2012).

The aquifer is the most degraded of the island in terms of both quantity and quality of water due to over-abstraction and seawater intrusion (Figure 1). During the last decades and despite the rapidly diminishing water resources, there has been an increasing demand of water for tourism (the study area is the most popular tourist destination on the island) and for agriculture. The region mostly produces potatoes.

Alternative water sources, namely water transfer from the Western part of the Island, desalination and re-use of treated wastewater, have addressed the problem of overexploitation to some extent, but without resolving it completely. As a result, the remaining GW is so saline in most localities in Kokkinochoria that it cannot be used directly for irrigation. Instead it is mixed with the water provided by the South Water Conveyor or it is first treated by illegal small mobile desalination plants.

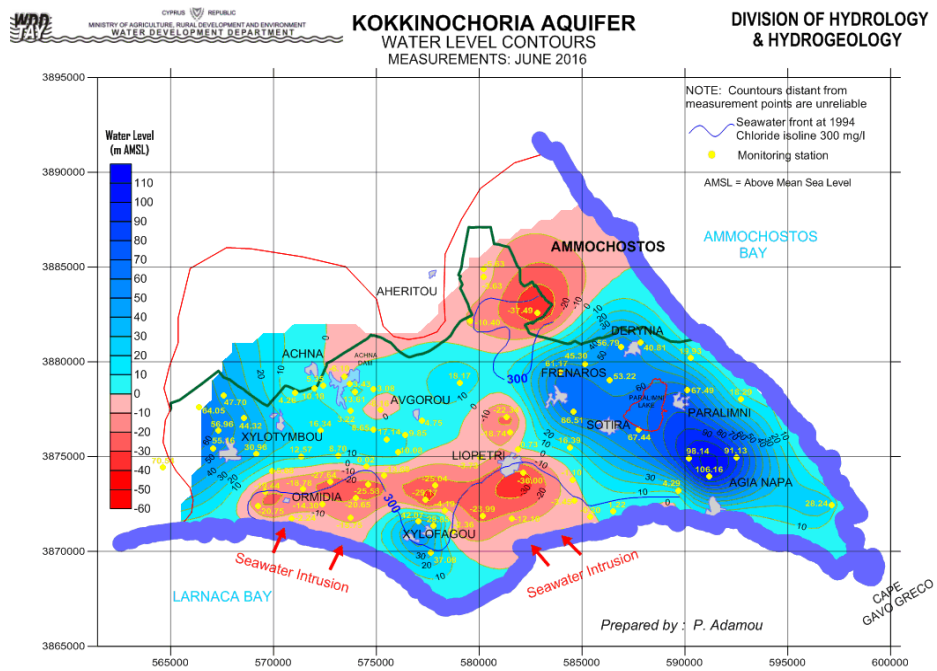


Figure 1- Kokkinochoria (CY_1) Aquifer (Water Development Department)

A number of socio-technical measures have specifically aimed at halting the overuse of GW, but with limited success. Specifically, the South Water Conveyor, the largest ever water development project undertaken by the Government of Cyprus aims at collecting and storing surplus water from the most water privileged regions of the island and convey it to areas of demand for both domestic supply and irrigation.

Kokkinochoria receives the lion’s share of the transferred water for irrigation. The project was expected to minimize GW use, a hope that gradually faded as the demand exceeded the supply. One of our interviewees explained the situation using a metaphor: “[...] the conveyor is like a bus. When it started, it was meant to have 50 seats, and the area of Kokkinochoria needed 30. What I mean to say is, the pipe network was more than sufficient. With the passage of time however, the demands increased but the supply remained the same. Right now, the bus passengers are sitting on the roof”.

Additional measures were specifically targeted at another problem characteristic for Kokkinochoria: the high number of unlicensed (illegal) boreholes. An integrative step-wise approach was adopted by the Water Development Department (WDD) aiming at first registering existing boreholes, then installing water meters and in parallel stopping the issuing of new licences. Although island-wide this effort was largely a success, the situation only had minimal impact on Kokkinochoria. The number of unlicensed boreholes remained excessively high and therefore the installation of water metres and the “no-new-licences” policy largely failed.

The following Table 1 summarizes the key policy elements of the case study:

Policy Goals	<ol style="list-style-type: none"> 1. Provide sufficient water in both quantitative and qualitative terms for domestic and agricultural use 2. Protect the GW quantity and quality in the Kokkinochoria aquifer
Policy Means	<ol style="list-style-type: none"> 1. Water transfer via the South Conveyor 2. Halt excessive water abstraction by: i) registering boreholes, ii) installing water metres iii) stopping the issuing of new licences
Policy Failures	<ol style="list-style-type: none"> 1. Limited capacity (out-dated project, increase of demand) 2. Problematic water distribution between users (not significantly taking into account differences between users and uses of water) 3. Failure to register the vast majority of boreholes (largely due to lack of trust in institutions), leading to minimum impact of water metering and the no-new licences policy

Time Framing	From several years to decades
Stakeholders	Ministry of Agriculture, Natural Resources and Environment via its National and Regional Departments (most notably the Water Development Department), Farmers, Agricultural Associations.

Table 1 - Key policy elements of the case study

3.2. The stakeholders

Several actors are involved in the decision-making processes regarding the GW use in Kokkinochoria. The National and Regional Governmental Agencies are:

- The Water Development Department (WDD) under the Ministry of Agriculture, Natural Resources and Environment has exclusive responsibility, according to the current legislation, for all water management on the island and according to the official mandate for “the protection and the rational and sustainable development and management of the country’s water resources within the framework of the Government of Cyprus’s water policy”. The regional office of the WDD deals with more technical aspects like recording the level of the water table, the network of deep drill wells and the falling level of groundwater. They are also responsible for measuring the quality and salinity of the water and for issuing permissions of water extraction, specifying who can pump water and how much.
- The Department of Agriculture, Ministry of Agriculture, Natural Resources and Environment, holds a consulting role and works closely with both farmers and the WDD at all levels. In a way, the Department also intermediates between the WDD and farmers, by estimating the water needs of cultivations, or monitoring the water use for irrigation, and advising the WDD on these needs. The process and advisory role are facilitated with the operation of regional offices.
- The Department of Environment, Ministry of Agriculture, Natural Resources and Environment, together with its regional offices, advises the government on environmental policy and the coordination of environmental programs. The department also supervises the adoption and implementation of European policies and national legislation on the

environment. Moreover, the department promotes the enforcement of laws relating to Water Pollution and Management of Waste and encourages environmental awareness and information. However, their practical role in GW management is rather minimal if any.

The stakeholders representing the agricultural sector are the farmers and the agricultural associations. Cyprus has a long history and a considerable number of very active farmers' associations, representing the agricultural sector and exercising influence on governmental decisions. Broadly speaking the associations (each representing a different political party) have the shared goal of developing the agricultural economy, improving the labour conditions and livelihoods of farmers, supporting social and technological innovation in the agricultural sector and protecting the environment. Agricultural associations lobby the government for solutions in irrigation and water supply.

The farmers in the region can be categorised into two types: large farmers, usually farming enterprises, and small family farms. These two categories may be further distinguished in terms of full time (either large or small farmers) and part-time farmers (usually small or very small landowners). The latter can be further distinguished into two subcategories: part-time farmers that are basically professional farmers but need to complement their income by a second profession (often in the tourism sector), and non-professional farmers exercising farming for pleasure (often without any profit from the activities).

Specifically, large farmers are often exporting their products. There is a recent trend to utilise – illegal- mobile desalination plants to treat the abstracted groundwater so it can be used for irrigation. These farmers are facing increasing costs of energy (pumping of groundwater) and their demand is rarely if ever satisfied by the available water from the South Conveyor. Smaller farmers, either full or part-time, are struggling to meet the demand for water for their crops and they strongly prefer water coming from the South Conveyor, although this is complemented by abstracted GW. These farmers increasingly quit agriculture or are forced to find a second or seasonal job. Family farms contribute significantly to regional production and to the income of the family.

Small farmers were criticised in most of the interviews, whether these be conducted with governmental agencies, associations or other farmers, as the most unsustainable users of water. The share of water they receive from the South Conveyor is also regarded by many as a complete waste of a precious resource. According to a governmental interviewee: “[this category] I call gardens of Eden, especially in areas with access to the water network or a drill well. They plant, for example, 50 citrus trees, for domestic consumption supposedly, although two trees would provide more than enough for a household. They might also have olive trees, or a holiday house. These cases I consider wasteful, because they end up serving non-productive needs, such as entertainment or relaxation. [...] This also creates conflicts around conveyors and the network about access and the quantity available”.

4. The applied methodology for an advanced policy design

The present section briefly describes the integrated methodology used for the innovative design of policy alternatives within a Design Theory framework (Pluchinotta et al. 2019a for details). A C-K theory-based tool, namely Policy-KCP (P-KCP) was improved and applied in order to overcome the barriers due to ambiguity in problem frames, and the creation of the shared concern as starting point for the generation of policy alternatives. For sake of brevity, the case study activity is used for describing the different steps of the adopted methodology.

4.1. The K-space building phase

The aim of this phase is to build a shared base of knowledge (K-space) by combining and aligning the individual stakeholders’ knowledge - i.e. the K-spaces - in order to support the subsequent generative phase (P-C phase). The construction of this shared knowledge space needs to be consensual. Thus, the P-K phase intends to: i) elicit and structure the different stakeholders’ problem understandings; ii) support the identification of common knowledge on the GW

protection and water management problem; iii) detect and analyse potential conflicts among decision-makers.

The stakeholder involvement process for building the K-space is structured in three phases:

- Elicitation and structuring of individual stakeholders' perceptions of the main issues and concerns related to GW protection and management through individual semi-structured interviews and individual Fuzzy Cognitive Maps (FCM).
- Analysis of the main differences in problem understanding (Ambiguity Analysis) through comparison of individual FCM. To this end, two elements were accounted for: the most central elements in the FCM and the expected dynamic evolution according to the FCM simulation.
- Development of the overall K-space combining the individual stakeholders' K-spaces and aligning the different perceptions. The final aim is to reach consensus over a *shared concern* and a common knowledge between each viewpoint.

Generally, the K-phase aims to gather missing information and build a comprehensive summary of current knowledge about the issue under consideration. In this work, it combines the stakeholders' knowledge - obtained through FCM analysis and scenario simulations - with scientific literature studies, the available data, emerging technologies, best practices, etc. As described further in the text, the overall K-space is developed by combining and aligning the individual stakeholders' K-spaces .

Firstly, individual semi-structured interviews were carried out aiming to understand how different decision-makers (institutional and not) perceive the same problem. During this step, stakeholders' roles, objectives and values were elicited. To this end, the interviews were based on 10 questions grouped according to three main issues: i) stakeholders' previous experience with water management issues; ii) stakeholders' knowledge on the main drivers influencing the problems pointed out and impacts, both direct and indirect; iii) stakeholders' knowledge regarding strategies used for dealing with these problems. The interviews were carried out involving institutional

decision-makers and farmers. Concerning the latter, a sample of farmers was interviewed. In order to guarantee heterogeneity, the sample was created by considering the different characteristics of farms, i.e. size, crop patterns, part or full time. The farmers' FCM was developed by aggregating the individual sub-FCM. The process of individual sub-model aggregation ended when no new concepts and/or relationships emerged after a number of interviews (e.g. Özesmi & Özesmi 2004; Pluchinotta et al. 2018). For the selection of the stakeholders to be involved in the knowledge elicitation process, the "snowballing" or "referral sampling" approach (Reed et al. 2009) was implemented. Specifically, the selection process started with the actors mentioned in the official documents and, during the interviews, each stakeholder suggested the involvement of other stakeholders considering their role and expertise.

Secondly, the information derived from the semi-structured interviews was processed in order to build individual FCM, allowing to investigate how people perceive a given system and compare the perceptions of different groups of stakeholders (e.g. Eden 2004; Kosko, 1986). Each FCM variable represents an item related to water management according to the stakeholder's conceptual model, while the weighted and directional arcs symbolise causal relationships between items. For instance, the individual FCM (Figure 2) shows that, following the WDD's conceptual model, the overuse of GW for irrigation purposes will lead to a decrease of the water quality, an increase of the seawater intrusion with a consequent reduction of the agricultural production, due to the decrease of the GW quality.

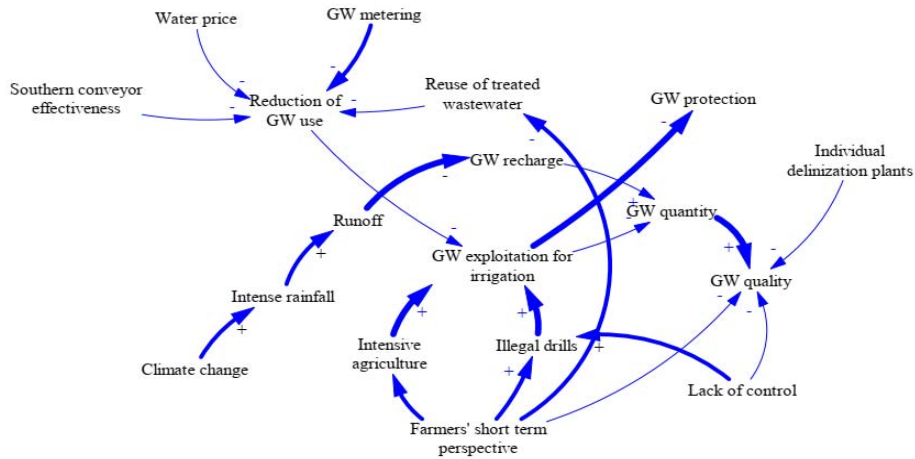


Figure 2 – Water Development Dpt.'s FCM

For each variable of the FCM, the Centrality Degree was measured. The higher the Centrality Degree, the more important is the concept in the stakeholder's problem understanding (see Giordano et al in press and Santoro et al. 2019 for more details on the methodology). Afterwards, FCM qualitative scenarios (e.g. Borri et al 2015, Kok 2009, Pluchinotta et al. 2019b) were simulated to investigate the expected evolution of the variables' states according to the stakeholders' problem understandings. Two different scenarios were simulated in this work, i.e. the Business-As-Usual (BAU) scenario and the GW stress scenario. According to Kok (2009), the FCM scenarios were simulated by changing the values of the variables in the initial state vector. That is, the GW stress scenario was simulated by activating the climate variables in the FCM initial state vector. Figure 3 shows the stakeholder 'Agricultural Dept.'s' conceptual map and Figure 4 displays the comparison between the two scenarios aforementioned.

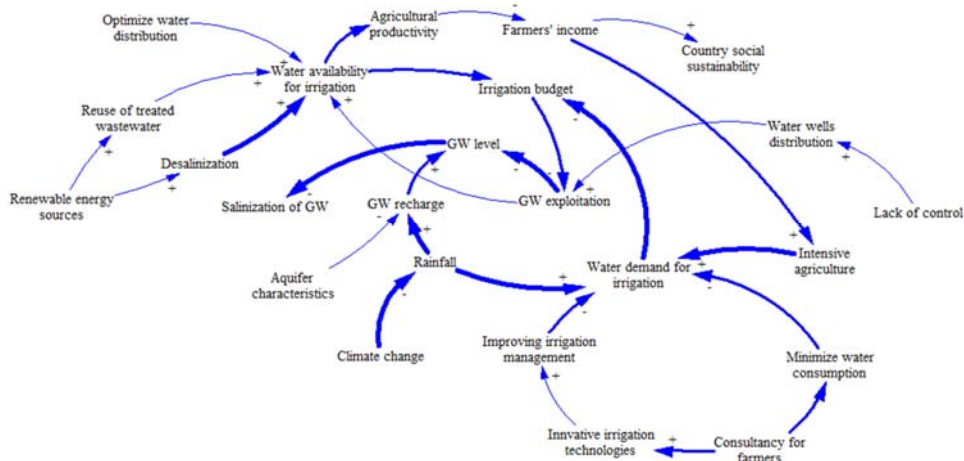


Figure 3 - Agricultural Dept.'s FCM

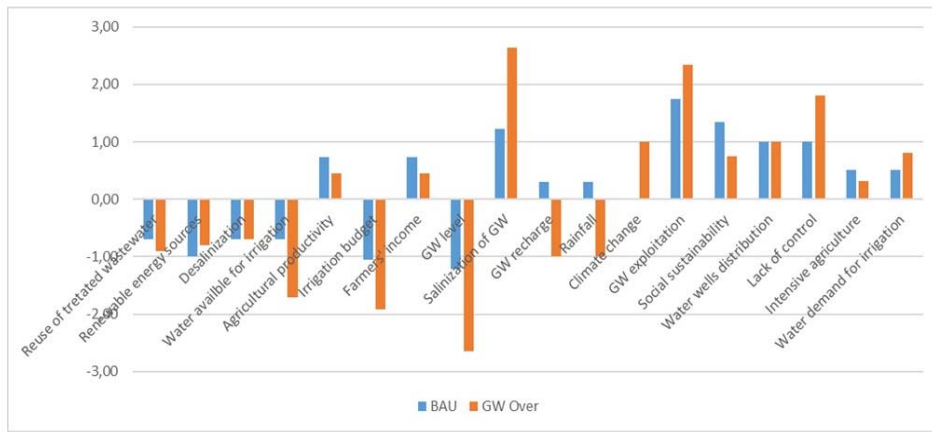


Figure 4 - Scenario comparison for the stakeholder 'Agricultural Dept'

The FCM scenarios allowed to simulate the dynamic evolution of the system, as perceived by the stakeholders, and to identify the key elements affecting the GW exploitation and the main impacts. The Impact Degree was assessed accounting for the change of the state of the variables in the two scenarios. The aggregation between the Centrality Degree and the Impact Degree allowed to define a ranking of the different variables influencing the stakeholders' problem understanding. Table 2 shows the main variables for the different stakeholders.

Stakeholder	Variable	Centrality degree	Impacts degree	Importance degree
	Infrastructure effectiveness	High	Weakly negative	Medium
	Reuse of treated wastewater	Medium	Negative	High

Water Development Department	Farmers' behaviour	Medium	Negative	High
	GW quality	High	Highly negative	High
	Territory control	Medium	Weakly negative	Medium
Farmers association	Agricultural productivity	High	Negative	High
	GW quality	High	Negative	High
	Energy costs for GW use	Medium	Negative	High
	Farmers' behaviour	Medium	Weakly positive	Medium
	Infrastructure effectiveness	Low	Positive	Medium
Regional Agricultural Department	Regional Livelihood	High	Negative	High
	Agricultural productivity	High	Negative	High
	Salinization process	Medium	Negative	High
	Infrastructure effectiveness	Medium	Weakly negative	Medium
The Department of Agriculture	Agricultural productivity	High	Negative	High
	Optimization of water distribution	Medium	Negative	High
	Social sustainability	Medium	Negative	High
	Innovation adoption in irrigation	Low	Negative	Medium
	Territory control	Medium	Weakly negative	Medium
Farmers	Farmers income	High	Positive	High
	Agricultural productivity	High	Weakly positive	Medium
	Energy costs for irrigation	Medium	Weakly negative	Medium
	Irrigation infrastructure eff.	Medium	Weakly positive	Medium
	Innovation adoption in irrigation	Medium	Weakly positive	Medium
Regional Branch of the WDD	Seawater intrusion	High	Negative	High
	Illegal drills	High	Negative	High
	Agricultural productivity	Medium	Weakly negative	Medium
	Territory control	Medium	Weakly negative	Medium

Table 2 - Identification of the most important elements in the stakeholders' problem understanding for the Cyprus case study

Finally, this analysis supported the K-space expansion and the identification of the *shared concern*, namely a shared representation and formulation of a “problem” which in reality serves as a representation or “recall” of the different concerns and stakes carried by the different stakeholders (see Ostanello and Tsoukias 1993, Pluchinotta et al. 2019), representing the starting point for group discussions leading to the generation of policy alternatives.

4.2. The C-space

Following the expansion of the K-space and identification of the *shared concern*, a one-day stakeholder workshop (Figure 5) was aimed at innovatively generating policy alternatives for the Kokkinochoria GW management using a C-K theory framework.

Within the P-C phase, stakeholders evaluate the dominant design (i.e. traditional policy alternatives) and propose innovative ones through the expansion of the C-space. The C-space allows to illustrate various alternatives as concepts connected to the “initial design task” thanks to the tree-like structure (Agogue et al. 2014a). It represents the map of all identified possibilities, highlighting the dominant design and improving the search of new alternatives.

Firstly, the individual K-spaces and the *shared concern* is discussed, in order to build a common knowledge ground, representing the starting points for the generative workshop. Secondly, the traditional policy alternatives derived from the semi-structured interviews and the P-K phase (i.e. dominant design), are described to all the participants. Stakeholders were asked to collectively discuss and rank the traditional policy alternatives (i.e. the ranking represents the initial importance that participants give to the proposed solutions as key action to resolve the problem under consideration). The traditional solutions are (from most important to be considered to the least important): Pricing strategy depending on water uses, Improvement of water distribution infrastructure (conveyor), Raising of the farmers and community’s environmental awareness, Alternative sources of water (desalination and reuse), Improvement of GW monitoring and metering, Agricultural subsidies (changing crops), Increase the control of the territory,

Improvement of the irrigation techniques; Centralized systems for irrigation, Reduction of irrigated areas, Central system for desalination, Use rainwater and surface water, Changing habits and mentality.

Thereafter, the participants were asked to suggest possible expansions of the C-tree, following the C-K theory framework. The discussion, facilitated by a C-K theory expert, led to the generation of different design paths within the expansion of the C-space. The outcome was a portfolio of policy alternatives shared with all the stakeholders which also included the introduction of few innovative policy alternatives. Lastly, a general discussion of the group activities concludes the generative workshop. The generative workshop represented a learning process since the participants turn to learn beyond their actual knowledge according to the principles of K- and C-spaces expansion (see Pluchinotta et al. 2019a for details).



Figure 5 - The P-KCP one-day generative workshop hosted by WDD

The C-tree showing the policy alternatives generated for the problem of GW protection and water management for the agricultural sector of the Kokkinochoria area is shown in Figure 6 and Table 3. Using a colour code, the C-tree is divided as follows: i) the branches with known policy alternatives are coloured in black (dominant design), ii) the ones in blue indicate policy alternatives generated using existing knowledge or a combination of K-space subsets (i.e. policy alternatives used in best practices of comparable case studies), and iii) the paths in green represent new path

for innovative policy alternatives. Both the alternatives in blue and green represent the C-space expansion, obtained thanks to the expansion of the K-space or of the C-space itself.

ID	Alternatives	Status
C0	To manage GW to ensure enough quantity and quality for agriculture	-
C1	Reduce Use	-
C1.1	Not Changing W Demand for Agriculture	-
C1.1.1	No-GW Management	-
C1.1.1.1	Management of Desalinated W	Dominant design
C1.1.1.1.1	Desalinated W for Domestic use AND W from Dams for Agriculture	Dominant design
C1.1.1.1.2	Desalinated W for Agriculture	Known
C1.1.1.1.3	Desalinated W for everyone	Unknown
C1.1.1.2	Management of Treated W	Known
C1.1.2	GW Management	-
C1.1.2.1	GW only for professional Farmers	Dominant design
C1.1.2.2	GW for all Farmers	Known
C1.1.2.2	Government ensures enough quantity (Improve GW monitoring)	Known
C1.1.2.2.1	Tax for non-professional GW users	Known
C1.1.2.2.2	Tax for professional GW users	Known
C1.1.2.2.3	Tax for all GW users	Unknown
C1.1.2.3	Government does not ensure enough quantity	Dominant design
C1.1.2.3.1	Government provides a reduced quantity of GW	Dominant design
C1.1.2.4	Centralized GW management system of irrigation	Dominant design
C1.1.2.4.1	GW centrally pumped by the Government	Known
C1.1.2.4.2	GW and Dam, W centrally collected and redistributed	Known
C1.1.2.4.2.1	Distributed according to crops plan	Known
C1.1.2.4.2.2	Not Distributed according to crops plan	Unknown
C1.1.2.5	Shared sustainable GW management	Unknown
C1.1.2.5.1	Award for target quality achieved	Unknown
C1.1.2.5.2	Award for target quantity achieved	Unknown
C1.1.2.5.3	Award for target quantity/quality achieved	Unknown
C1.2	Changing W Demand for Agriculture	-
C1.2.1	Efficient irrigation techniques	Dominant design
C1.2.2	Pricing strategy	Dominant design
C1.2.2.1	Different tariff depending on W use	Dominant design
C1.2.2.1.1	GW use	Dominant design
C1.2.2.1.1.1	Charge desalination costs in case of GW use..	Dominant design
C1.2.2.1.1.1.1	..to non-professional farmers	Dominant design
C1.2.2.1.1.1.2	..to professional farmers	Known
C1.2.2.1.1.1.3	..to all farmers	Unknown
C1.2.2.1.1.2	Charge environmental costs in case of GW use..	Dominant design
C1.2.2.1.1.2.1	..to non-professional farmers	Dominant design
C1.2.2.1.1.2.2	..to professional farmers	Known
C1.2.2.1.1.2.3	..to all farmers	Unknown
C1.2.2.1.2	No-GW use	Unknown
C1.2.3	Changing crop patterns	Dominant design
C1.2.3.1	With subsidies	Dominant design
C1.2.3.1.1	Direct subsidisation of changing crops cost	Dominant design

C1.2.3.1.2	Indirect subsidisation of changing crops cost	Known
C1.2.3.2	Without subsidies	Dominant design
C1.2.3.2.1	Programme for increasing env. Awareness	Dominant design
C1.2.3.2.2	Government improved export trades	Known
C1.2.3.2.3	Helping developing plan	Known
C1.2.3.2.4	Improved information sharing	Unknown
C2	Increase W Availability	-
C2.1	With improved infrastructures	-
C2.1.1	W Treatment	Dominant design
C2.1.1.1	Desalination	Dominant design
C2.1.1.1.1	Centralized Desalination	Dominant design
C2.1.1.1.2	Distributed Desalination	Dominant design
C2.1.1.2	Wastewater Recycling	Dominant design
C2.1.2	Collection	Dominant design
C2.1.3	Transport	Dominant design
C2.1.3.1	Increase coverage of the conveyor	Dominant design

Table 3 – List of the policy alternatives generated during the stakeholder workshop (C-space expansion)

5. Discussion and conclusions

This paper develops and tests an upgraded methodology for policy design based on an integration of PSMs, for building and expanding the K-space, and a C-K theory-based tool, for supporting the generative C-phase. The results of the activities carried out in the Cyprus case study allows us to demonstrate that the integration between PSMs and C-K theory could be considered as a suitable approach for supporting policy design, accounting for the main differences in problem framings among the different decision-makers and stakeholders. Generally, the P-KCP is a methodology formalizing the policy design process based on C–K theory. It supports the generation of innovative alternatives thanks to the co-evolution of the K- and C-spaces according to the C–K framework. It connects local and expert knowledge within the whole design process thanks to the construction of a collective problem understanding. The difference between the proposed method and other participatory and/or brainstorming procedures is that the collection of new ideas and suggestions is structured by the C-tree where the explicit presence of attributes (characterising any new design) are expected to be relevant for given stakeholders. The tree-like structure allows pinpointing how the problem and the possible solutions are seen by the

stakeholders collectively. In other terms a C-K theory-based tool for the design of policy alternative aims not only to collect ideas, but also to structure values who matter for designing and deciding. Specifically, PSMs demonstrate to be suitable to support the elicitation of the different viewpoints involved in the collective decision-making process. As already demonstrated in the literature, differences in problem framings could enhance the effectiveness of the collective process by improving the creativity. Nevertheless, the polarization of the participants' opinions, with consequent difficulties in finding a common base for discussion and for creating innovative policies, is a risk that need to be dealt with in collective decision-making process. The experiences carried out in the Cyprus case study demonstrated that structured methods for collecting different problem understandings, and to detect and analyse differences/similarities greatly facilitated the discussion for the development of the C-space.

Moreover, it is worth mentioning that the collection and integration of individual problem understanding allowed to build the policy design process attributing equal weight (importance) to the different pieces of knowledge gathered through the stakeholders' engagement. The risks associated with power relationships have been constrained bounded by the structure of the C-K expansion process and the dichotomy between expert and local knowledge, characterizing the traditional policy design approaches, has been reduced thanks to the construction of the K-space. The construction of the C-Space is strictly dependent on the enhanced K-space, as explained by the C-K theory framework. The coevolution of the two spaces re-establishes communication between stakeholders by unfixing the group from the dominant design, i.e. traditional and known policy alternatives. Fixation phenomena within the policy design process bring policy makers and stakeholders in conflicting and unsustainable situations. Furthermore, the one-day generative workshop for the C-space expansion lead antagonistic stakeholders to discuss on the collected knowledge. The new knowledge injections represented the starting point for stimulating discussions during the generative mechanism for the C-space exploration. For instance, initially, the discussions were driven by conflicting situations due to knowledge limitations and fixation

phenomena, while after the injection of new knowledge and the alignment of problem frames, participants were more willing to cooperate in constructive and operative debates. This had positive effects on the workshop results, i.e. unfixed participants proposed non-traditional solutions or integrated known alternatives in a different perspective (Table 3).

The experiences described in this work showed also some limitations of the implemented approach. Firstly, capturing and processing stakeholders' knowledge starting from individual inputs is time consuming and requires substantial efforts by skilled analysts for post-processing the information collected during the individual interviews. Secondly, the selection of the stakeholders is a key step in making the process successful. The knowledge elicited by interacting with them is at the basis of the whole process. Therefore, their representativeness needs to be accounted for during the selection of the stakeholders to be involved. Moreover, the process described in this work is quite long and requires the stakeholders to go through different phases of individual inputs and group discussions. Thus, the stakeholders' selection should also account for their willingness to commit themselves to the whole process. Thirdly, the use of FCM for simulated qualitative scenarios was questioned by some of the participants. The participants seemed inclined to prefer quantitative evaluation, rather than qualitative results. Efforts for combining the FCM with more quantitative modelling approach are already being performed. Concluding, although some improvements are still needed, the integrated approach described in this work could be a valuable method for enhancing the policy design process.

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