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Design Theory for Generating Alternatives in Public Decision Making Processes

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Abstract Public decision making including stakeholders' engagement offers best practices but also unsuccessfully case studies. Meaningful participation activities require direct integration of stakeholders into all the phases of the public decision process to unleash innovation. Recurrently, policy making incorporates participation late in the process, after the problem definition has occurred, alternatives have been defined, without considering stakeholders' knowledge and problem understanding. The early stage of policy alternatives design is essential to the development of policy. However, the formal process of generation of alternatives has been little investigated. Within this context, there is a demand for methodologies aiming at supporting policy makers and relevant stakeholders during policy design. In this regard, we are interested in introducing (and exploring) the operational role of design theory in the policy making process for the generation of policy alternatives. Design thinking, as a way to inform a collective problem definition leading to innovation, highlights the value of early stakeholders' engagement. The aim is to understand from an operational point of view what "design" means in a policy making context contributing in creating an innovative approach for assisting the formalization of policy design. The paper shows the results of a pilot case study where a Concepts-Knowledge theory framework is applied in order to

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support the design of policy alternatives for the groundwater protection policy of the Apulia Region (southern Italy).

Keywords Policy Design · Policy Analytics · Decision Analysis · Design Theory · Participatory Process

1 Introduction

Governments and public bodies are beginning to involve stakeholders and the general public to a far greater extent than previously in the public decision process [14]. Stakeholders' participation is described as forums for knowledge exchange, aiming at facilitating communication between government, institutions, citizens, community members, interest groups and business related to a specific policy issue [137]. Different people with different stakes, points of view, rationales, and values are brought together to participate more or less directly, and more or less formally, in public decision making processes or, more often, in some stage of it ([25], [36], [40]). Public participation is widely documented as being a valuable component of policy making processes (e.g. [17], [28], [29], [87], [140]), bringing the problem of facilitating multi stakeholder contributions and building collective commitment [36] in order to consolidate the legitimacy of the whole policy making process and its outputs [40].

Policy making processes, including stakeholders' participation, offers best practices but also unsuccessfully case studies (e.g. [27], [38], [63], [131], [133], [135]). Meaningful participation requires direct integration of public participation activities into all the phases of the public decision process [87]. Initially, policy making has been characterised as a rational process; a linear path from the problem definition to the analysis of options and development of policy solutions [95]. Participation aimed at collecting inputs of external expert actors for decision making processes was traditionally reserved for the formal political and administrative authorities [25]. Increasingly, this view is being contested due to the inherent complexities facing the public sector (e.g. [30], [130]). Uncertainties abound, data and knowledge are limited, and complex tasks are required to analysts and policy makers. The transition to a more inclusive participatory decision making processes is marked by the work of Rittel and Webber [108], stating that societal problems are wicked problems, and thus not resoluble in the sense of finding definitive and objective answers [25].

Instead of a rational selection among policy alternatives, public decision making is the result of negotiations between the various agents within the political subsystem [112]. Based on that, it is noteworthy that public decision making comprises not only information gathering and processing, but foremost incorporates a component of interaction and sharing of structured knowledge of various actors, whose preferences and interests diverge [97].

Many academic studies have investigated participation, suggesting that all modes of public participation can potentially benefit the society (e.g. [14], [15], [16], [17], [25], [28], [43], [44], [49], [107], [136], [122]). Stakeholders' participation has been investigated in Decision Analysis where stakeholder's engagement, knowledge elicitation and problem structuring were considered pivotal elements of the policy making process, (the interested reader can see: Soft Systems Methodologies and Problem Structuring Methods [26], [103], [109], Group Modelling and System Dynamics [123], [124], [134], Stakeholder Strategic Management [1], [42]). Often the contribution of experts obtained more attention than the local stakeholders' knowledge (e.g. [35]). Although literature recognises the use of public and stakeholder participation necessary, it expresses doubts on the the used methodologies (e.g. [43], [110]). Furthermore, approaches of participation are being used to draw stakeholders into the process of deciding between different options, but not on their generation [14].

Usually, policy making incorporates consultation with stakeholders late in the process, after the problem definition has occurred, alternatives have been defined and analysed, raising the risk of the consultation being construed as a formality, intended to limit the ability of stakeholders to seriously inform the mechanism of policy design [95]. In the tradition of public policy theory, design has long been seen as a component of policy development without any operational characteristic ([63], [84], [95], [116]). There seems to be a relatively small literature on how to formally design policy alternatives [65]. The advent of stakeholders' involvement in the policy making increases the need for effective design processes since the systems have to be build before use and there is much less scope for tailoring the processes to meet public needs as the debate progresses [39]. Experience suggests that well-structured and formalized methods are needed to structure integrate knowledge from different sources, allowing transparency of the process [106]. This should represent the starting point of a generative process [127]. Moore [96] talks about the structured inclusion of different stakeholders's knowledge, in order to unleash creativity and conceive new solutions.

Within this context, there is a demand for methodologies and instruments aiming at supporting the policy makers and relevant stakeholders during the design of alternatives during the policy making process. Policy makers create policy alternatives [65]. Indeed, Lasswell [74] argued that policy design or "the invention of policy proposals" is as essential to the development of policy as it is an integral part of public decision making [139]. The policy cycle has to be completed for a policy to emerge and policy design is one of the major critical issue in order to pursue innovation [73]. It aims at improving the understanding of how the processes, methods and tools of policy making are employed to better formulate effective policy alternatives [67]. A worthy policy design process has a preponderant impact on the quality of the policy alternatives being considered. Nevertheless, there are not significant research activities examining formal design processes for the generation of alternatives in the policy making domain [65].

In this regard, we are interested in introducing (and exploring) the operational role of design theory in the policy making process for the generation of policy alternatives. Design thinking highlights the value of early engagement with stakeholders. Various academics and public commentators have underlined the use of design thinking as a way to inform problem definition ([24], [33], [78], [95], [111]). This could challenge some current mainstream of policy making [95]. This paper aims at contributing in creating an innovative approach for assisting the formalization of the policy design process. It discusses an emerging context of using design theory-based approach for policy design. The aim is to understand from an operational point of view what "design" means in a policy making context.

There is already a specialized literature in design theory and, we would like to use the derived knowledge, methods and expertise for the policy making process. Fifty years ago, design community/researchers started to explore how it is possible to design products, formalizing the design process in order to better manage it [3]. Design theory is now considered essential for product development (e.g. [21]). Design theory offers formal approaches and methodologies, and the formalization of the design process is the asset of the policy design, e.g. Concept and Knowledge (C-K) Theory [56]. We claim that design theory can change the policy making process and that C-K theory can be a suitable policy design methodology.

This paper is structured as follows. After the present introduction, section 2 depicts the mainstream approach to policy design. Sections 3 briefly illustrates the design theory framework. Section 4 describes the proposed methodology while section 5 and 6 discuss the case study, the obtained results and the lessons learned. Concluding remarks are reported in section 7.

2 Policy design: notes

Bobrow [18] argues that policy design is a really important step within the policy cycle, but it is surprisingly understudied in the contemporary policy analysis literature. Only in the past three decades received some significant attention (e.g. [88], [89], [90], [138]).

The roots of policy design studies can be found in the policy sciences literature since the 1950s, while policy design research was developed during the 1980s and 1990s, involving interdisciplinary literature such as economy and law. In the 2000s, the policy design focused on the impact of policy outcomes on society behavior (for instance [63]).

In his early works on public policy making, Lasswell [72] stated that the understanding of the range of policy instruments available to policy makers is an important feature of both policy formulation and implementation.

In the 1970s the research was focused on the evaluation of the economic impact of implementation-related tools (e.g. taxes and subsidies), in order to aid policy makers in considerations of policy use and effectiveness ([92], [125], [141]).

In the 1980s and 1990s the policy design literature shifted towards understanding design both as process and outcome. Several researchers and practitioners wrote about problem formulation, policy instrument choice and policy design outcomes (e.g. [18], [65], [88], [89], [90], [138]). In the 1980s, the policy research was interested in the links between implementation failures and policy success ([91], [100]). In the early 1990s the focus turned towards the subject of how implementation alternatives were crafted and formulated, with ex-post evaluation of the impact of policy outcomes ([19], [126]). Furthermore, an interdisciplinary approach combined economic and law studies in order to focus on policy outputs and governmental processes. On the one side, law studies analyzed how regulations mediated the delivery of goods and services, and how formal processes of rule-making led to policy [70]. On the other side, management and administrative studies provided information on the links between administrative systems and implementation modes ([81], [82], [83], [102]). Specifically, both Bardach [12] and Salamon [113] argued that the early policy studies analyzed policy in terms of "problems", "issues", "areas" or "fields" rather than in terms of "instruments of government action" and "techniques of social intervention". In this regard, a specific policy design literature appeared in the mid-1980s [65] through a systematic study of policy instruments. Policy analysts' attention shifted from practice to theory, classifying policy instruments in order to identify the reasons of their use ([20], [59], [113], [129]) and to improve both policy designs and outcomes ([80], [92], [141]). In the late 1990s, policy design literature focused on instrument selection [60]. It aimed to systematically assess the development of optimal policies by using mixed strategies, moving away from the single instrument studies and designs characteristic of earlier works ([50], [62], [63]).

The end of the 1990s are characterized by the dispersion of policy design scholars in specific fields such as economics, and environmental studies ([31], [66]). One of the main causes was a rise in general interest of policy studies on decentralized governance. Attention shifted from centrality of authority (i.e. state-centeredness) to the collaborative governance involving non-governmental actors, among others [64]. Due to the complexity of relationships between inter-organizational actors, policies seemed to be less "designed" within the "networked society" [63]. This change in direction had a significant impact on policy design research.

More recently, policies are seen as the outcome of a decentralized process, involving the actions and interests of several public and private stakeholders. As a result, the implemented policy design practices became increasingly participatory and consultative in nature (e.g.[7], [11]). They replaced previous top-down formulation processes dominated by government

analysts with bottom-up ones. As Howlett [65] argued, this change reduced government capacity for independent actions and limited their design alternatives ([32], [76]) as well as their authority in policy formulation disputes (e.g. [85], [98], [114]). The demise of policy design research could be associated by the change in demand for more participatory and less "command-and-control" governance (e.g. [34], [63], [68], [71], [77], [118]). Behind what would seem as a "random product of a political process", behavioral researchers identified that policies have underlying patterns and logics [116]. Schneider and Ingram [115], used both constructionist and behavioral lenses to understand the factors leading to both the articulation and adoption of specific policy designs. This framework posits policy designs as institutional structures consisting of identifiable elements: goals, target groups, agents, an implementation structure, tools, rules, rationales, and assumptions [120]. Governments continued to design systemic modes of governance and established the nature of the policy instruments adopted for the pursuit of these goals [94]. Studies revealed the important role played by governments both in contexts of social "steering" and in more traditional areas of policy activities [128]

Lastly, policy implementation has been investigated as depending on the design of products and services also [6]. Considering design thinking essential in product development ([22], [86], [95]), traditional public policy making contemplates policy development from a design theory prospective (e.g. [63], [84], [116]). Whilst policy making constitutes a design activity, it is yet to be explicitly discussed in design terms [95]. The lack of methodologies for the generation of policy alternatives can be handled introducing design theory based approaches. This paper aims contributing to the establishment of a methodology formalizing the process of innovative design of policy alternatives.

3 Innovative design and C-K theory

Design is defined as a process of changing an existing situation to a desired one [121], through the conception of an idea and the description of the proposed artifact([5], [10]). Design portrays a generative process by which something unknown can intentionally emerge from what is known [57].

The early design theory is characterized by the desire to understand design as a systematic process, based on objectivity and rationality: design complex tasks are broken down into simplified sub-tasks [4] through abstract mathematical notation and terminology ([9], [10]) within methodical and repeatable step by step procedures ([5], [41]). The main focus of the early design theory is the attempt to incorporate scientific knowledge and engineering techniques into a rational design process [13].

On the one side, the so called rule-based design methodologies are based on the "dominant design" of objects, helping firms to face the growing need for a mass production around well-identified objects, and thereby allowed the establishment of optimized product lines process ([3], [37]). According to Utterback and Abernathy [132], the dominant design, identifies key features and attributes that become standard over the evolution of the industrial dynamics (see the key contribution of Pahl and Beitz [101]). Consequentially, conceptual breakthroughs are occasional or rare [54]. The rule-based design is unable to describe objects outside their dominant patterns, moving around its known and stable characteristics [3]. New solutions are produced, but neither new requirements nor new product identities are generated: development activities are structured around known performance parameters and research activities focus on specific research questions [37].

On the other side, the modern generation of design theory explores "disruptive innovation challenges", modifying the identity of objects [53]. In order to provide breakthrough innovations, the identity of the object is challenged. Thus, managing the renewal of object identity appears as a central issue to innovative design [3]. The attributes of products are questioned, the existing competencies may not be sufficient anymore and new expertise may need to be developed [37]. Consequentially, rule-based design methodologies are not suitable design approaches when designers address the renewal of object identity. With a purpose to meet such challenges, Hatchuel and Weil [55] aimed to analyse the mechanisms of innovative design through the development of the Concept-Knowledge (C-K) theory.

Ever since the beginning (i.e. [56], [57]), the features of C-K theory have been recognized as being unique for describing creative reasoning in design process for the generation of alternatives [119]. Over the last years, C-K theory has gained a growing academic and industrial interest ([3], [54]). It has been developed to guide the work of design teams working on highly innovative projects in several industries [52].

C–K is a theory of reasoning for innovative design situations ([55], [56]), overcoming the limits of traditional design theory [57] and creativity methods [69]. It provides researchers and practitioners with a framework to describe and analyse innovative design processes for the generation of alternatives [54]. Indeed, C-K theory goes beyond two traditional design notions: i) the design reasoning is arranged on a stabilized set of functions (i.e. rule-based design); ii) the creativity in design is interpreted as an uncontrollable process of idea generation [52].

C-K theory is based on the distinction between two expandable spaces: a space of Concepts (C-space), and a space of Knowledge (K-space). The process of design is thus defined as the co-evolution of C and K through four types of independent operators ($C \rightarrow C$, $C \rightarrow K$, $K \rightarrow C$, $K \rightarrow K$) (a detailed description can be found in [56], [69] and [119]). According to Hatchuel et al. [57], the K-space is a space of propositions that have a logical status for a designer. Namely, a logical status of a proposition is an attribute that defines the degree of confidence that a designer assigns to a proposition. Whereas, the C-space is a set of Concepts, i.e. undecidable propositions from which design processes may be initiated [56]. A Concept is a proposition describing an object, that has no logical status in the current K-space: when a Concept is formulated, it is an "unknown" entity, and it is impossible to prove that it is a proposition of the K-space. A Concept usually expresses a group of properties qualifying a given entity [2], such as "C: there exist an object x with the properties p_1, p_2,..., p_n". Therefore, within the C-K theory, the design activity is defined as the process by which a Concept generates other Concepts or is transformed into Knowledge, i.e. the co-evolution ([52], [75]).

The construction of a C-K model relies on a set of rules that structure both the C-space and the K-space [2]. Within a given design process every C-space has a strong dependency on the related K-space, i.e. K-relativity of the C-space. Every element and possible expansion in the C-space relays on the structure and contents of the Knowledge base [52].

Within a C-K model, the C-space is structured as a tree including three different types of C-paths: i) describing the attributes of the existing dominant design, ii) characterizing concepts that are reachable and attainable using existing knowledge or a recombination of the existing knowledge and iii) exploring the K-space in order to expand the C-space. Building a C-K model (Figure 1) with different types of design paths (on the left part) and different levels of mastery of the Knowledge base (on the right part), leads to the definition of the C-space with the existing dominant design of the object and possible expansion, thanks to the identification of new alternatives [2].

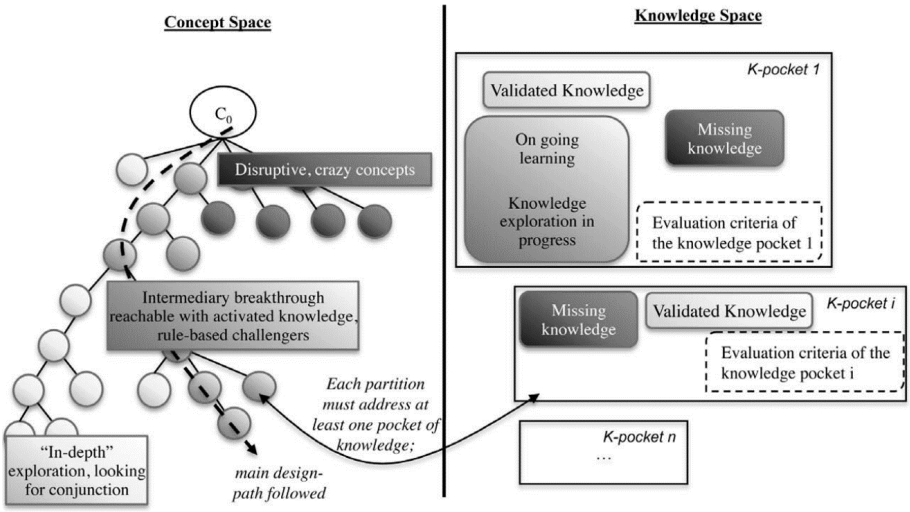

Fig. 1 C-K model [2]

C-K theory offers a formal framework, providing a definition of the design process independent of any domain [58], where creative thinking, learning process, knowledge structuring and sharing, and innovation principles are not external phenomena but are the central core of the theory itself [52].

Therefore, C-K theory helps to analyze the limits of traditional methods of collective creativity design [54]. Methods of group creativity, such as more or less sophisticated brainstorming, tend to lead to a consensus with very few breakthroughs. Alternatively, potential well-structured creativity task forces are not able to follow the created breakthrough due to the limited size of the Knowledge base or the lack expert inputs. The C-K theory is used to overcome these constraints while creating a formal framework for collectively innovative design processes [58].

3.1 The KCP tool for innovative collective design activities

As we discussed above, according to the C-K theory theoretical framework, the design reasoning is interpreted as the co-evolution of the C- and K-spaces. This *dual expansion* allows to formally describe the learning process (expansion of K-space) and to decode the way in which new knowledge supports the generation of new concepts (expansion of C-space).

Operationalizing the C-K theory, the KCP methodology (i.e. *K* for knowledge, *C* for concepts and *P* for proposals) was developed in order to manage the dual expansion within a more collaborative design process [61]. KCP is a C-K driven tool [58] supporting design processes where many participants are involved (i.e. experts, users, researchers, engineers, designers, customers, ...) [54], aiming to combine cognitive and organizational goals in an innovative design method [2].

The KCP workshops, described in detail by Hatchuel et al. [58] and Agogue et al. [2], are composed by three phases briefly outlined below:

K phase. The K-sessions aim to collectively build and share the available knowledge about a given object under design: the state of the art and the state of the "non-art". They consist of several days of seminars in which experts make presentations to the design team (i.e. 6-10 half-day K-sessions). The knowledge-exchange activities can be both internal to the design team (i.e. sharing internal knowledge usually compartmentalized in different departments and unshared) or external involving experts. This phase does not contain any creative activity and allows to open up new perspectives in a field of knowledge with an exploration scope. Thus, at the end of this phase, the team is able to (re)structure the K-space of the exploration perimeter, identifying possible polysemy and ambiguity, isolating conventional forms of design to highlight paths of possible breakthrough. The K-phase can reveal some weaknesses in the initial individual K-space, in order to prepare for future C-expansion, supporting the inclination of the team of accepting "rule-breaking" and "rule-rebuilding" processes.

C phase. The C-phase consists of a series of creativity sessions (over 1 or 2 days) during which the design team is involved in a "conceptual building effort". It aims to activate and encourage unexpected concepts-exploration, adding attributes to the initial (often reformulated) concept, participants give a new general definition of it. The C-phase leads to collectively built innovative design reasoning by sharing views and ways to cover the exploration scope. The design team is split into sub-teams. Each sub-team starts working on a search-light-concept and needs to propose paths, concepts, or knowledge to be explored. The C-phase alternates small group activities and general presentations and discussion, in order to foster a culture of exploration of the entire team. Detailed proposals of innovative concepts characterize the output of the C-phase. It differ from creativity techniques such as brainstorming in the way that disruptive paths are explored through pre-defined concepts that guide the creativity session (i.e. contrary to brainstorming, relying on free divergence, the C-phase manages a divergence phase).

P phase. The last phase consists in synthesizing the outcomes of both the K and the C phases into a structured innovative design strategy. It focuses on the identification of the values associated to the different design paths and to strengthen strategies to address those paths. The P-phase aims to commit actors at all levels (top management, designers, engineers, scientists, cases customers, users, partners...), preparing them, i.e. make them informed, competent, aware of learning issues. This phase requires a dedicated working team to manage the re-structuring of areas that are to be explored. The P-phase helps the Decision Makers to which the results will be presented, to assimilate the structure of the innovation field, to keep the variety of alternatives and avoid to focus on one apparently dominating solution. This phase does not consist in selecting a single idea to be developed. It proposes a design strategy, presenting and keeping alive multiple alternatives. Furthermore, as stated by Agogue et al. [2], the management of a KCP workshop consists in: i) identifying an initial explorative problem definition; ii) planning and organizing the workshop sessions as well as introducing participants to innovative design; iii) updating the C-K map of the design process throughout the exploration; iv) selecting elements of the K-space to integrate into the exploration; v) developing various axis of exploration during the C and P phases, with the help of the working team.

The KCP methodology has been successfully used in a variety of contexts (e.g. product design for the industry as well as in assisting strategy formation) ranging from large companies in the transport sector to agricultural cooperatives or firms from the energy industry [2].

It is lacking however, any application and validation with respect to the more complex issue of public policies, i.e. the design of abstract objects such as a policy in order to introduce and explore the possible role of design theory in the policy making process. To this end, we propose a new participatory instrument for the innovative design of policy alternatives, based on the KCP and within the C-K theoretical framework. We present an experiment aiming at extending KCP in the area of policy design. The reasons of the experiment is twofold, one practical and one theoretical: how practically conduct a KCP in policy design? Does C-K theory need to evolve and adapt with respect to policy design?

4 Policy-KCP: a systematic generative mechanism for policy design

Our Policy-KCP (P-KCP) participatory instrument for the innovative generation of policy alternatives, is based on the C-K theory and KCP approach and adapted to the design of abstract objects such as public policies. It aims at formalizing the innovative design of policy alternatives within a public decision making process. A formal methodology is developed allowing systematic design of public policies (i.e. a generative process) that can go beyond traditional policy solutions with stakeholder's engagement. Therefore, the P-KCP aims at supporting the creation of *shared artefact* ([99]) motivating participation and the stakeholders' commitment to a participative policy making process.

The steps for the design of new policy alternatives using the P-KCP participatory instrument, are described in the following.

Policy-Definition phase (P-D phase). The preliminary phase aims to determine key topics and relevant expertise, underpinning the development of policy alternatives. It is build in order to identify the relevant stakeholders and to support the initial problem formulation of the policy issue under analysis.

Firstly, the policy design management team defines the list of suitable participants. In order to support the stakeholder engagement process, it is important that the participants are chosen based on their ability to inform the process and to be knowledgeable about it. In participatory approaches, stakeholder analysis has been seen as a way of generating information on the relevant actors to understand their behaviour, interests, agendas, and influence on decision making processes ([23], [105]). Usually, in order to minimise the selection bias and the marginalization of stakeholders [8] a top-down stakeholder identification practice, namely "snowballing" or "referral sampling", is implemented (e.g. [51], [105]). At the end, the stakeholder analysis leads to an in-depth characterization of the relevant actors, their objectives [79] and the relationships between them [48].

Lastly, the collected knowledge is structured in a initial problem formulation. In public decision making processes, the problems are often complex and witched ([30], [108]) and stakeholder groups have different perspectives and interests that need to be incorporated in a participated process [87]. Differences in problem framing and understanding are unavoidable, deeming ambiguous problem definitions and actions. On the one hand, a diversity in frames can enhance the co-production of knowledge offering opportunities for innovative solutions. On the other hand, the presence of ambiguity can be a source of discrepancies or conflict in a group, hampering the implementation and/or reducing the effectiveness of policy [45]. Thus, preliminary interviews allow to define an initial problem understanding, underlining the differences between the stakeholders' points of view.
The expected outcomes are: i) a preliminary synthesis of the state-of-the-art knowledge, ii) the stakeholder analysis with the depiction of objectives and values, and iii) a preliminary

analysis of the different problem understandings according to the stakeholder's perceptions.

Policy-Knowledge phase (P-K phase). The aim of the subsequent phase is to reach a collective problem understanding and formulation agreed upon by all the involved stakeholders. This is accomplish by gathering missing information and building a comprehensive summary of current knowledge about the policy issue under consideration. Thus, the P-K phase provides the creation of a shared base of knowledge supporting the following generative phase, i.e. P-C phase.
The management team combines the outputs from the stakeholders analysis and the initial problem formulation with scientific literature studies, available data, emerging technologies, best practices, current policies, etc. Afterwards, individual meetings with stakeholders, (e.g. community members, institutional actors etc.) complete the problem formulation stage. The individual meetings are organized as semi-structured interviews, where participants' opinion and knowledge concerning the specific policy problem is investigated. Interviewees are free to share their personal knowledge about the given topic. A report of each interview is validated with the interviewed.
This phase supports the building of the overall K-space as the integration of the individual (intermediary) K-spaces, in order to reach a common understanding of each point of views. It allows to: i) clarify the existing knowledge, identifying also missing studies, models, and action plans; ii) integrate new stakeholders' views into the initial problem formulation; iii) identify potential barriers or preconditions to work with stakeholders according to participatory principles; iv) analyze what competencies stakeholders need before the generative process starts in terms of motivation, knowledge, and practical expertise, in order to be able to effectively participate to the P-C phase. Consequentially, the expected outcomes are: i) a summary of the complete state-of-the-art knowledge on the case study and policy issue under analysis, ii) an improved and detailed stakeholder analysis, iii) the definition of the common problem formulation including the individual points of view and iv) the identification of the dominant design concerning the traditional policy alternatives represented via a preliminary C-tree model.
At the end of the P-K phase, the document summarising the complete K-space is shared with all the participants in order to prepare them to the following phase.

Policy-Concepts Generation phase (P-C phase). The aim of the P-C phase is to generate policy alternatives using the C-K theoretical framework. It consists of one day generative workshop with a group of participants and it is divided in four steps. Firstly, the common problem formulation is shared, discussed and validated in order to built a common knowledge ground and a collective shared problem formulation for the generative workshop. Secondly, the preliminary C-tree is explained to all the participants. Afterwards, the participants are divided in heterogeneous groups of stakeholders, in order to collectively evaluate and discuss the elements representing the policy dominant design and to suggest the expansions of the C-tree. During this step, each group need to agree on the evaluation of the alternatives and C-expansion, in order to facilitate a "local" process of defixation. Lastly, a general discussion on the group activities is concluding the workshop, in order to structure a starting point for the participated learning process.
The C-tree for the innovative design of policy alternatives displays different exploration paths. In Figure 1 is showed an example of the paths on the left describe the genealogy of known objects, i.e. the hierarchy of attributes stabilized in the dominant design [2]. Specifically, the central branches outline the first C-expansions allowed by the incremental addition of knowledge or the re-organization of existing K-space. Ultimately, the right side of the C-

tree displays the expansions leading to innovative policy alternatives, which are not explored in the K-space yet.

Policy-Project phase (P-P phase). The P-P phase uses the K-space and the C-tree generated in the previous steps, in order to build a set of policy recommendations, including the innovative set of policies alternatives. Similarly to the KCP approach, an expert team is involved in this phase in order to test feasibility of the policy alternatives identified.

In order to experiment an innovative methodology of policy design, the developed P-KCP workshop methodology has been tested in a pilot case study concerning an environmental policy problem described in the following section.

5 The groundwater protection policy within the agricultural sector of the Apulia Region (southern Italy)

The current section describes the experimental implementation of the P-KCP design methodology for the generation of innovative policy alternatives in a pilot case study. The case study concerns the groundwater protection policy and water management within the agricultural sector of the Apulia Region (southern Italy).

The P-KCP experiment has been defined to be carried out over a period of approximately 9 months. The current timeline for the case study is outlined in the following Table 1.

Table 1 The P-KCP process and timeline

Event/Action	Duration
Workshops planning	1 month
Documents/Reports review	1 month
Definition phase and 1st round of interviews	1 month
Knowledge phase and 2nd round of interviews	2 months
Interview reports validation	1 month
Structuring of the preliminary C-Tree	3 months
C-phase and generative workshop	1 day
Writing the C-phase report	2-3 months
P-phase	To be developed

5.1 Case study description

The case study is located in the north of the Apulia Region (southern Italy). The Apulia Region is characterized by a share of prevalent irrigated crops (i.e. tomato for industries) compared to the rainfed crops (i.e. wheat). It could be considered as a typical example of groundwater (GW) overexploitation due to the limited availability of surface water (SW) resource for irrigation practices [46]. The area under analysis is characterized by uncontrolled GW withdrawals while the management of the SW irrigation networks is handled by the Capitanata Irrigation Consortium (IC). IC is a private board of public law and non-profit organizations [47]. IC provides SW management for the agricultural sector, ensuring an adequate technical and administrative assistance to farmers. The area is characterized by the combined use of both SW and GW for irrigation, and by the strong impact of the water

management policies on farmers' behaviour [45]. The IC, one of the largest in Italy, provides water to approximately 58.000 farms with different extensions, ranging from very extensive to intensive [104]. The SW annual availability depends strictly upon weather conditions and rainfall patterns, being an area characterised by recurrent drought events.

Considering the general objectives of the main involved stakeholders, it is possible to observe that: the strong GW dependency of the agricultural sector and consequential over-exploitation generates social and environmental problems. The Regional Authority, needs to protect GW quality and at the same time to preserve high productivity standards for the agricultural sector. In 2009 the Regional Authority implemented the Water Protection Plan, in order to significantly restrict the GW use (according to the European Water Framework Directive, CEE 2000/60). Based on a traditional policy design approach, this policy was defined without considering the potential impacts on the stakeholders (i.e. farmers and IC) and it caused strong conflicts between them [46]. The policy resistance mechanisms mainly occurred due to the economic damages to the agricultural sector, highly dependent on the water-demanding crops and irrigation practices [45]. On the one side, the IC has to deal with the water shortage and with the Farmers' water requests. Specifically, it uses an increasing pricing strategy (based on the Water Protection Plan suggestions), defining two different price thresholds for the SW that ensure the equal distribution of SW for the whole duration of the irrigation season: the base water supply volume (0.12 €$/m^3$ for 2050 m^3/ha) and the additional water supply volume considerably more expensive (0.36 €$/m^3$ for 2050-4000 m^3/ha). In the IC's problem understanding, this policy would force Farmers to reduce the irrigated areas and/or to select less water demanding crops, without considering the GW alternative (*REF EJOR*). On the other side, each farmer maximizes her/his profits by choosing the crop plan with regard to the quantity of available water (i.e. SW and GW) and the hectares of arable land owned. Due to the strong irrigation practices, the base water supply volume is not adequate to cover the water request. Within this situation, each farmer can choose between two alternatives: paying for the additional water supply volume (sold by the IC) or using the GW, a cheaper (approximately 0.19 €$/m^3$) and easily accessible resource. Thus, the use of GW is restricted by the Water Protection Plan but the price of the additional water volume is higher than the price of GW withdrawal. Even if the GW quality is lower than the water managed by the IC, farmers tend to prefer the use for GW. The farmers perceive the price for the additional water volume as unsustainable. Therefore, they use the base water supply volume, combined with the GW for the remaining water demand. Consequently, the key issue of the case study is the increasing level of conflict between stakeholders, i.e. the conflict arises from contrasting objectives of preventing GW deterioration and supporting the productivity of the local agricultural sector. A detailed description of the case study can be found in [45] and *REF EJOR*.

Given this context, the main objectives of the P-KCP workshops in respect to the stakeholders were: i) to allow a collective and participated analysis of the water management issues and policies, in order to reach a shared understanding of the different problem framing; ii) to contribute to the conflicts mitigation and renewed understanding of the problems by all parties; iii) to ensure a better participation of all the stakeholders and integration of their knowledge, in order to overcome the limits of the traditional methodologies; iv) to suggest innovative alternatives and improvement elements for the GW protection policies and water management strategies within the agricultural sector; v) to investigate how innovative policy alternatives can be integrated into a Regional plan, in order to develop new ways to solve the policy problems. From a methodological point of view we aim: i) at testing and validating the effectiveness of a C-K based tool for the innovative design of policy alternatives within the policy cycle; ii) at showcasing a proactive approach to supporting research

and "best practice" participatory processes as an example in order to improve the policy design process.

5.2 The Policy-KCP participatory instrument for the generation of innovative policy alternatives

P-D phase

During the pre-workshops activities, the policy design management team outlines a first list of relevant participants, determining which stakeholder is involved in or affected by the policy issue under investigation. The stakeholders were considered as all the individuals or entities/institutions related to the policy problem. Further details on the identified stakeholders and their role are showed in table 2. To make sure that all the categories of relevant stakeholders were included in the process, the selection process starts with the identification of the stakeholders mentioned in the official documents, reports, and institutional protocols. Furthermore, preliminary interviews with experts and institutional actors allowed to widen the set of stakeholders to be involved (examples of questions are: which stakeholder should be involved in the policy design process and in the P-KCP workshop? Why? What are your interests concerning the policy goal? What are the other stakeholders' interests? etc. The profile of each possible participant was created including personal objectives and points of view concerning the GW management problem. Moreover, the relationships with other stakeholders were investigated in order to detect conflict situations. Previous research activities on the case study supported this preparatory phase. The preparatory phase allows an initial definition of the problem formulation, reducing the GW dependence, ensuring a suitable water volume for the agriculture (C0).

Table 2 List of P-KCP Participants

Stakeholder	N.	Role
Farmers small scale	4	Water user
Farmers large scale	3	Water user
Consortium of Capitanata - Technical	3	Local water management authority
Consortium of Capitanata - Political	3	Local water management authority
Regional Authority	1	Regional political authority
River Basin Authority	2	Regional technical authority
Expert IRSA-CNR	1	Water management and governance
Expert IRSA-CNR	1	Water balance physical models
Expert CIHEAM	1	Agricultural land/water governance
Expert University of Bari	1	Agricultural economy
Management team	1	C-K theory expert
Management team	1	Decision theory
Management team	1	Case study expert
Assistants	1	-
Observers	2	-

P-K phase

Within the case study, the P-K phase supports the identification of the common knowledge on the GW protection and SW management problem, including the quali-quantitative

state of GW aquifers in the Region and the analysis of the different stakeholders' problem framing. Knowledge elicitation activities were carried out by integrating scientific and technical evidences available in literature with expert and local knowledge ([39], [117]), according to participatory work principles. After the first round of interviews of the preliminary phase, a second extended round of semi-structured interviews was carried out with all the stakeholders. The detailed interviews inspected several topics such as the water management current and suggested strategies, the peculiarities of the IC's SW management, the main characteristics of the agriculture sector and farmers' behaviours , the issues related to field controls, the known effects of the high irrigation practices on the GW aquifers state, etc. Due to the stakeholders' time constraints, C-K seminaries and common knowledge sharing sessions were not possible (see section 3.1). Nevertheless, the policy management team interacted and collaborated with all the participants along all the phase. The information provided was written and distributed to all the stakeholders, developing the first version of the P-K space. The knowledge sharing process supporting the alignment of the different stakeholder's perception of the policy issue (i.e. the social aspect of the K-sessions) was organized as starting point of the C-phase with a general discussion at the beginning of the 1-day generative workshop. Lastly, in this phase, students supported and simplified the time-demanding task of GW management best-practices identification. The students attending the 2017 master of ENSAM-Mines ParisTech were trained with the C-K principles for three months, enriching the innovative technical part of the P-K space. During this phase, participants started learning from other's knowledge and realizing missing knowledge elements.

P-C phase

Similarly to the traditional KCP methodology, the P-C phase includes the generation of different paths within the C-tree. Using a color code, the following figure 2 shows the whole preliminary C-tree while figures 3 and 4 display its parts in details: i) the branches describing the attributes of the existing dominant design of known policy alternatives are colored in black, ii) the ones in blue characterize attainable policy alternatives that are using existing knowledge or a combination of K pockets (i.e. policy alternatives used in best practices of comparable case studies), and iii) the paths in green represent breaking new ground policy alternatives, requiring the expansion of the K-space in order to enlarge the C-space.

Fig. 2 C-tree showing the policy alternatives generated for the problem of GW protection and WM for the agricultural sector of the Apulia Region

Table 3 lists the elements of the C-tree, underling the concepts hierarchy and the preliminary stakeholders' interest on alternatives. The expected output of the P-C phase is to frame possible innovative alternatives to be explored in the following P-P phases. Through

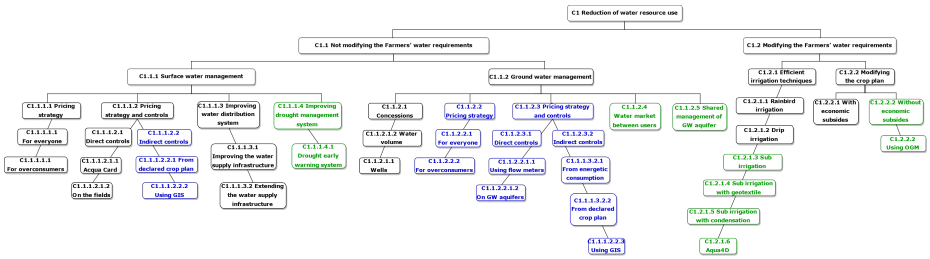

Fig. 3 C-tree, left branches

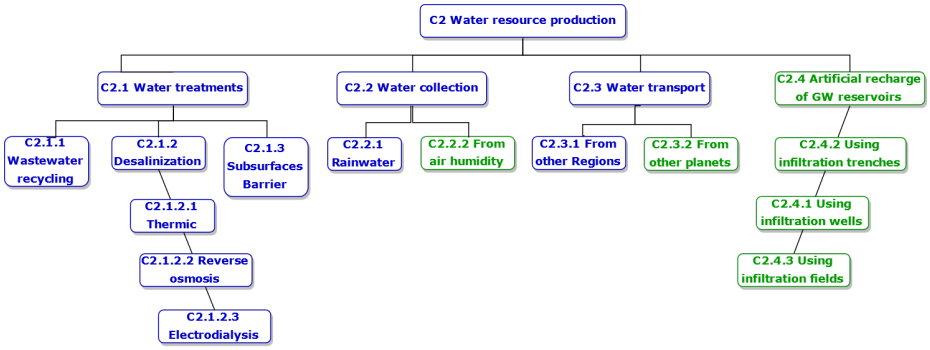

Fig. 4 C-tree, right branches

the generative workshop, a collective problem understanding and formulation have been settled and the set of policy alternatives have been analysed and improved. During the 1-day generative workshop, the process of design policy alternatives was supported and managed accordingly to the C-K principles of innovation management.

Table 3: List of policy alternatives generated in order to reduce the GW dependence, ensuring a suitable water volume for the agricultural sector (C0)

C0 To reduce the GW dependence, ensuring a suitable water volume for the agriculture

ID	Policy alternatives	N.	Status
C1	Reduction of water resource use		
C1.1	Not modifying the Farmers' water requirements		
C1.1.1	Surface water management		
C1.1.1.1	*Pricing strategy*	-	*Dominant Design*
C1.1.1.1.1	*Pricing strategy for everyone*	*1*	*Dominant Design*
C1.1.1.1.1	*Pricing strategy for overconsumers*	-	*Dominant Design*
C1.1.1.2	*Pricing strategy and controls*	-	*Dominant Design*
C1.1.1.2.1	*Direct controls*	*2*	*Dominant Design*
C1.1.1.2.1.1	*Direct controls using Acqua Card*	-	*Dominant Design*
C1.1.1.2.1.2	*Direct controls on the fields*	-	*Known*
C1.1.1.2.2	*Indirect controls*	*1*	*Dominant Design*
C1.1.1.2.2.1	*Indirect controls from declared crop plan*	-	*Known*
C1.1.1.2.2.2	*Indirect controls using GIS*	*1*	*Known*
C1.1.1.3	*Improving the water distribution system*	*1*	*Dominant Design*
C1.1.1.3.1	*Improving the water supply infrastructure*	*2*	*Dominant Design*
C1.1.1.3.2	*Extending the water supply infrastructure*	*2*	*Dominant Design*
C1.1.1.4	*Improving drought management system*	-	*Unknown*

C1.1.1.4.1	*Drought early warning system*	*7*	*Unknown*
C1.1.2	Ground water management		
C1.1.2.1	*Concessions*	-	*Known*
C1.1.2.1.1	*Concessions - wells*	-	*Known*
C1.1.2.1.2	*Concessions - water volume*	-	*Known*
C1.1.2.2	*Pricing strategy*	-	*Known*
C1.1.2.2.1	*Pricing strategy for everyone*	-	*Known*
C1.1.2.2.2	*Pricing strategy for overconsumers*	-	*Known*
C1.1.2.3	*Pricing strategy and controls*	-	*Known*
C1.1.2.3.1	*Direct controls*	-	*Known*
C1.1.2.2.1.1	*Direct controls using flow meters*	-	*Known*
C1.1.2.2.1.2	*Direct controls on the GW aquifers*	*2*	*Known*
C1.1.2.3.2	*Indirect controls*	*4*	*Known*
C1.1.1.3.2.1	*Indirect controls from energetic consumption*	-	*Known*
C1.1.1.3.2.2	*Indirect controls from declared crop plan*	*1*	*Known*
C1.1.1.2.2.3	*Indirect controls using GIS*	*4*	*Known*
C1.1.2.4	*Water market between users*	*2*	*Unknown*
C1.1.2.5	*Shared management of GW aquifer*	*10*	*Unknown*
C1	Reduction of water resource use		
C1.2	Modifying the Farmers' water requirements		
C1.2.1	Efficient irrigation techniques	3	
C1.2.1.1	*Rainbird irrigation*	-	*Known*
C1.2.1.2	*Drip irrigation*	-	*Known*
C1.2.1.3	*Sub irrigation*	*2*	*Known*
C1.2.1.4	*Sub irrigation with geotextile*	-	*Unknown*
C1.2.1.5	*Sub irrigation with condensation*	-	*Unknown*
C1.2.1.6	*Aqua4D*	*4*	*Unknown*
C1.2.2	*Modifying the Farmers' crop plan (CP)*	*3*	*Dominant Design*
C1.2.2.1	*Modifying the CP with economic subsides*	*6*	*Dominant Design*
C1.2.2.2	*Modifying the CP without economic subsides*	*1*	*Unknown*
C1.2.2.2	*Using OGM*	-	*Unknown*
C2	Water resource production		
C2.1	Water treatments	2	
C2.1.1	*Wastewater recycling*	*8*	*Known*
C2.1.2	*Desalinization (general suggestion)*	*4*	*Known*
C2.1.2.1	*Thermic desalinization*	-	*Known*
C2.1.2.2	*Reverse osmosis desalinization*	-	*Known*
C2.1.2.3	*Electrodialysis desalinization*	-	*Known*
C2.1.3	*Subsurface barriers*	*1*	*Unknown*
C2.2	Water collection	2	
C2.2.1	*Rainwater collection*	*4*	*Known*
C2.2.2	*Water collection from the air humidity*	*6*	*Unknown*
C2.3	Water resource transport		
C2.3.1	*From other Regions*	*3*	*Known*
C2.3.2	*From other planets*	*1*	*Unknown*
C2.4	Artificial recharge of GW reservoirs	9	
C2.4.1	*Using infiltration wells*	*3*	*Unknown*
C2.4.2	*Using infiltration trenches*	*1*	*Unknown*
C2.4.3	*Using infiltration fields*	*1*	*Unknown*

Following the P-KCP description, the one day generative workshop consisted on four main steps divided as follow:

1. A general discussion on the collective problem formulation starting form the different stakeholders' problem perspectives collected during the previous P-K phase. This step focused on the definition of the GW overexploitation policy issue according to the different participants' backgrounds (Figure 5).

2. Brief explanation of the C-K theoretical framework made by a C-K theory expert and general illustration of the preliminary C-tree (1h30min). The detailed description of each policy alternative identified at the end of the P-K phase supported the following activity. The description of the C-tree branches was supported by the linked elements of the K-space. At the end of this phase, each participant had to express preferences over the five most interesting/suitable policy alternatives for the given policy issue.
3. Small group activities regarding the evaluation of the dominant design of policy alternatives and the proposition of innovative policy alternatives through the expansion of the C-tree. The policy design management team regrouped the participants in 3 small heterogeneous groups. To each group was give a representation of the C-tree and formatted paper sheets. Each group had to choose at least 5 policy alternatives/elements of the C-tree and analyse the selected items in the following ways: carrying out a collective evaluation of the items providing specific and practical observations and criticisms, defining the interest of each chosen item using scale from 1 to 5 (from very useful to not-useful at all for the case study), providing suggestions and group recommendations for improving the analysed items, and prompting new policy alternatives or innovative combinations of them. Table 3 lists the elements of the C-tree selected from the groups for the second part of the generative workshop.
4. A general discussion concerning the results of the small group activities and the C-tree expansion suggestions . The general discussion leads to a portfolio of preferred policy alternatives shared with all the stakeholders and to the introduction of few innovative policy alternatives.

Fig. 5 The experimentation of the P-KCP one-day generative workshop hosted by the Consortium of Capitanata

Specifically, during the generative workshop (Figure 6), the three groups worked on policy alternatives discussed in the following paragraph.

Fig. 6 Group activities during the P-KCP one-day generative workshop

5.3 The outputs of the C-phase generative workshop

All three stakeholder groups considered "Water resource production - Artificial recharge of GW reservoirs" (C2.4) and "Shared management of GW aquifers" (C1.1.2.5) to be valuable alternatives. The "Drought early warning system" (C1.1.1.1.4.1) and " Water resource production - Wastewater recycling" (C2.1.1) alternatives were discussed at length. Perhaps the most interesting observation was the groups shifting focus from the alternatives generated via dominant design at the beginning of the workshop to the alternatives in the more innovative C-tree branches towards the last part of the workshop. The explored policy alternatives are shown in table 4.

The workshop ended with the generation of a new set of innovative policy alternatives: i) delocalization of the tomato production as new option for modifying the crop plan with economic subsidies (C-tree branch C.1.2.2), ii) sales at the end of irrigation season for the SW managed by the IC, i.e. a lower price for additional water volume in case of abundance (C-tree branch C1.1.1.1), iii) construction of new dams and related infrastructures at different scales. Furthermore, during the discussion, participants highlighted the need to combine policy alternatives in order to have a portfolio of actions as a policy strategy.
Specifically,

– The alternative "Water resource production - Artificial recharge of GW reservoirs" (C2.4) was proposed for increasing the water availability, considering GW aquifers as reser-

Table 4 Summary of the groups' activities

ID	Policy alternatives	Groups
C1.1.2.5	Shared management of GW aquifers	G1, G2, G3
C2.4	Artificial recharge of GW reservoirs	G1, G2, G3
C1.1.1.1.4.1	Drought early warning system	G1, G2
C2.1.1	Wastewater recycling	G1, G2
C2.3.1	Water transport from other Regions	G1
C1.1.2.3.2	Indirect controls of GW use	G2
C1.2.2	Modifying the crop plan	G2
C1.1.1.2.2	Indirect controls of SW use	G3
C1.1.2.3.1.4	GW aquifers monitoring	G3
C2.2.1	Rainwater collection	G3

voirs for properly treated water. This alternative defined a new role/attribute for the GW reservoirs. The participants underlined the need to analyse the interdependencies between the C2.4 alternative and economic and management issues (e.g. the high costs of investment, the need for a detailed analysis of the aquifers state, the farmers' will to accept). During the discussion G1 suggested that the strength of this alternative was related to the abundance of winter water flow that could be collected and reintroduced by helping the aquifer hydrologic balance in dry and summer seasons (i.e. requiring newly built storage space). Participants were inspired by the alternatives explored in the related C-tree branch and suggested implementing a decision support system to evaluate the economic and technical feasibility of the proposed sub-alternatives (C2.4.1, C2.4.2, C2.4.3) through detailed hydrological studies and analysis of current regulations.

– The alternative "Shared management of GW aquifers" (C1.1.2.5) has been recognised a promising long term policy strategy, enhancing the innovative management of GW through shared and informed decision processes. The starting point has been the awareness (i.e. via a specific K-pocket) of the attributes defining the GW resource. Thus, GW is a shared resource characterized by a highly distributed structure with several collection points (i.e. wells) in private properties. In this regard, farmers tend to deny the legitimacy of a centralized entity for its management. Furthermore, stakeholders' knowledge clarified that the centralised "command and control" approach fails in verifying the actual number of wells and GW volume consumptions due to high management costs. However, a shared GW governance could empower the Farmer community through reward regulations for virtuous GW use (e.g. GW use reduction). Shared GW governance is supported by non-centralized self-organizing management structures (i.e. groups of farmers managing shared sub-aquifers). Following the discovered GW attributes the discussion leads to considering a distributed management system, in order to overcome the shortfalls of a centralized management for GW. At the end of the discussion, the principles of shared governance were revised by a few stakeholders inspired by the IC example. The arising alternative considers the IC as an integrated water resource management authority (i.e. SW and GW) through a specific GW withdrawals legislation, legitimated by a bottom-u participative decisional process in order to preserve the equal water distribution principle. For the shared management policy alternative, participants identified the necessity of: i) a detailed database on the quali-quantitative state of the aquifers from a physical point of view; ii) Farmers' crop plan patterns from a management point of view in order to organize farms in sub-structures; iii) a learning process via pilot a case study from the social point of view.

- The alternative “Drought early warning system (DEWS)” (C1.1.1.1.4.1) was discussed with a twofold perspective. On the one hand, all the participants recognised that a DEWS does not have a direct effect on GW availability, underlining (i.e. via a specific K-pocket) the differences between superficial drought and GW shortage, the latter becoming visible with a significant delay. On the other hand, some participants observed that a DEWS managed outside the IC structure, could erase the farmers’ dependency on the IC information system, encouraging irrigated crop practices in case of water abundance with a major negative impact of the GW aquifers. However, the experts of the G1 highlighted that analysis based on historical data could be beneficial for supporting the annual farmer’s crop planning phase through timely information on water availability
- The “Water resource production - Wastewater recycling” (C2.1.1) was considered a pragmatical alternative despite several technical reports show that it does not increase significantly the quantity of available water. New elements were added to the K-space during the discussion (i.e. the IC is developing a project for introducing recycled wastewater in its distribution system). The discussion focused on the role of the IC as a management authority for an integrated water distribution system. The participants identified the following actions to be considered in a portfolio of policy alternatives: i) exploring innovative water treatment technologies in order to expand the related C-tree branch; ii) developing a reliable treatment process in order to recognize the different responsibilities in the production and distribution phases; iii) facing problems related to the recycled water quality and avoiding a decrease in crops conditions; iv) to fairly dividing the energetic consumption of the treatment plant (i.e. paid by the Farmers or by the whole community); v) developing strategies and infrastructures (i.e. water storage systems) in order to secure the water distribution in case of breakdown.
- The known alternatives “Indirect controls of GW use” (C1.1.2.3.2) and "Indirect controls of SW use" (C1.1.1.2.2) were considered as basic actions for the implementation of the more innovative policy alternatives. Providing more detailed information about the current situation would improve policy effectiveness. A key step would be the introduction of new institutional actors that could support the phase of gathering the abovementioned information. Expansion of the two C-tree branches involves: i) controls on the energetic consumption via the collaboration with the energy company; ii) controls on the actual cultivated hectares and crop plans; iii) introduction or re-organization of a dedicated institutional actor for the data set task. Furthermore, G3 suggested a combination of policy alternatives, including the declaration of the annual crop plan as fundamental constraint for the access to the SW distribution system. Similarly, "GW aquifers monitoring" (C1.1.2.3.1.4) was recognized a basic action for the implementation of other policy alternatives.
- The “Water resource production - Water transport from other Regions” was considered a well established alternative with several related technical and organizational issues. Several Regions neighbouring the Apuglia Region have a surplus of SW and this additional water volume is already used for the urban potable distribution system. The participants underpinned that there is available knowledge on the topic but that this alternative has not been explored yet for the agricultural system due to political issues concerning specific institutional actors that were not involved in the process. Consequentially, the missing knowledge did not allow to expand the C-tree branch.
- Within a generic perspective, the G2 suggested to explore the C-tree branch related to the alternative “Modifying the crop plan” (C.1.2.2). The economic subsidies driving the farmers’ tendency to prefer irrigation practices were proposed, i.e. an economic compensation for voluntary GW quantity monitoring and reduction of GW consumption.

Participants suggested that this branch should be explored in detail thanks to the combination with a related K-space expansion (i.e. missing knowledge on the subject).

– Lastly, the alternative "Water resource production - Rainwater collection" (C.2.2.1) was pictured as an essential, even if limited, answer to the GW overexploitation problem. The collected rainfall represents a small volume, but this alternative combined with other options of water resources production (i.e. "Wastewater recycling") could reduce the GW dependency of the agricultural sector. During the discussion a new alternative was generated and the group proposed to use rainwater and recycled wastewater for softening the seawater intrusion, increasing the GW quality. The rainfall collection practices were well-know from the participants and they did not explore any discussion on the technical aspects.

5.4 Workshop Evaluation

The results of a short questionnaire distributed to the participants at the end of the workshop and few detailed follow-up interviews helped in the evaluation of the P-KCP participatory instrument for the innovative design of policy alternatives. Within the pilot case study, the methodology received positive feedbacks. It was considered an innovative and intriguing methodological approach since during the final discussion further innovative alternatives emerged.

The highlighted advantages include the pre-workshop activities for eliciting the available knowledge on the policy problem under consideration. Indeed, the K-phase and the preliminary C-tree allowed to structure the discussion during the one day generative workshop, without influencing the stakeholders' opinion because it was mirroring their own point of view and partial K-spaces. Several participants appreciated the supplied information about the policy problem, with specific emphasis to the K-sessions and the definition of a shared problem understanding. Several stakeholders recognized that the P-KCP approach brought them at the same level during the discussions, in a more inclusive participative perspective.

On the other side, the pinpointed disadvantages were mainly concerned the one day workshop timeline and the C-K theory key elements transmitted. On one hand, few participants complained about the lack of time for continuing exploring the alternatives on the C-tree and for further discussions. For them the general K-session was a time-demanding activity despite they recognized that the lack of stakeholders' availability was an important driver for the workshop organization decisions. On the other hand, one of the experts stated the need of a longer training on the C-K theory, in order to deeply understand the generative process the creativity driven the process was not visible. Lastly, one of the participants underlined the missing validation for the terminology used in the C-tree.

6 Discussion

From a methodological point of view, the C-K theory framework and the P-KCP participatory instrument offer a formal support for policy design, assisting the design of innovative policy alternatives. In the presented policy design process based on C-K theory, it was possible to observe and formalize a "generative mechanism" aimed at modifying the stakeholders' values structure with the consequential expansion of the set of policy alternatives. It improved the quality of the participation for the policy design and expand its scope. This was achievable thanks to three main differences between the P-KCP participatory instrument

and other traditional participatory approaches (e.g. [27], [135]): i) the alignment of different stakeholders' knowledge independently from the source in order to build a collective problem understanding and formulation; ii) the assisted sharing of structured knowledge allowing the expansion of the available knowledge (i.e. K-space expansion) as a starting point for the *unfixation* process; iii) the methodological support for innovation management applied to policy design.

Firstly, the dichotomy between expert and local knowledge, characterizing the traditional participatory approaches, has been overcome thanks to the P-KCP participatory instrument for the design of policy alternatives. Different knowledge have been aligned in a more inclusive participatory process. On one side, stakeholders are experts of the local policy issue and they offer a valuable insight for the problem formulation with a K-space expansion. On the other side, experts in several domains linked to the policy goal (e.g. technical, organizational, legislative expertise) facilitated the group learning process through the K- and C-space co-evolution. P-KCP aims at using equally each stakeholder's knowledge, in order to support the group generative mechanism for the innovative design of policy alternatives, enhancing a common problem understanding and improving engagement and consensus on the whole policy making process. New information that were not considered before become now valuable.

Secondly, P-KCP reestablishes communication between stakeholders by unfixing the group from the dominant design, i.e. traditional and known policy solutions. Fixation phenomena within the policy design process bring policy makers and stakeholders in conflicting and unsustainable situations. As it is possible to observe from our pilot case study, at the beginning of the one-day generative workshop, participants tended to debate only about the dominant design, while at the end they were able to explore and expand more innovative branches of the C-tree with mutual consent, on both traditional and non-traditional solutions. Thus, the first part of the workshop leaded antagonistic stakeholders to discuss on the collected knowledge and to agree with the different problem formulations presented, allying their differences (see section 5.1). Each participant realized the missing information and was more accommodating to new K-space expansions. This represented the starting point for stimulating discussions during the generative mechanism for the C-space exploration. 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, they were wilier to cooperate in a constructive debates. Also the injection of new knowledge related to non-traditional solutions (and provocations) had positive effects on their collective activities and workshop results. Unfixed participants were available to propose new solutions or integrate known alternatives in a different perspective. Moreover, they were able to introduce more useful knowledge that become operational in the new alternative propositions. This C- and K- spaces expansion is a traditional effect of a C-K based workshop (see section 3).

Lastly, P-KCP and the C-K theory framework provides a support for the innovative generation of policy alternative. Traditional participatory approaches focus their efforts on the problem identification and the collective evaluation of known alternatives, following the dominant design. Several approaches such as Problem Structuring Methods drives the identification of known alternatives and not of the ones *inconceivable*, creativity and innovation are not considered or managed. In order to allow the emerging of *inconceivable* alternatives a formal methodology for innovation management is needed. Under such perspective, C-K theory and P-KCP represent the required guidance for a wider and inclusive policy design process.

The first difference between P-KCP and KCP to discuss is the peculiar context in which we operate. The main features defining public policy are discussed in [30] and *EJOR*. KCP has been conceived and operationally validated in the private sector where innovation is a basic driven supporting activities. Participants to KCP are generally incentivized to work together sharing the same company objectives and the only differences are between departments expertise and specific goals. Whereas, in public decision processes, the information is shared between different stakeholders with their own goals, backgrounds, expertise and knowledge bases. The lack of motivation to participate to the policy design process as well as of the willingness to change towards a more inclusive participatory approach are pivotal drives. Under a participatory decision making perspective, an effective policy design process requires the identification of a *shared concern* in order to motivate stakeholders' commitment. Generally antagonistic stakeholders are not motivated to work together, they have conflicting objectives, different values systems and distant personal perceptions of the same problem. The P-KCP methodologically supports the participants to identify a *shared concern*. A similar concept has been discussed in [99], where the identification of the meta-object of the Interaction Space allows an integrated problem representation to be developed. In this regard, P-KCP builds a collective problem understanding and formulation allowing the stakeholders to entice to participation. This represent a starting point for a forceful participatory processes.

In case of lack of stakeholders' proactive efforts and of a *shared concern*, each stakeholder tends to thinks and discusses policy alternatives related only to their individual problem framing (i.e. fixation phenomenon). Building a collective problem understanding and formulation allows the activation of the design process while conflicting situations considering the individual perceptions causes clashes.

More in detail, in classical KCP, participants are physically working in the same company, while stakeholders and institutional actors are often delocalised and have to interact from distance. The geographical constraint and the time limitation make the realization of the classical seminars for the K-space expansion difficult. During a KCP, each participant develops its own K-space and several seminars are developed in order to offer a more knowledgable guidance for the generative phase and the C-space evolution. On the other side, during a P-KCP process, the learning process characterizing the K-phase is compressed because the K-space has been built by analysts. Stakeholders receive an initial set of alternatives and it is required to discuss the starting point and explore it in order to support the C-space expansions. The design management team elicits and structures stakeholders' knowledge before the generative workshop due to the lack of engagement in the process and policy issues and of skills in developing research activities in a systematic way. This represents an innovation in C-K theory based tools.

7 Conclusion

This paper presents an experiment aiming at testing an original approach for the innovative design of policy alternatives. P-KCP is a methodology formalizing the policy design process based on C-K theory. It supports the generation of *inconceivable* alternatives thanks to the co-evolution of the K- and C- spaces accordingly 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 and formulation.

Mainstream policy making does not focus on the generation of innovative policy alternatives. It is more effective in relation with the evaluation of known alternatives. The

identification of the dominant design is an ordinary process thanks to several approaches derived from Problem Structuring Methods. Participatory processes have been designed to facilitated the exchange of knowledge in order to develop more or less shared process of evaluation. For this reason, we suggest the use of a generative participatory process separated from the evaluative one.

The experiences carried out in the Apulia case study support the experimentation of the P-KCP instrument for policy design. It creates new insights and evidence. It brings together stakeholders, experts, institutional and non-institutional actors aiding them to find new ways of working together efficiently, generating innovative possible alternatives and encouraging longer term thinking. P-KCP facilitates the transfer of knowledge, enabling participants to embed learning back into their organisations. As result of the experiment, we realize that policy design is a generative process for the creation of a new dimension of values, overtaking fixation phenomena through the creation of new variables and/or the elimination of useless variables. For example, within the water management case study, thanks to the C-K theory based policy design tool, we were able to introduce new alternatives in order to modify the value structures in a successful policy making process. Our objective is to identify and integrate these innovative alternatives into a policy.

In conclusion, this work demonstrates that the traditional participatory methodologies focus on how different stakeholders with different preferences and decisional criteria are going to decide together once design of alternatives is given. C-K theory, instead, offers a theoretical framework for the generative participatory process of policy design. Indeed, P-KCP assists policy makers and stakeholders to work together for the generation of alternatives overcoming difficulties of the traditional approaches. The knowledge alignment represents the starting point for breaking the fixation phenomena, i.e. the identification of well-known solutions and its characteristics, toward a generative phase to go beyond known solutions.

Lastly, the issue of the policy design group legitimacy has not been investigated in this paper and in general in participate public decision making processes; a notable exception is [93]. The topic will be discussed and deepened in a further development of this work.

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