Constellation analysis as a means of interdisciplinary innovation research: theory formation from the bottom up

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Constellation Analysis as a Means of Interdisciplinary Innovation Research – Theory Formation from the Bottom Up

Dörte Ohlhorst & Susanne Schön [*]

Abstract: *»Konstellationsanalyse als Werkzeug der interdisziplinären Innovationsforschung – Theoriebildung mit Bottom-up-Ansatz«.* Constellation Analysis is a methodological approach of innovation research that aims at understanding highly complex processes of invention and diffusion. It was developed as a tool for inter- and transdisciplinary research on technology, sustainability and innovation. Its set of tools facilitates access to a scientific object from different perspectives, using different approaches. The methodology is characterized in particular by two factors: Heterogeneous factors of influence and their effectiveness in innovation processes are principally considered equivalent, existing in relation to one another and thus fitting together into constellations. Furthermore, the methodology facilitates a bottom-up approach, similar to the Grounded Theory Approach. According to this principle, constellations are described based on their singular units and their relationships to each other. The methodology is thus appropriate to the individual course of innovation processes. It enables the search for new patterns through the comparison of different innovation biographies and allows experimentation with strategic approaches as a special form of validation.

Keywords: Constellation analysis, innovation research, inter- and transdisciplinary research, sustainability research, participative approach.

1. Introduction

This article looks at Constellation Analysis as a methodological approach of innovation research which aims at understanding highly complex processes of invention and diffusion. Constellation Analysis was developed as a tool for inter- and transdisciplinary research on technology, sustainability and innovation. Its set of tools facilitates access to a scientific object of study from different points of view and using different approaches. The methodology is charac-

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terized in particular by two factors: For one, heterogeneous factors of influence and their effectiveness in innovation processes are considered to be equal. This means that elements that are principally equivalent exist in relation to one another and thus fit together into constellations. This assumption characterizes the analytical approach of Constellation Analysis toward innovation processes and fundamentally distinguishes it from other approaches. On the other hand, this methodology facilitates a bottom-up approach, similar to the Grounded Theory Approach (cf. e.g. Glaser and Strauss 1967; Strauss and Corbin 1998). According to this principle, constellations are described based on their singular units and their relationships to each other. This methodology thereby does justice to the respective individual course of innovation processes (cf. Van de Ven et al. 1999). It enables the search for new patterns through the comparison of different innovation biographies and allows experimentation with strategic approaches as a special form of validation.

2. The Innovation Concept in Constellation Analysis

Inspired by Actor-Network Theory (Latour 1987, 1996a, 2005), Constellation Analysis sees innovation processes not only as a specific type of social change, but incorporates other processes of change as well, which are not always exclusively socially determined, but exist instead in interaction with other factors such as nature and technology. Constellation Analysis is based on the conclusion that empirical societal objects of investigation cannot be understood without the interlinked technical artefacts and infrastructure systems – and vice versa. Phenomena such as climate change, demographic change or economic structural change evolve in a specific interaction of societal, technical and natural factors – and Constellation Analysis takes these heterogeneous elements and their effectiveness within innovation processes into account as equivalent forces. Constellation Analysis is therefore based on a broad concept of innovation that sees innovation as an invention or variation that is both more or less technical as well as societal in nature.

Constellation Analysis can tie in seamlessly with the chronological, factual and societal relations that are relevant to innovations, as proposed by Rammert. The chronological relation is taken into account by the "phase constellations" of innovation processes describing the next respective temporal stage of socio-technical change, or by way of an outlining of the elements, relations and functional conditions that are necessary for the desired innovation within the framework of a prospective, strategic approach. The factual dimension is taken into account insofar as the new or novel aspect is differentiated from the conventional aspects based on the perspective of different disciplines. The societal dimension is expressed in the actors and symbolic elements (see elements

typology in section 2) that show the "new normality with other rules," which can describe an innovation (Rammert 2010, 12).

The analysis levels relevant for the societal dimension of innovations – semantics, pragmatics and grammar (cf. Hutter et al. 2015, in this HSR Special Issue) are not explicitly named in Constellation Analysis. However, the analysis does incorporate the influence of discourses, concepts and ideologies, of changing or institutionalised practices or behaviours as well as of relevant societal changes (regulatory systems, institutions, spatial settings etc.) on the innovation process. Against the background of analysing these factors of influence, we are looking for superordinate patterns in the framework of Constellation Analysis: patterns of synchrony or asynchrony of (sub-)processes, of integration or isolation of niches, of consistency or inconsistency of objectives, strategies or steering impulses.

2.1 Subject of Constellation Analyses

A typical research problem of *inter- and transdisciplinary* innovation research is presented by the difficulty of developing a mutual understanding of the innovation process, of the conditions of the innovation development and of the possibilities to exert targeted influence on those conditions. The subject of constellation analyses is therefore both the retrospective study of the constellations in innovation biographies as well as the prospective identification of strategic approaches for driving of innovation processes.

- The reconstructive analysis perspective examines how the innovation process has taken place in the interplay of various factors of influence. Constellation Analysis looks at this interplay and its relevant changes in socio-technical constellations. Usually, but not always, a technical innovation is at the focus of interest. The focus is on the question of which complementary developments and innovations (technical, economic, social etc.) benefited, supported or enabled the selection and diffusion process (see above) in the first place. The subject of Constellation Analysis is also the points of reference – the changing functional principles of the constellations or partial constellations which lead to the selection and reinforcement of an innovation.
- In the strategic analysis perspective, the focus is on an innovation that is considered to be desirable and that is still in the midst of a selection process (niche), or one that has not yet become established. What is examined here is which references the innovation that is deemed to be desirable currently makes use of (which functional principles it follows), which ones it must prospectively make use of in order to survive the selection process, and which complementary impulses and innovations are needed to achieve this. What is needed are strategic reference points for influencing the selection process in a dynamic way.

3. Methodical/Methodological Problem and the Resulting Questions

The starting point for the development of Constellation Analysis was the challenge of bringing together social science and engineering questions, methods and expertise into interdisciplinary research alliances in the fields of technology, innovation and sustainability research – this was precisely the task of the Centre for Technology and Society at the TU Berlin, which was established in the mid-1990s.

The task was made more difficult by the fundamental differences in scientific culture that existed between engineers and social scientists – differences which made cooperation nearly impossible: While engineers tend to be more solution-oriented in their work, social scientists are more knowledge-oriented; while engineers feel impeded by the theoretical baggage of social scientists ("too much talk"), social scientists consider engineers to be unreflective ("tunnel vision"). From a cognitive standpoint, these differences often led to the division in the production of knowledge along disciplinary lines, and from a social standpoint to the research teams simply putting up with each other.

What was needed was a method that would enable the preservation of epistemic interests, working practices and methods according to the existing differences in scientific cultures and disciplines, while still bringing together the expertise and knowledge to achieve joint results – and this at eye level, not by defining meta and service disciplines. The question was therefore which methodological set of tools could enable constructive collaboration that would preserve the disciplinary particularities while bridging the scientific cultures of the engineering sciences, natural sciences, social sciences and humanities.

Around the turn of the millennium, a heterogeneous working group at the Centre for Technology and Society took up this methodological challenge and, out of necessity, developed Constellation Analysis as a very pragmatic yet functional approach to the cognitive integration of different methods, partial results and bodies of knowledge. The key conceptual component of Constellation Analysis is the visualization of various elements – social actors, technical and natural elements, symbolic elements – and of their respective interaction within specific constellations. This graphical mapping allows constellations to initially be captured in all their complexity, after which point they can be gradually reduced through interdisciplinary and transdisciplinary discussion processes down to the essential elements and relations.

The graphical representation managed not only to win over the engineers for participation, it also brought about a fundamental improvement in the cooperation with actors who have practical backgrounds in transdisciplinary research projects: It enables a structured representation and discussion of largely complex scientific (interim) findings, the identification of points of consensus and

dissent held by the various participants and the joint development of strategic areas of action and bundles of measures.

4. Constellation Analysis – How To

4.1 Goal and Function of Constellation Analysis

Because the aim of Constellation Analysis is to open up innovation research processes for different perspectives regarding problems, bodies of knowledge and problem-solving approaches practiced by scientists, experts and stakeholders, Constellation Analysis is not only an analytical approach, but is also discursive methodology (Schön et al. 2007, 10). The focus of Constellation Analysis is on all the relevant, material and non-material factors of influence that are related to a particular innovation. These include societal, institutional, technical, environmental and spatial factors as well as their correlation with each other. The goal is the outlining of a system architecture (constellation) in which the heterogeneous elements are linked to each other based on their functions (cf. Krohn 1989, 38), and which changes over time. Missing links between elements are as well relevant information. The central elements and their relationships are identified and visualized by mapping the constellations, and based on this mapping, the disciplinary knowledge is integrated in a discursive process. The results are arranged mappings of complex problems in which patterns can be identified that ideally are shared by all parties involved in the research process.

4.2 The Question as Pivotal Point and Determinant for Drawing Boundaries

The starting point of a Constellation Analysis is a problem or a question which allows the problem-relevant elements to be defined and placed in relation to each other. Against the background of the common question or problem, the team agrees in a discourse on which elements are to be included in the constellation and how they are to be positioned. This also determines the boundaries of the constellation. The content of a constellation can only be established through the intended purpose (question at hand) that it pursues – an assessment of the constellation that aims at its complete inventory is neither possible nor useful. A central value of the representation of the constellation is that it highlights the relevant relations of the identified elements within the meaning of the question.

4.3 Technology and Working Steps

Within the framework of Constellation Analysis, four types of elements are distinguished.

Figure 1: The Types of Elements used in Constellation Analysis

Source: Schön et al. (2007, 18).

The element type "actors" refers to persons and groups of actors (e.g. institutions or organizations); the symbol for "technical elements" depicts artefacts (e.g. technical elements, procedures); "natural elements" refers to materials, resources, environmental media, plants and animals, the landscape or a natural phenomenon, and the element type "symbolic elements" stands for concepts, ideologies, standards, laws, discourses, as well as institutional, legal or economic factors.

The objects of research (e.g. specific technology, actors, landscape, laws etc.) of the participating disciplines are represented in the constellation mappings by these element categories. They provide linkages for all scientific disciplines (natural sciences, engineering, social sciences etc.), as well as for non-scientific participants, and allow an incorporation of their own perspectives. Constellation Analysis thus fulfills its function as a bridging concept. In the application of Constellation Analysis, it has been shown that a greater differentiation of this typology does not improve the functionality of the methodology.

A Constellation Analysis is ideally carried out in three steps (Schön et al. 2007, 24):

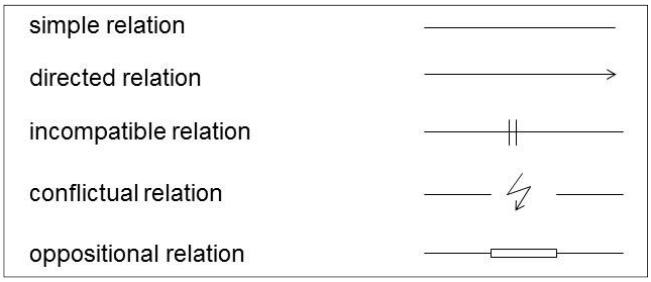
a. Mapping of the Constellation

The initial working step identifies those elements that characterize the particular problem. Each constellation focuses on those driving forces that are deemed to be central. This core of the constellation can be designated with a circle. The spatial proximity or distance shows how close or loose the relation between the elements is. The relationship of these elements to each other might be directed or undirected, oppositional, conflictual or even undetermined. A conflictual relation means that an element explicitly and intentionally acts against one or multiple other elements; an oppositional relation means that an element offers passive, not explicated resistance to the expectation or attribution of others. The relations between the elements are shown by corresponding lines or arrow types (see Fig. 2).

The relationships between the elements are not necessarily "hard" in the sense of measurability; instead, the indicator is the empirically determined relationship. The (interim) findings of the different disciplines and professional partners involved in the research project form the database for the Constellation Analysis. Since different disciplines use different scientific methods of data collection and data processing, the database for the Constellation Analysis consists of different formats.

Finally, the constellation is given a name. These steps are performed by the Constellation Analysis team, whose composition may be both inter-and transdisciplinary in nature. The relevance of the elements and relations is developed through discourse.

Figure 2: Examples of Types of Relations in Constellation Analysis



Based on Schön et al. (2007).

The respective constellation is embedded in a context. Context conditions refer to overarching framework conditions with a significant relevance to society as a whole, and which have an influence not only on individual elements within the constellation, but also on the overall constellation (e.g. political and policy changes, catastrophes or events that affect the perception of the problem). They form the background that drive or restrict certain developments.

A central conceptual principle of Constellation Analysis is that the heterogeneous elements which make up the constellation are considered to be equivalent. This is meant to prevent a premature differentiation between important and unimportant elements types. This principle is also meant to facilitate cooperation between partners as equals (Schön et al. 2007, 22).

The methodological core of Constellation Analysis is the mapping of the factors relevant to the question at hand, as well of their relations to each other. The illustrations are empirically secured; they are based on sources and knowledge of the scientists involved and, if needed, on the expertise of professional partners.

b. Analysis and Interpretation of Characteristics

A second working step determines the principles according to which the constellation functions (functional principles) and the characteristics and particularities it displays (characteristics).

The constellation is not self-explanatory, but always requires a textual description. Image and text complement each other, thus compensating for their respective deficits: While the mapping forces a concentration on the key influencing factors and their relations, the textual analysis and interpretation put greater emphasis on the consideration of the complexity that exists in reality

(Schön et al. 2007, 17, 62). Not only the graphical representation, also the interpretation of the constellations comes about in a discursive negotiation process on the best representation of reality. The model of the constellation does not reflect and integrate reality, but rather the understanding of the participating perspectives on that reality. The model thus promotes inter- and transdisciplinary understanding (cf. Ohlhorst and Kröger 2014). It is essential to make the respective reductions and abstractions in the construction of the scientific observation explicit and transparent, i.e. in a language that is designed to be accessible for all disciplines.

c. Analysis of the Processes of Change

The third step involves the processes of change that affect or could affect the constellation. Crucial questions to pose retrospectively are: What changed, and in what way? What triggered the changes? When and how did changes take place? And questions to pose prospectively are: What elements could change the constellation in the future, and in what form? The analysis looks at how stable the constellation is and what could possibly destabilize it. On the one hand, it focuses on the previous history (retrospectively). On the other hand, it tries to anticipate future developments, and in the process asks which elements need to be changed in a constellation in order to achieve certain goals or implement strategies (prospectively). In general, both the retrospective and prospective perspectives look at societal processes of change and transformation that are not limited to technical innovations. The focus of Constellation Analysis is on the interplay of influencing factors across longer chronological periods. When it comes to the active transformation, the focus is on possibilities of intervening in this interaction in ways that have a steering effect.

These three steps, which build on each other, are blended in the practical work of Constellation Analysis and represent iterative processes that can be repeated in loops. It is important that all three stages are executed at least once.

5. Case Studies

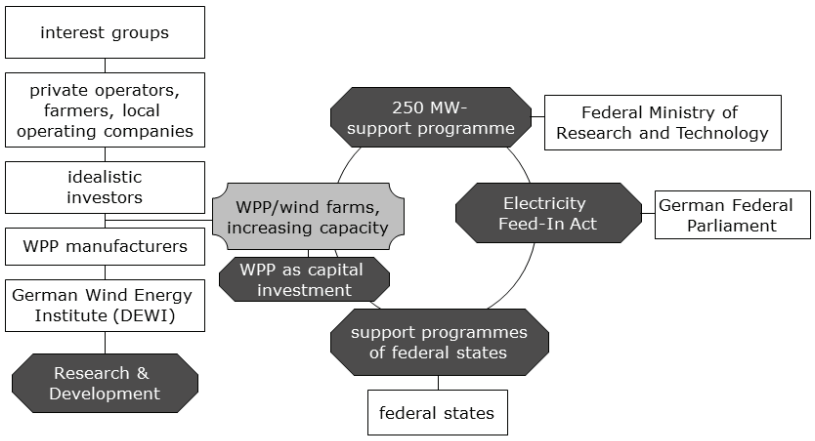
In the following section, two case studies will illustrate the retrospective (reconstructive) and the strategic approach, as well as the different associated analytical dimensions and epistemic interests. The possibilities of comparing different reconstructed processes will also be shown.

5.1 The Reconstructive and Comparative Dimension of Constellation Analysis

Constellation Analysis has been used in numerous interdisciplinary projects with a retrospective approach. The aim was to depict and analyse the course of

development or innovation processes. The reconstruction of the process is based on comprehensive research into all relevant influencing factors. The interdisciplinary team divides the process into phases, which can be distinguished from each other by identifying significant events and changes. In a second step, key influencing factors as well as their correlations and interdependencies are mapped out for each of the identified phases ("phase constellation"). This work step is based on the evaluation of empirical material, and experts from the field can also be involved in the mapping. Each of the phase constellations depicts a socio-technical configuration for a specific, chronologically delimited section of the development process with its own individual characteristic. The sequential arrangement of the phase constellations illustrates the course of the development, which in innovation processes is often characterized by alternating phases of stability and change. The phase constellations form the basis for a jointly composed textual description and interpretation of the course of development – the "innovation biography." The following example shows two-phase constellations from the innovation biography of wind energy (see Figures 3 and 4; Bruns et al. 2009, 261ff).

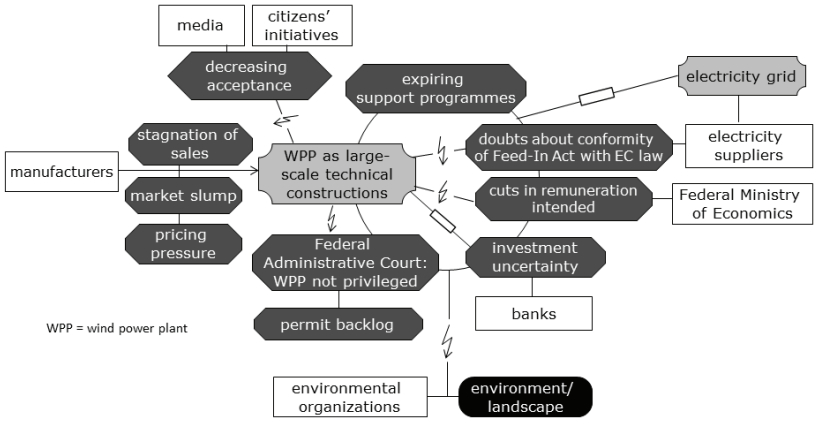
Figure 3: Breakthrough of Wind Energy in Germany 1991 to 1995



WPP = wind power plant
WE = wind energy
Based on Bruns et al. (2009).

The actors involved in the innovation process were not part of the research team, although the team conducted interviews with the parties involved. In addition to the interviews, further empirical sources (primary and secondary literature) were analyzed and evaluated. The research team prepared the constellations and the associated descriptive text in parallel; in a further step, the interpretative texts were developed collectively with the interdisciplinary team.

Figure 4: Development Dip in the Mid-1990s



Based on Bruns et al. (2009).

Although every innovation process has its own specific, individual character, a comparative study of innovation biographies can highlight commonalities that exist in the conditions for innovation, can emphasize central driving and restricting influencing factors and can identify typical development patterns. The retrospective comparison can also shed light on the constellations of actors, the distribution of power and the state's role in the innovation process, as well as provide insight into the strategic use of policy planning and control instruments in innovation processes.[1]

On the one hand, the results of the analysis have been used to further develop theories for innovation courses and the characteristics of their specific phases. On the other hand, the analysis aimed at developing indicators for policy design of innovation development. For example, in the context of a project comparing innovation biographies in the area of electricity generation from renewable energy sources, it was shown that the very heterogeneous innovation processes each went through a sequence of *pioneer or pilot phase*, phases with incipient *dynamics* (inception, breakthrough, expansion or boom), phases of *instability* (crises, development dips, stagnation) or phases of *stabilization* or consolidation. Although generalizations with regard to the possibilities of steering can only be made to a limited degree, it was established that there are certain identifiable basic principles that can be decisive in determining whether or to what extent an innovation process can come about or maintain itself (Bruns et al. 2009, 367ff).

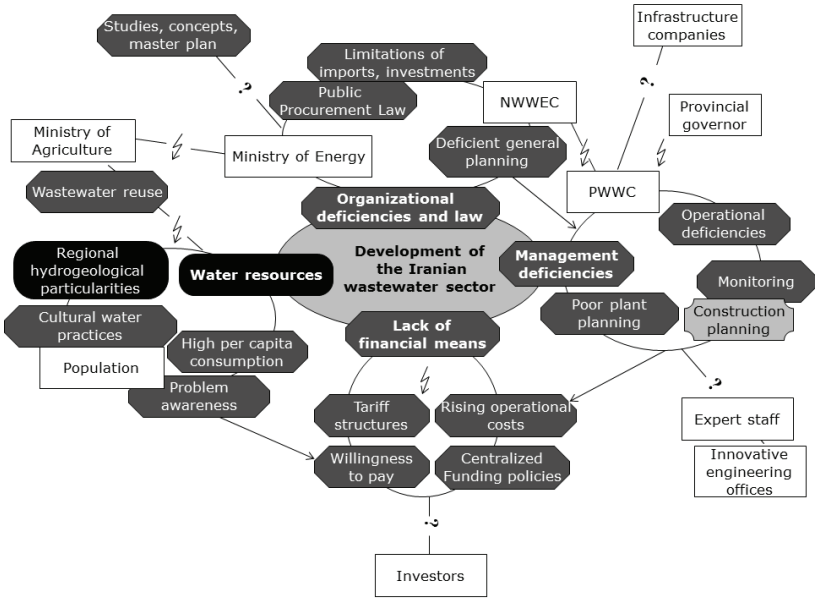
[1] Innovation biographies are comparable if they were processed according to the rules described in this text, and if they were analyzed using the same scientific question.

5.2 The Strategic Dimension of Constellation Analysis

Constellation Analysis has now been successfully used in numerous transdisciplinary research projects, including some that take a strategic approach. The aim is to identify, based on a thorough and comprehensive analysis of the problem, the interventions that are necessary for a desired development. This is why, in transdisciplinary research alliances strategic objectives, two mappings are always created: The status quo constellation shows the current situation/problem, the target constellation develops an "ordered" image of the future, according to what the desired situation might look like. In doing so, it builds on the methods of status quo analysis (which will be explained below).

The following case study revolves around the targeted development of Iran's wastewater sector (Mohajeri and Dierich 2009).

Figure 5: Status Quo Constellation "Development of the Iranian Wastewater Sector"



Based on Mohajeri and Dierich (2009).

The mapping of the status quo constellation is based on the analysis of existing studies, the collection of additional data – e.g. documents, statistics – as well as on a significant number of expert interviews. The research team developed a preliminary draft of the problem analysis (status quo constellation, see Fig. 5). In a meeting with representatives from the Iranian wastewater sector in politics, administration and management, this draft was initially validated. Subsequent-

ly, the strategic areas of action and the necessary innovation processes (target constellation, see Fig. 6) were again developed by the research team and presented in a second meeting, in which they were discussed and specified with the Iranian representatives.

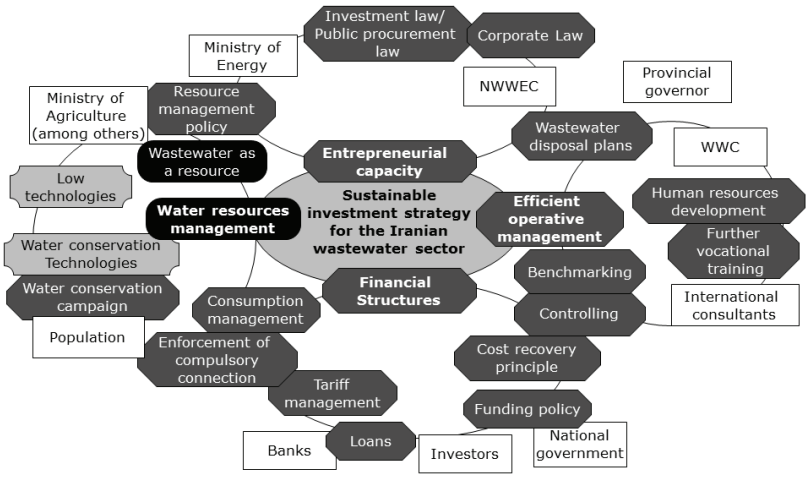
The development and depiction of findings in the status quo constellation led to the following central findings for the Iranian partners:

- In contrast to their previous assumptions, the expansion of the wastewater sector is not primarily a funding problem. Instead, numerous other barriers and hurdles must be overcome in order to ensure that the intended large investment sums can be effective.
- Based on the mapping, they were able to recognize which problems are central, how they correlate to each other and which respective actors are involved or need to become involved.
- The mapping allowed the involved parties to discuss the problems in a structured way, to make the different perspectives and interests visible and negotiable and enabled them to arrive at a common representation of the situation in the sense of a mutually agreed problem diagnosis – a key prerequisite for the innovation processes necessary for the further development of the wastewater sector.

The dynamic effect of the design-oriented Constellation Analysis was already demonstrated in the second meeting, in which the target constellation (see Fig. 6) was presented and discussed: Two of the packets of measures depicted therein had already been implemented or were in the process of being implemented.

From a methodological standpoint, the target constellation is a projection of the status quo constellation onto a desired future time period. It entails a continuation of the work with the actors and elements identified in the status quo constellation, incorporating additional elements as necessary and reorganizing the constellation so that it is (for the most part) inherently consistent and can function as smoothly as possible. The four elements on the central circle – entrepreneurial capacity, efficient operative management, financial structures and water resources management – take up the central problems mapped in the core of the status quo constellation and transform them in a positive way. They structure the strategic areas of action for the necessary innovation processes. The elements that are arranged on each of the four peripheral circles, the subconstellations, must be interwoven into the innovation processes.

Figure 6: Target Constellation "Sustainable Investment Strategy for the Iranian Wastewater Sector"



Based on Mohajeri and Dierich (2009).

5.3 Various Analytical Dimensions and Epistemic Interests

The two examples show that Constellation Analysis can be used for various purposes, which vary in terms of approach, analytical dimension and epistemic interest:

One of the applications of the Constellation Analysis method is to gain an (retrospective) understanding of innovation processes. The mappings of the constellations have an interim character and lay the groundwork for developing the actual research questions. They support the production of innovation biographies; when taken together, analysis, description and interpretation of a constellation form a pointed statement about the respective reality. The analysis entails a retrospective concentration on the interaction of the influencing factors in the various phases of the innovation process. The epistemic interest focuses on patterns and generalizable principles of innovation processes as well as on conclusions regarding their controllability. The term “innovation biography” is a metaphor for the individual, interpreted story of the innovation being examined, in which particular attention is given to the phases, ruptures and dynamics at work. Innovation biographies based on phase constellations take a system perspective (Edquist 2005) that takes into account all relevant determinants. At the same time, they reflect the process-based character of innovations.

The other use of Constellation Analysis is for a strategic (prospective) approach. Strategies are frequently not viable because the stakeholders involved in the practical implementation often hold competing views and follow contro-

versial lines of argumentation. In order to stand a chance of being implemented, strategies must be developed that are close to societal and political realities. The early involvement of experts and stakeholders is of particular relevance to prevent measures from failing when confronted with the realities on the ground. Despite differing thematic and practical perspectives, a shared view of the problem is an essential prerequisite for finding and implementing jointly supported solutions. Constellation Analysis can be used to uncover hidden contradictions and discrepancies or to show the absence of central stabilizing factors. The mapping of constellations can be the starting point for the development of goal-oriented, responsible and collaborative strategies of action, and can help to identify (undesired) implications and side effects of strategies and address these early on in the process. Target constellations incorporate insights from the comparison of various retrospective Constellation Analyses, in which different innovation processes with similar scientific questions were investigated: for example on the current innovation phase, on the specific constellation structure, on functional principles and characteristics as well as on appropriate steering instruments and impulses. The constellations can be used to show which framework conditions (e.g. institutional, technical or legal framework conditions) can impede or foster the success of a particular strategy. They can also provide support in communicating the resulting recommendations to decision-makers.

6. Constellation Analysis within the Context of Methodical and Methodological Debate

Ever since the scientists at the Centre for Technology and Society as well as in the inter 3 Institute for Resource Management set out some 10 years ago to develop methodological support instruments for their interdisciplinary work, Constellation Analysis has proven itself in many projects to be an effective tool for collective thinking and strategic development.

Various areas of application: The examples of applications listed illustrate the possibilities that Constellation Analysis offers for retrospective and prospective approaches. Both approaches focus on a common problem or a common object of study. A key benefit, both for the analysis of complex problems and for the development of solutions, lies in the productive incorporation of various perspectives on the common topic as well as in the integration of diverse sources of knowledge and experience. Both approaches show that Constellation Analysis is useful for research that derives its questions not only from a scientific point of view, but for research that intends to apply its solutions to societal problems as well.

Analysis tool: Constellation Analysis works as an analytical method that builds upon disciplinary findings, which it shakes up in an interdisciplinary fashion – the findings can then be reintegrated into the existing discipline-

specific theory, as well as into technical and political concepts. Moreover, it also functions as an analytical tool for the theoretical and supporting analysis for technology-oriented problems and strategic ambitions.

Production of joint results: Using Constellation Analysis, expert knowledge and insight can be consolidated into joint results and findings – at eye level and with mutual recognition of the respective disciplines as equally valued. There are two prerequisites for this: For one, based on a scientific question, a perspective for the interpretation has to be chosen. Secondly, the disciplines and the categories of elements must be recognized by all involved parties as equivalent.

Visualization as a bridge; combination of language and image; heterogeneous elements: Analogous to the sketches of engineers, Constellation Analysis is intended to open up the essential aspects of a constellation to discussion and further development, and to do so in a structured manner. The combination of language and graphical representation forms a bridge between the different scientific cultures of the engineering and natural sciences on the one hand and the social sciences and humanities on the other (Schön et al. 2007, 59ff). It makes it possible for different technical expertise and findings to be brought into correlation with each other and to engage in focused discourse.

Facilitating processes of understanding: The constellations support the inter- and transdisciplinary process of discussion and deliberation on the best possible representation of a given reality. The set of tools used by Constellation Analysis can form a helpful basis for integrating the different pillars of knowledge and for actively linking the identified factors of influence in a synthesizing way.

At the same time, Constellation Analysis has no particular obligation to any one theory or discipline, but is instead oriented toward the object of study and the question at hand – an important premise for inter- and transdisciplinary research (Baccini 2006, 29). With the help of the graphic representation based on a coherent system, extensive empirical material can be examined and processed and complex issues represented in a comprehensive, differentiated and at the same time clearly laid out fashion – which facilitates the recognition of structures and connections. Constellation Analysis also takes into account both material foundations and societal processes – in one and the same picture. An added value of Constellation Analysis thus consists of the systematic and clear depiction of knowledge regarding heterogeneous influencing factors, how they work and how they are interrelated. This forms the basis for determining overarching functional principles of socio-technical constellations.

Phenomenological approach; bottom-up: Constellation Analysis examines the societal reality from the point of view of its practical, everyday circumstances and actions and their structures ("that which is there"). In other words, it is oriented toward the phenomena. It achieves this – in a similar way to Grounded Theory – through a bottom-up approach.

Communication of findings and discourse: Furthermore, Constellation Analysis has proven to be helpful in the transmission and discussion of inter- and transdisciplinary findings, because complex constellations can be built up and understood in a step-by-step process. At the same time, they remain present as a larger picture and serve as a discursive anchor. They promote the problem-oriented dialogue between various disciplines and can also be used in the dialogue between science and practice (Ohlhorst and Kröger 2014). The methodology provides the different perspectives with shared points of reference to investigate the interaction of problem-relevant factors.

Bridging Concept: Constellation Analysis thereby positions itself within innovation research as a bridging concept. It rises to the challenge posed by the need to build bridges between the different disciplinary approaches to the development of general conclusions, and the need to develop methods that can support this endeavour. Even within the disciplinary boundaries of science, there is often the need for concepts that can bridge differences – for example when an increasing fragmentation into sub- and sub-sub-disciplines is considered to be a problem or when the question arises of which approach or which theory is better suited to answer research questions or to effectively compare empirical data. This applies to a far greater extent to interdisciplinary research teams, which have to integrate diverse methodological approaches and aspects of discipline-specific knowledge with regard to the problem at hand (see introduction). Ultimately this cognitive process also applies to the linking of empirical data and theoretical concepts from very different social science and natural science backgrounds (see Nölting et al. 2004). The increasing differentiation of disciplines, each of which working with highly specialized terminology, constitutes one of the central difficulties in interdisciplinary collaboration. It is also one of the reasons why such collaboration is often very time-consuming (Lowe and Philippson 2009; Böhm 2006; Bromme 1999).

The external purpose of Constellation Analysis is to facilitate focused, interdisciplinary cooperation on a given problem. To a certain extent, the results have an interim character. They organize the subject matter, make it analytically accessible and lay the groundwork for the development of the actual research questions. Each stage of the mapping of a concrete constellation also establishes a preliminary assumption on the central interconnections, which are in a next step then tested in terms of their viability (Schön et al. 2007, 49).

6.1 Limitations, Methodological Problems and Weaknesses

However, Constellation Analysis also has its limitations:

Limited explanatory value of mappings: The constellations facilitate the inter- and transdisciplinary discussion process on the optimal representation of a given reality. At the same time, the explanatory value of the representations is limited, as discourses have more capacity for explanation than do illustrations.

Patterns of interaction and networks between actors are only shown in unrefined form, but are not described in differentiated terms – this can only take place in the accompanying text.

Social construction: It must also be taken into account that within the Constellation Analysis, the perspectives onto the particular problem are socially constructed: It is not the issue itself which poses the problem, but rather its perception and assessment on the part of the involved parties (framing). Social constructions, however, are often not stable, but are instead subject to a process of change. Patterns of interpretation can change, and this process of change can also be promoted by, for example, the exchange between scientists and representatives of societal groups or organizations. This is often welcome within the context of Constellation Analysis, because the participatory process of mapping and discussing is meant to achieve a coordinated definition of problems and strategies in spite of the different perspectives.

Element types: In certain cases, the determination of four categories of elements – actors, technical elements, natural elements and symbolic elements – does not seem to have the necessary degree of differentiation and theoretical foundation, for example with regard to the underlying concept of nature and technology. A clear-cut and unambiguous designation is not always possible. Water, for example, can be a natural element, and can play a role in technical processes as well. A regenerative resource such as wood can, depending on the perspective, be either a natural or a technical element.

7. Conclusion: Constellation Analysis as Pre-Theoretical Tool

Like many other methods as well, Constellation Analysis has its strengths and weaknesses. Its conceptual core, however, has doubtlessly proven its worth: The treatment of heterogeneous elements as equivalent factors and their correlations to each other as a bottom-up analysis approach, and the mappings that are discussed and validated in an interdisciplinary and, if need be, transdisciplinary fashion, have proven to be a very helpful and effective means of fostering cooperation. And successful cooperation – not only between the main scientific cultures, but also between actors in the field – is a prerequisite for achieving an inter- and transdisciplinary validation of findings.

Conceived of as an adaptive instrument that is being continually developed and modified in the course of its application according to relevant needs, Constellation Analysis has undergone several stages of development between its initial conception and its many years of application. For example, the areas of application have been more clearly defined, the analytical dimensions and the procedures involved in mapping have become more precise and differentiated, and the relationship between the micro, macro and meso levels have been clari-

fied, albeit not conclusively. Further details on this aspect extend beyond the scope of this chapter.

Some of the methodological questions that have been addressed to us as developers of Constellation Analysis include the following:

How does Constellation Analysis differ from Actor-Network-Theory (Latour 1987, 1996a, 1996b), Strategic Niche Management (e.g. Kemp et al. 1998; Weber et al. 1999; Schot and Geels 2008), Multi-Level Perspective (e.g. Kemp 1994; Schot, Hoogma and Elzen 1994; Kemp and Rotmans 2001; Geels 2005) or Situational Analysis (Clarke 2005)? It is true that there are numerous approaches which at first glance are similar to Constellation Analysis.

Studies in the context of Actor-Network Theory, for example, point out in a radical – and provocative – manner that the social sciences do not take technology and nature into consideration. The studies shed light on the role of the non-human elements that are respectively involved. However, the approach differs from that of Constellation Analysis because the activities of network formation are primarily understood as enforcement, since it is mostly actors (persons) who are at the focus (e.g. the figure of Pasteur with Latour 1988), and because only two development alternatives are envisioned for the actor networks: to grow or to die (Latour 1996a; see Schön et al. 2007, 53ff).

The authors of Strategic Niche Management studies are interested in transformations that lead to fundamental shifts in socio-technical systems, and these systems are analysed in their sectoral contexts, involving a variety of factors such as technologies, markets, regulation, user practices, and science (Geels and Kemp 2007). The approach of Strategic Niche Management is based on the assumption that innovation processes can become more sustainable through the creation of socio-technical niches. Niches are considered as protected areas where the experimentation with the co-evolution of technology, user practices and regulation structures is possible. The assumption is that the constructed niches can serve as building blocks for larger societal changes toward sustainable development. Reconstructive Constellation Analysis, by contrast, looks at the structure of a constellation in a neutral fashion, and in the process points out sustainable paths of development for niche constellations, including paths that are not or only to a lesser degree sustainable (Schön 2010). And while prospective Constellation Analysis pursues a similar approach, that approach is not only focused on the innovation within the niche, but also looks at the constellation and the context in which the niche is embedded.

Another example is the Multi-Level Perspective, in which three levels of innovation processes are distinguished: the micro level of 'technological niches,' the meso level of 'socio-technical regimes,' the macro level of 'socio-technical landscape.' Although these levels are similar to the individual elements of a constellation, the constellation made up of interlinked elements and the context of a constellation, Constellation Analysis puts a stronger emphasis on the rela-

tionships between the elements. Also, the Multi-Level Perspective is not explicitly focused on inter- and transdisciplinary work.

Finally, using her approach called Situational Analysis (Clarke 2005), Clarke offers three kinds of maps: Situational maps that lay out human, non-human, discursive, and material elements and the relations between them; social worlds/arenas maps that lay out the collective actors and their arenas of commitment; positional maps that examine the major positions taken in the discourses. Although the basic concept of mapping is comparable, the appearance and performance of the Clarke mappings and the Constellation Analysis mappings differ significantly. While Clarke developed grounded theory into a constructionist grounded theory to provide methodologically sound analytics for social sciences, Constellation Analysis is a very pragmatic tool that can be used to bridge the scientific cultures of the engineering sciences, natural sciences, social sciences and humanities.

Despite these similarities to related approaches and concepts, what we see as the unique characteristics of Constellation Analysis are its analytical focus on the types of elements and relations, its visualization with the help of mappings and its distinct discursive character.

To what degree are the mappings that are developed in the inter-/transdisciplinary teams objectively and intersubjectively reproducible? And related to this: How can the inter-/transdisciplinary results of the constellation analyses be made compatible for "peer-review" processes? The mappings and analyses are based on preliminary discipline-specific work and (interim) results, developed for example using the instruments of empirical social research. Up to this point, they are clearly intersubjectively reproducible. It is only when, in the context of the discursive work on mapping a specific constellation, questions have to be answered and decisions have to be made which require an interpretation of these sub-results in light of the expanded discursive context that Constellation Analysis departs from intersubjective reproducibility in the strictest sense. On the other hand, through its multi-perspective incorporation of the various sub-findings, it gains a wider analytical force and can, under certain circumstances, result in decisive progress for discipline-specific knowledge. However, it will likely still be some time until this becomes "peer-review"-compatible.

In summary, we would refer to Constellation Analysis as an explorative approach that provides a useful way of organizing information, which can be developed further within the context of the respective disciplines: Based on the specific subject of study and the main influencing factors – analogous to the approach of Grounded Theory – qualitative empirical information is systematically brought together and organized from the bottom-up. Thereafter follows the view from above – an attempt of interpretation, of identifying macro-correlations or a comprehensive logic. Where appropriate, a comparison with other innovation processes is carried out. Constellations are used for the development of theoretical approaches, which have an explanatory value for the examined phenomena.

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