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Enabling and integrative infrastructure policy: The role of inverse infrastructures in local infrastructure provision with special reference to Finnish water cooperatives

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Abstract
Infrastructures are necessary to support the functionality of urban communities. Globalization, increased polycentricity, new trends in governance and tightening public budgets have increased interest in alternative ways of providing such infrastructures. One product of this trend is the 'inverse infrastructure,' which refers to a modularized, semi-autonomous and user-driven infrastructure that is a result of the self-organization of local actors. In this study, we discuss the nature of such infrastructures and the challenges they pose to local infrastructure policy with special reference to the case of water cooperatives in Finland. Our conclusion is that inverse infrastructures have a potential to contribute to local infrastructure services either as cost-effective alternative or as supplement to large technical systems. Their full utilization requires, however, enabling and integrative infrastructure policy.

Keywords: infrastructure, infrastructure policy, public policy, local government, inverse infrastructure, complex adaptive system, adaptation, self-organization, resilience, volunteering, water services, water cooperative, Finland

JEL classification: H41, H54, H76, L95, L98, O18, P13

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1. Introduction

Infrastructures are necessary to support the functionality of densely populated territorial communities. During the 20th century, economic growth, public sector expansion, urbanization and increased pluralism created fertile grounds for the growth of publicly planned and funded Large Technical Systems (LTSs), which decreased the need to build decentralized micro-infrastructures to meet local needs. Historically, however, community-based systems have been indispensable. For example, in Finland's early history, a large proportion of infrastructures were built by relying on various forms of joint ownership, such as communal granaries, roads, small harbors, and the like. Later, in the 20th century, the most common forms of the provision of self-organized infrastructures were local and regional cooperatives, such as telephone, energy, water, forestry and road cooperatives. In recent years, the discussion of similar kinds of user-driven, semi-autonomous infrastructures has gained ground, sometimes labelled as 'inverse infrastructures' (Egyedi and Mehos, 2012). They can be seen as a counter trend to 'splintering urbanism' –privatization of infrastructures with a range of ramifications, such as segregation in metropolitan areas (Graham and Marvin, 2001; Edwards, 2003)– as they reflect bottom-up design and active involvement of local actors.

One of the characteristic features of the development of Western societies was an attempt to create order through the standardized development of infrastructures that served the needs of modern life. In most welfare societies, this development was accompanied by the rapid expansion of the public sector. In such context, infrastructures were regarded as public goods best delivered through public or private monopolies. Such development provided fruitful soil for the creation of LTSs. Whether they became truly universal, can be challenged on several grounds, however (Graham and Marvin, 2001). For example, small and remote communities fall outside the interest of the usual infrastructure providers, those of federal, national or regional governments that aim primarily to reach large populations and national or international private providers with an intention of making a profit (Gonzalez et al., 2014). In such a situation the primary instance of collective provision of infrastructures and of public governance and, ultimately, the outpost of modernity, is local government (Stewart, 2000). As the importance and capacity of local government gradually increased, its role in establishing local infrastructure and controlling inverse infrastructures became more and more prominent.

In most democratic societies, local government is the single most important institution responsible for creating and maintaining local infrastructures, which is why municipal infrastructure policy plays a significant role in determining the context for various self-organized small-scale infrastructures. *Local infrastructure policy* seems to gain new impetus in the time of prolonged financial crisis and heavy pressure to cut municipal budgets. In many cases local government simply lack the financial strength to warrant municipal ownership or initiate and execute infrastructure projects. Of the three major forms of ownership of utility services – public, private, and cooperative – cooperative is the organizational form that has shown some potential in dealing with remoteness, sparse population, and small scale. Where the involvement of private companies is not feasible in the form of Public-Private Partnership (PPP) or Private Finance Initiative (PFI), there is a call for alternative ways of developing infrastructures, such as cooperatives, non-profit organizations, and community-based initiatives (Gonzalez et al., 2014; Warner, 2011; McNabb, 2005, 25).

Local government is a local instance of modern public administration, which implies that as a rule it relies on a representative system of democracy, bureaucratic procedures, and comprehensive planning. Today's systems of public administration, especially in advanced democratic societies, can most accurately be described as 'networks of hierarchies,' in which hierarchically organized public entities relate to each other in a collaborative manner. However, the core of this system is nevertheless hierarchical by nature and relies on administrative procedures and policies that are largely top-down by design. The heritage of bureaucratic culture is visible in such general aims as maximization of safety, predictability and continuity, which are characteristic approaches to infrastructure issues in public administration. From this perspective, inverse infrastructures may resemble a force that drives systems toward uncontrollability. This view connotes natural tension between conventional municipal infrastructure policy and inverse infrastructures, which is the point of departure for this working paper.

2. Objective and methodology

The objective of this paper is to theorize the ability of self-organized systems to contribute to local infrastructure provision. We seek answers to the following three questions:

1) What are the special features of self-organized small-scale infrastructures from theoretical and practical points of view?

2) How does the decentralized logic of inverse infrastructures contribute to their resilience?

3) What role should be given to self-organized micro-infrastructures in local infrastructure policy?

We pay special attention to *self-organization* and *resilience* as the fundamental features of micro-infrastructures. Their conceptualization is based on the theory of *Complex Adaptive Systems* (CASs). Theoretical discussion aims thus to shed light on the general features of self-organized infrastructure systems. At the same time, we need to assess how such a theoretical picture of inverse infrastructures aligns the realities of social action and, in this case, the operations of water cooperatives in particular.

Our empirical research focuses on a few Finnish cases of water cooperatives with special reference to the town of Ikaalinen, in which cooperatives provide water services in the sub-urban and rural areas of the municipality. Methodologically, our case provides a chance to enhance our understanding of self-organization in the real-life setting (Yin, 2008). Data were gathered by the authors by conducting a group interview relying on a thematic interview design. Group interview took place in Ikaalinen on October 26, 2012. The interviewees included six informants from four local cooperatives, one informant from a municipal water company, and one informant from the water services department of the municipality of Ikaalinen. Group interview was used to obtain a comprehensive and dynamic picture of the view of both the representatives of the water cooperatives and the representatives of the municipality (see also Heino and Anttiroiko, 2014).

3. Theorizing inverse infrastructures

3.1 Background of the idea of inverse infrastructure

The term ‘inverse infrastructure’ was coined by Professor Wim Vree. He used it in his inaugural speech at Delft University of Technology in 2003. At that time it was applied to the developments in the field of information and communication technologies. Tineke Egyedi and her colleagues later contributed to the development of this concept within the context of other infrastructural fields (see Egyedi and Mehos, 2012).

The concept of *inverse infrastructure* refers to modularized, semi-autonomous and user-driven infrastructures that have emerged as a result of the self-organization of actors who share an interest in establishing physical structures, utilities or platforms, such as water utilities, energy plants or wireless hot-spots. The concept contrasts sharply with that of conventional large-scale, centralized infrastructures. Inverse infrastructures are usually micro-infrastructures owned and operated by user cooperatives or organized into a similar arrangement, such as mutual organization or community buy-out.

Inverse infrastructures can arise both despite and because of the conservative nature of Large Technical Systems (LTSs), which reveals their evolutionary and adaptive character (Egyedi et al., 2009). Inverse infrastructures develop evolutionarily and spontaneously, from the bottom up, without masterminded planning. They are sources of innovative services that can operate either independently or in symbiosis with existing LTSs (Egyedi and Mehos, 2012). Inverse infrastructures can be linked to LTSs or other micro-infrastructures, but they are not a *sine qua non*.

3.2 Inverse infrastructures as complex adaptive systems

Approaches to inverse infrastructures have two different theoretical roots. The dominating comes from concepts that reflect paradigm shifts in natural science, such as new physics, chaos theory, complexity theory, cybernetics, and systems theory (see, e.g., Holland, 1992; Dressler, 2007; van den Berg, 2012). Such theoretical thinking has been applied to the human and social sciences in many areas and in many ways, the basic message being the need to understand the complexity of adaptive social systems and our ability to find solutions to problems in a manner similar to that used to address how complex systems operate in nature. Thus, if we can extract certain properties of complex natural systems and inject them into our infrastructural planning mentality –via so-called biomimicry– we may be able to build more innovative and robust structures to meet local needs. (See Benyus, 2002; Sagarin et al., 2010; Shermer, 2012; Zanowick, 2012.)

The other root of anomalies that aggregate against the LTS paradigm is thinking that emphasizes the special nature of human and social life and often takes a normative stance, as in Schumacher's (1973) "small is beautiful", the notions of emancipation and human scale of Frankfurt School's critical theory (e.g., Herbert Marcuse and Erich Fromm), various forms of communitarianism and localism (Amitai Ezioni, Robert Putnam etc.), radical environmentalism (e.g., Murray Bookchin), participatory democracy (e.g., Benjamin Barber and Carole Pateman), and the emphasis of collective action, clubs and voting-with-the-feet of public choice theory (e.g., Elinor Ostrom and James Buchanan).

Criticism toward elitism, bureaucracy and top-down design resulting in larger technical systems arise from these two previously discussed sources. In this working paper, we focus on the previous dimension and especially the theory of *Complex Adaptive Systems* (CAS). Our assumption is that the general theory of CAS may be useful for both analyzing the characteristic features of micro-infrastructures set up by users and producers and making assumptions about the relationship between self-organized systems and their relationship with LTSs planned and constructed by local governments.

In the next section we will take a closer look at the idea of self-organization, which is a specific control paradigm for complex systems (Dressler, 2007). One might think that water utility is not that 'complex.' However, *complexity* is not only about the large number of interacting elements, but also about the nature of systems. Socio-technical systems, such as water utilities, include not only technical elements but also human agents and institutional arrangements to fulfill their functions. They are thus systems with many interdependencies of a behavioral and social kind, which determine the functionality of such systems (Ottens et al., 2005). This same feature is what makes organizations complex irrespective of their size (Schneider and Somers, 2006).

3.3 Self-organized adaptation

The term "self-organization" is nebulously linked to engineering and infrastructures. Even if in today's science we are able to understand the behavior of self-organizing systems, we are still far away from a general model of self-organization that may be utilized in a straightforward manner in engineering (Herrman, 2006, 15; Imada, 2008). In this work, we attempt to construct a view of self-organization as a guiding principle in understanding infrastructures.

Self-organization refers to the phenomenon through which a system is able to change and increase in complexity by making its structure more complex and by learning and diversifying. Controlling complex set of subsystems requires some kind of 'controlled autonomy,' which is a precondition for the durability and functionality of systems. If such an adaptation process does not rely on external control, the system is self-organizing (Dressler, 2007, 4).

Dooley (2002, 5020) defines a system to be self-organizing if "*it undergoes a process --- whereby new emergent structures, patterns, and properties arise without being externally imposed on the system. Not controlled by a central, hierarchical command-and-control center, self-organization is usually distributed throughout the system.*" It goes without saying that all systems are not successfully self-organized in the sense understood here. Most importantly, connections between various parts of a complex system form interactive loops that are typically limited to a minimum in highly hierarchical, bureaucratic systems.

Self-organization is a process, often presented as an adaptation cycle or process at the intersection of order and chaos. In a paradigmatic *adaptation process*, a system recognizes external shock and is averse to chaos, from which it begins to renew itself by self-organization and reaffirms order or a sufficient degree of stability. In general, social life can be seen to proceed through periods of institutional stability, challenge, crisis, and reorganization, with the possibility for social systems to become locked into any one phase (Pelling and Manuel-Navarrete, 2011; Handmer and Dovers, 1996). The capabilities of adaptive systems are based on the creative self-organization of their components. The formal ontological core of such systems lies in their potential to increase and decrease *entropy*, which is understood in the given context as a degree of decay within a social system (cf. Bailey, 1990). This implies that a system creates value and ensures its potential ability to exist, to develop and to evolve in time by reducing the entropy that leads to its decay. Entropy reduction is ultimately about generation of intangible resources that can be utilized for systems' survival and evolution (cf. Cravera 2012).

It is important to remember, however, that even stability is dynamic in the real-world social-ecological systems. Their durability as systems is not because of some kind of stasis (from Greek στάσις, state of motionlessness) but because of dynamics that Capra (1982, 271) describes as follows: "The stability of self-organizing systems is utterly dynamic and must not be confused with equilibrium. It consists in maintaining the same overall structure in spite of ongoing changes and replacements of its components. [...] The same is true for human organisms. We replace all our cells, except for those in the brain, within a few years, yet we have no trouble recognizing our friends even after long periods of separation. Such is the dynamic stability of self-organizing systems."

Adaptation processes may vary from homeostasis (perfectly adapted process) to disruption or collapse. Nevertheless, theoretically speaking, all such processes imply living at the frontier between order and chaos. Chaos or disorder is a source of development and renewal, but it may also start threatening the existence of the system. Dramatic changes may lead to a critical turning point, so called *bifurcation point*, in which the system has to take a new course or perish (Chen, 2011, 65).

3.4 Managing resilience

Adaptability is the capacity of actors in a system to influence required recovery, reorganization or restructuring processes, which can be for instance locally perceived need to secure continuity of water cooperative in the face of economic distress. In practical sense, this amounts to the capacity of humans to manage resilience. Such a process can reflect "self-organization without intent" in the sense that the system as a whole cannot be reduced to the intentions and motivation of participating individuals (as in the case of a market). This is actually an important point in which CAS differs from actor-oriented approach associated with multi-agent systems (MAS), i.e. the former pays attention to aggregate and system-level features, including self-organization and emergence.

On the other hand, because human actions and social conditions dominate in social-ecological systems (SESs), including socio-technical systems such as water utilities, adaptability is primarily a function of the social component. In the case of a small-scale water cooperative in a rural area, for example, the inhabitants of the village are those who act to manage their water utility (Walker et al., 2004). This is actually one of the points of departure in applying CAS to infrastructure development. Van den Berg (2012), for instance, interpret infrastructure systems as CAS precisely because their control is dispersed among users. These systems involve a plenitude of interconnections and interactions among elements that are controlled in a highly decentralized fashion. Systems' coherent behavior forges interactions between agents that are capable to learn and change adaptively. Yet, rather than reducing self-organization to the agency, CAS takes the explanation to a higher level of abstraction.

In macrosociological systems theory known as Social Entropy Theory (SET) every organization or socio-technical system needs to consume its energy to counteract social entropy (Bailey, 1990). This leads us to the idea of resilience, which refers to system's capacity to cope with change, i.e. to maintain its functions and structure in the face of internal or external changes. *Resilience* is about flexibility, the ability of a system to recover after dramatic changes. Theoretically speaking, it refers to the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, and identity. Resilience has four components of which three apply to any system —latitude, resistance, and precariousness— and the fourth, panarchy, apply to influences from dynamics at scales above and below the system in question. The concept of resilience has, thus, different facets. It can be about the maximum degree a system can be changed before losing its ability to recover; the ease or difficulty of changing the system;

how close the current state of the system is to a limit or threshold; and the modular and inter-scalar dimensions of system's existence (Walker et al., 2004; Walker, 2005; Folke, 2006; Holling, 1973).

The ability to self-organize is the most fundamental form of resilience (Meadows, 2008). In such a case adaptation process is initiated and organized within the system, deriving its adaptability from its internal dynamics. Sometimes it works, sometimes not. We just have to consider people and their behavior when facing changes. Some collapse under pressure, some are paralyzed, some are tolerant, and some view their situation as an opportunity. The same applies to organizations and communities. A resilient organization or community has the ability to adjust its activity to new conditions by observing both its own activity and its operating environment (Hollnagel, 2008).

Self-organization also refers to the ability to incorporate completely new balancing and reinforcing loops or new rules into a system (Meadows, 2008). In the most radical cases of change we may speak of *transformability*, i.e. the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable (Walker et al., 2004).

3.5 Emergence

Self-organization creates emergence within complex systems. In a general sense, *emergence* refers to the ability of low-level components of a system develop and integrate into higher-order complexity and create novel solutions (Johnson, 2001; Holman, 2010). It reflects a macrosociological phenomenon sometimes called 'social emergence,' which pictures a complex modern society through the social interaction that emerge from communication processes among individuals (Sawyer, 2005).

Emergence, or irreducibility, is one of the central concepts associated with self-organization. It implies that the properties of a complex system cannot be reduced to the properties of its parts. Self-organization and emergence refer to different aspects of a system, however, and they can also exist in isolation but, when combined, they provide promising approach to complex multi-agent systems (De Wolf and Holvoet, 2005).

Emergence enables systems to cope creatively with changes in their environment. In a self-organizing system, it can lead to creative and unexpected outcomes. This is how new properties, phenomena and levels of action appear in a system. Such a process is characterized by decentralized logic and modularity, for macro-scale behavior is modulated through the activity of micro-scale units responding to available information (Moore, 2006). What is unique in emergence is that its properties cannot be manipulated by analytical tools and they do not yield to causal explanations (Gharajedaghi, 2006). In short, it expresses genuine novelty with system-level resonance.

3.6 Decentralized structure and modularity

The development of inverse infrastructures represents an instance of *decentralized* logic or structure. According to such logic, functions are distributed in such ways that if a malfunction or disturbance occurs in one part of a system, it does not have a critical impact on the other functions or parts of the system. This distribution is also a way of placing a function close to its necessary resources, avoiding the energy cost of transportation (Zanowick, 2012).

Decentralized logic is connected to *modularity* in the sense that both are based on the notion that the whole is determined by its semi-autonomous parts. A *module* refers to a system element whose behavior is highly –albeit not completely– independent from its interactions with other elements. Another way to conceptualize similar logic is the idea of Systems of Systems (SOSs). According to Maier (1998, 269), SOSs are assemblages of components that individually can be characterized as systems. Each component can physically operate independently and has managerial independence. Various forms of coordination among all of these systems can arise without any predetermined pattern. Such approach is of particular importance in analyzing ‘panarchy’ or the relationships between systems and sub-systems at different levels, which provides for understandable reasons relevant picture of infrastructure issues at metropolitan, national, macro-regional and global levels rather than in remote and sparsely populated areas.

Modularity enhances infrastructure systems' ability to adapt to changing conditions; because each component displays a certain degree of randomness in its behavior, it can explore new states and possible actions. Modularity contributes to the flexibility, diversity, scalability and expandability of a system (Miraglia, 2010). In social contexts, this feature is particularly important in knowledge processes and the evolution of complex socio-technical systems (see e.g. Oguz, 2000, 72).

3.7 Redundancy

Self-organizing systems, such as inverse infrastructures, typically consist of a large number of redundant components, making the systems more robust (Herrman, 2006, 18). The definition of *redundancy* depends on the context, but it generally refers to a surplus of parallel or overlapping functions. For example, low redundancy in the social network hinders entrepreneurship and innovativeness and decreases resilience, whereas high redundancy created by wide interpersonal network, trust and transparency, brings about positive social outcomes (cf. Jenssen and Greve, 2002). Instead of quantity of social contacts *per se*, the idea of redundancy emphasizes the quality of connections and their relevance for the given organized entity.

Due to various reasons, inverse infrastructures contain at least some redundancy that is not necessarily available in LTSs. In traditional infrastructure planning, redundancy is considered a source of extra costs that should be eliminated. This stance relates to the perception of a predictable world where all risks are identifiable and manageable, making any redundancy unnecessary. LTSs have also tendency to depend of continuous support from the government, which may become a problem in the time of fiscal distress. In all, although redundancy associated with self-organized infrastructures produces extra costs, it also provides protection and options when facing uncertainty.

Figure 1 outlines the basic aspects of water cooperatives as inverse infrastructures and their social morphology by utilizing the concepts derived from CAS theory.

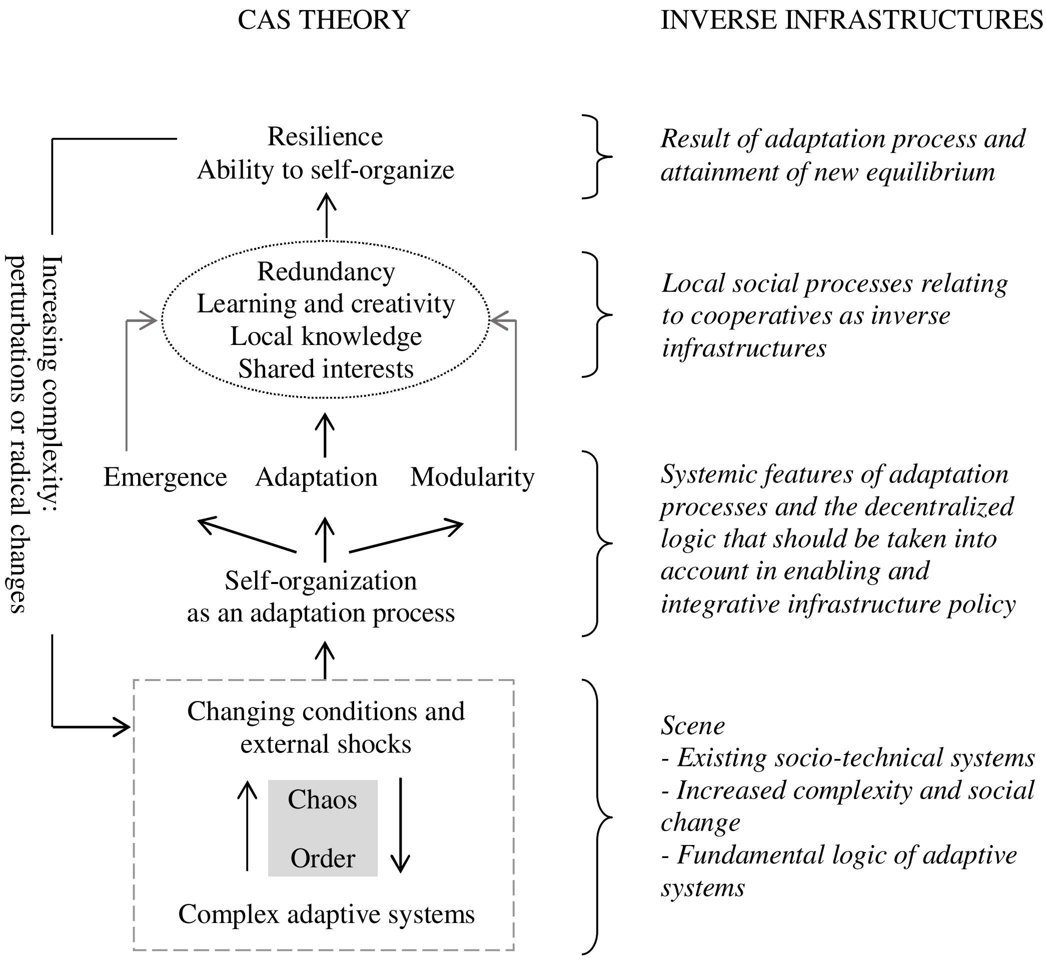

Figure 1. Perspective of CAS on changes in local infrastructures.

4. Inverse infrastructure in practice

4.1 Paradigm shift in constructing infrastructures

Many current infrastructures in our societies have been developed through top-down, centralized planning, where control is managed through democratically governed hierarchical organizations. The glorification of large systems and masterminded planning has affected both physical infrastructures and their management in local government.

Inverse infrastructures have long historical roots. Indeed, many of the systems developed before nations entered their modern state were to some extent built on the basis of such self-organized systems. However, when nation-states started to dominate the system building process, self-organized systems gave way to more efficient, comprehensively planned, and publicly funded large-scale systems (Clifton et al., 2011; Hausman et al., 2008; Graham and Marvin, 2001).

Since the late 1990s, decentralized and self-organized infrastructures initiated from the bottom up have gradually taken root (Egyedi et al., 2007). Nevertheless, the implementation of the new paradigm has encountered various barriers. For example, many architects and engineers – disliking uncertainty and unpredictability – have tried hard to waive away all elements of complexity to develop rational and analytical construction processes (Schalcher, 2009). In general, large established organizations have tendency to favor order, at the expense of creative freedom, with far-reaching economic and societal consequences (Schumacher, 1973).

At a more philosophical level, inverse infrastructures are not only novel structures but also novel ways of thinking about engineering. To enhance the proliferation of inverse infrastructures, there is a need for a paradigm shift from old concept of conventional infrastructure – where infrastructure is perceived only as a physical and technical system – to a new paradigm of more intelligent, creative infrastructure provision. Egyedi and Mehos (2012), for example, argue that policy makers consider infrastructure systems static, although they hold enormous, underutilized potential for innovation.

As the pace of change continues to accelerate, the infrastructure services of cities are facing pressures to change. Coping with pressures requires adaptability, quick response and resilience – the ability to recover from turbulent changes toward the type of equilibrium that provides sufficient support to the everyday life processes. The abovementioned aspects require creativity, a culture of collaboration and problem-solving skills of a new type that does not exist in organizations that rely on rigid operations and a bureaucratic culture (Meadows, 2008). The success of LTSs is typically based on the ability to improve risk management and control complex processes. The ideology of inverse infrastructure is based, to some extent, on opposing premises: the ability to produce redundancy, adherence to simple rules at a low level and an understanding that uncertainty is an inherent feature of a system. Therefore, inverse infrastructure can be perceived as a threat to existing power and governance structures. Such organizations may thus have difficulties in gaining a toehold alongside LTSs.

4.2 Cooperatives as an example of inverse infrastructures

The construction of infrastructures through cooperatives is an important part of the inverse infrastructure phenomenon. Cooperatives became common during the Industrial Revolution, when farmers, the producers of goods, and many other professionals discovered that they could succeed by working together. This realization led to the creation of volunteer-based, autonomous, democratically governed organizations based on co-ownership. The cooperative proved to be successful, for it quickly became common an alternative for producing services for communities.

In 1995, the International Co-operative Alliance (ICA) formulated in *The ICA Statement on the Cooperative Identity* seven cooperative principles through which cooperatives put their values – self-help, self-responsibility, democracy, equality, equity and solidarity – into practice. The principles are:

1) Voluntary and open membership
2) Democratic member control
3) Member economic participation
4) Autonomy and independence
5) Education, training and information
6) Cooperation among cooperatives
7) Concern for community.

Members of cooperatives play a special role: every member is justified in decision-making by a one member–one vote system. Thus, neither the status of a member nor the amount of good consumed by that member is weighted in the decision-making process. Moreover, different perspectives are widely taken into account, and each member is also an owner who encourages sharing all necessary information within the organization. Thus, information asymmetry is reduced and trust enhanced (Ruiz-Mier and van Ginneken, 2006).

Infrastructure development through cooperatives may have some potential advantages compared with the traditional paradigm. Let us consider this issue from the point of view of water services. First, because water service operation is location-bound, such operation is well suited to solve local problems. Second, because the associated risks can be significant, creating redundancy in an infrastructure may prove to be valuable. Third, water services are facing significant challenges, such as aging networks. There should be sufficient amounts of money for rehabilitation investments, but in municipal water utilities, the situation is often the opposite – rehabilitation debt is growing. Because cooperatives are not tied to the municipal budget, they may have better chances of making necessary investments (Warner, 2011).

5. Real-life developments in Finland

Finland is blessed with natural resources, which are the foundation of high-quality water services. Sparse population creates a particular structural problem, however, which has led to a large number of small water service providers with limited managerial capacity. Thus, public ownership of waterworks is supplemented by hundreds of small private cooperatives and associations in sparsely populated areas, which has made it possible to guarantee water services as 'universal service' in the country (Herrala, 2011, 76-77).

5.1 Cooperatives in Finland

Finnish cooperatives have been based on a bottom-up approach since the inception of the co-operative movement in the beginning of the 20th century. Finland has a reputation as "a country of cooperatives." An important part of this development was the development of rural cooperatives, small-scale local water cooperatives included. According to information sources of Pellervo, Confederation of Finnish Cooperatives, there are proportionally more members in co-operatives in Finland than in any other country in the world (memberships in cooperatives amount to some 7 million in a country with some 5.2 million inhabitants). Beside small rural cooperatives and large consumer cooperatives such as S-Group (retail trade) or OP-Pohjola Group (finance), since the late 1980s the number of small-scale entrepreneurial "new cooperatives" has been increasing, surpassing 3,000 in the early 2010s (Tenaw, 2012).

An important contextual factor that has conditioned the development of small-scale utilities especially in rural areas is the development of Finnish welfare society during the post-war decades. Namely, some investment-intensive infrastructures, such as water services, could not be extended to all local communities the same way as, let's say, health care, social services, and education. This is where water cooperatives came into the picture, for in many cases the joint effort of community members appeared to be the only option for improving water services in rural areas when LTSs did not reach them (on rural water supply and the development of water cooperatives in Finland, see Katko and Viitasaari, 1990; Katko, 1992; Takala et al., 2011).

Another feature of Finnish society that has affected the development of cooperatives is the decentralized system of public administration and most notably the key role of local government. Accordingly, the responsibility for organizing water services and other infrastructures is by law vested in municipalities. This does not, however, mean that municipalities have to provide the services by themselves. Thus, the development of water service infrastructures via cooperatives is one option for providing those services. Although Finland is a small country with approximately 5 million inhabitants, it is host to some 900 water cooperatives, of which about half operate in sparsely populated areas. The attitudes of municipalities toward establishing water cooperatives vary significantly, however. Some municipalities do not support the establishment or operation of cooperatives at all, whereas some actively provide assistance and financial support (Herrala, 2011; Takala et al., 2011).

There are historical variations in how municipalities have supported water cooperatives. Takala and her colleagues (2011) divide the development of and local governments' support to Finnish water cooperatives into four periods:

- I Cooperatives established between 1900 and 1950 operated without any municipal support. People used to cooperate in their local communities to improve their living conditions without support from the state.

II Between 1950 and 1970, municipalities and the state began to grant financial assistance for service provision (In 1951 a law on the loans and grants for organising water supply and sanitation in rural municipalities (397/1951) came into force).

III From 1975 to 1990, municipalities actively encouraged inhabitants to establish new water cooperatives especially in sparsely populated areas. Cooperatives created during this period were, however, less independent than the earlier ones (weaker ownership, passive members).

IV The fourth period covers the years subsequent to 1990, when government still supports the establishment of cooperatives. Cooperatives have been established also to provide wastewater services. Municipal support varies case by case.

To sum up, in Finland, municipalities are in principle responsible for providing water services (Water Services Act 9.2.2001/119), and in larger population centers, these services have been produced by municipal utilities since the late 1800s. In rural settings people typically have to fend for themselves and build their own water services, including water cooperatives and on-site systems, such as wells. Even if most cooperatives in the countryside serve small number of users, they still play *de facto* central role in providing water and sanitation services especially for rural population (Herrala, 2011; Takala et al., 2011).

5.2 Ikaalinen as a case municipality

Our case municipality, the town of Ikaalinen, is a small rural town with approximately 7,300 inhabitants located in the central part of Finland, some 50 km from the city of Tampere (see Figure 2). The town is a minor center of education, commerce and administration in the Tampere region. The number of inhabitants has been gradually decreasing since 1990, though in general, the population trend has been stable and is expected to continue to be so in the coming decades.

Source: The town of Ikaalinen.
Available at: http://www.ikaalinen.fi/kaupunki/ [Retrieved Nov 28, 2014]

Figure 2. The location of the town of Ikaalinen, Finland.

Ikaalinen is most aptly characterized as a tourist town, with a nationally well-known spa, currently known as Spa Hotel Rantasipi Ikaalinen, which is the most important employer in the town. Ikaalinen is also nationally well-known as the host of the Sata-Häme Soi accordion festival. Public and private services are the main source of employment (65%), followed by manufacturing and construction (24%), and agriculture (11%) (Tilastokeskus, 2013).

Approximately 3,000 inhabitants live in the center of the town. The rest of the population resides in the approximately 40 villages that are dispersed throughout different parts of the town. The population density is fairly low, under ten inhabitants per square kilometer. Tens of lakes in different parts of the community have provided favorable locations for a large number of summer cottages (there are more than 2,500 summer cottages in the town). The geographical conditions and dispersed community structure create challenging conditions for the construction and operation of water services.

The municipal water utility department provides water services to approximately 5,000 people, implementing the LTS solution. In addition to this LTS network organized by municipal company, water services are organized through 13 water cooperatives established voluntarily by people in different villages. The majority of the cooperatives were established between the middle of the 1980s and the early 1990s. Due to the LTS network design and water cooperatives, the coverage of water supply in the town is as high as 97 %.

Let us take a closer look at the emergence of water cooperatives in Ikaalinen and their integration into local infrastructure system (slightly lengthier discussion of the case of water cooperatives in Ikaalinen is presented in Heino and Anttiroiko, 2014).

5.3 The establishment of water cooperatives in Ikaalinen

Poor-quality well water in the villages was an essential factor affecting the establishment of the water cooperatives. In particular, a high metal content caused taste problems and thus made the consumption of water unpleasant. The local government did not want to expand the operating area of the LTS network to villages. Therefore, people, especially those in many of the larger villages, decided to take the improvement of the water supply conditions into their own hands. A significant prerequisite for self-organization in villages seems to have been that villagers were able to identify common problems. Increasing understanding and creating a favorable spirit for change were largely effected only by a few people or sometimes even just one enthusiast who had a vision of what needs to be done. It seems that a self-organizing system requires a critical human component, someone who can identify problems, inspire others and concretize the required actions.

> *In our village, there happened to live one professor of Helsinki University of Technology. He always criticized the quality of well water. --- The information awakened villagers to react. Without this, the water cooperative would not have been established.* (Cooperative manager 1)

It is also noteworthy that in the case of Ikaalinen, as in most of the cases in the Finnish countryside, subsidies from the state government appeared to be an important impetus in the process. Significant subsidies have been awarded since the 1980s, which correlates positively with the mushrooming of the new water cooperatives throughout the country. This development has, however, affected the internal dynamism of cooperatives. Namely, *"[i]t seems that in water co-operatives that have been set up under strong external pressure or support, the sense of ownership is not as strong, and they have problems with motivating members"*, as concluded by Takala and others (2011).

Another impetus of critical importance has been the positive attitude of local government toward the bottom-up development, as evidenced by the case of Ikaalinen.

> There was Tapani Jokela as a town engineer. He put a lot of effort into planning and consultation of these water service systems. We would not have been able to manage without him. (Cooperative manager 3)

Mutual interaction between villages has also affected self-organization considerably. One informant refers to the phenomenon as "positive village envy."

> *I have been working in this development as an elected representative from the very beginning. (…) When the construction of water cooperatives begun, a type of positive village envy took place ---. Then, we draw up a program (…) it seemed to be one or two cooperatives per year. I must say that the financial support from the local government was substantial.* (Cooperative manager 2)

From the local government's point of view, the idea to develop water service infrastructure through cooperatives was warmly welcome. In spite of obvious capacity and competence problems, self-organized, user-driven micro-infrastructures have led to cost-effective and flexible solutions that do not create unreasonable economic burdens on municipalities.

5.4 Water utility management and 'talkoo' culture

Small water cooperatives are flat organizations, which in spite of their formal structure rely on informal management and work processes. The manager of the water cooperative is usually the person who makes urgent decisions and urges other members to act if needed. The case of Ikaalinen indicates that transaction costs of mobilizing voluntary work can actually be relatively high.

> *If you know what needs to be done, the best way to solve it is to do it by yourself ---.* (Cooperative manager 2)

> *I am now retired and working on voluntary basis. Anyway, this keeps me very busy, after all.* (Cooperative manager 3)

From the point of view of daily operations management, there is simultaneously freedom in actual work and some degree of control, which is achieved through rudimentary management practices. As the leading figure's stewardship is usually enough, the majority of water cooperatives' daily duties require no additional workforce. However, the other side of the coin is a 'talkoo' tradition of mutual help, which manifests itself when there is a need for volunteers to perform special tasks on an *ad hoc* basis ('talkoo', as an activity usually in plural 'talkoot', is a Finnish expression for gathering neighbors or villagers to accomplish a specific task, similar with 'barn raising' in the UK and North America).

> *When we constructed the pipe which goes under the lake, there were (...) at least 20 people there. So, people are ready for ad hoc works like this.* (Cooperative manager 2)

5.5 Cooperatives, the LTS operator and the town hall

Interaction between the water cooperatives, the municipal water company (LTS operator) and the public works department has been smooth in the case of Ikaalinen. It has helped in the establishment of cooperatives as well as in solving problems and detecting weak signals early. This entails that the LTS operator and public works department take seriously the problems raised by cooperatives.

> *I always take care of smaller jobs by myself, but if some bigger problems emerge, then I will contact directly Water Ltd. [LTS-operator]. I have always gotten help there.* (Cooperative manager 3)

The municipality has given practical help to cooperatives in various ways, as in supporting electronic network documentation. In addition, ensuring technical interoperability has been a shared goal from the outset.

> *It was taken into account at the time of the establishment [of the cooperative], that technical system matches with the system of the Water [municipal water company], so that expertise is available when needed.* (Cooperative manager 4)

Mutually appreciative interaction has increased trust, learning and the ability to utilize local knowledge. In this sense, self-organization seems to have important situational and contextual preconditions, which relate to local social capital. This includes also communication between cooperatives.

> *The town has convened us, the cooperative managers, to the "water meetings." I have found them very important, and I think this is others' opinion as well. There we share thoughts, approaches, etc.* (Cooperative manager 1)

> *We just discussed that [a new water meeting] should be organized soon. We decided that a representative from ELY Center [The Center for Economic Development, Transport and the Environment of Finland] could come and tell about those possible changes, which will take place at the national level. She will discuss, advise and consider future challenges. [...] We could ask questions because they have the best knowledge about significant policy guidelines.* (Representative of water services of the town of Ikaalinen)

One manifestation of the interconnectedness of service providers is the building of connection pipes, which have been constructed both between water cooperatives and between water cooperatives and LTS networks to secure a reliable water supply. These pipes have proved to be vital, for example, when dealing with the problems with water intake plants and insufficiency of ground water during dry periods. They are a paradigmatic case for technical redundancy, a feature that characterizes CASs.

5.6 Future prospects

Like any socio-technical system, water cooperatives have their life cycle with stable periods and turning points. At the practical level, one of the critical aspects of their development is the aging of active members who have much know-how and tacit knowledge. When they retire, some of that expertise and knowledge will disappear. Therefore, the continuity of the water cooperatives may reach a bifurcation point, as expressed in CAS theory.

Generational change is a topical issue in many of the water cooperatives of Ikaalinen and remains in the agenda in the near future. If new active volunteers are not found, cooperatives may have to seek expertise and maintenance work from external service providers. Various solutions to this problem have already been considered, including the intensification of collaboration between the water cooperatives.

> *The problem is that volunteers cannot be found anymore.* (Cooperative manager 2)

> *We have thought to start paying salary (...) to a villager who would do this operational work full-time.* (Cooperative manager 6)

Tightening requirements in water utilities' operations pose another challenge to small-scale cooperatives. They increase both demand for professional expertise and operational costs. The interviewees considered this as unwanted development as they feel that tightening regulation does not necessarily result in factual improvements in service.

> *But, sure, any tightening of regulation causes always problems to us. It make our work more difficult. It increases costs. And we do not see that it is conducive to our work, then it feels quite unpleasant.* (Cooperative manager 2)

If the water cooperatives do not find solutions to continue as autonomous organizations in an environment of ever increasing internal and external pressures, one possible option is that they will be acquired by LTS-operator. From the cooperative managers' point of view, this is not a desirable option because the very nature of the organization will change (especially volunteering) and rates are likely to rise.

> *I hope this is not topical in the near future because we have been able to keep our rates so good. The water rates would rise. So I hope that we could keep ourselves [i.e. cooperative] autonomous. (Cooperative manager 6)*

Discussion about the short-term and long-term views of the future of inverse infrastructures relate to the following short citation in which Herrala (2011, 162) describes strengths and weaknesses of water supply in Finland: *"Cooperatives' independence from political regulation and decision-making can be considered as a clear strength. However, their weakness lies in small-scale operation and the threat is a lack of expertise if services are provided with volunteer work."* (Cf. Takala, 2008). Namely, the short-term view emphasizes usually the latter aspects – small scale and lack of expertise – and reduces the question to a dilemma of LTS-oriented solution vs. merger with neighboring cooperative. Thus, in infrastructure field such a standard response to problems with operation and maintenance of infrastructures is derived from the logic of top-down infrastructure policy. Such a solution relies on acquisition (expansion of existing LTSs) or mergers of providers coupled with the introduction of market-oriented management models (cf. Hudson and Herndon, 2000). Herrala (2011, 105), for example, sees cooperation and consolidation with other cooperatives or municipally-owned waterworks as an opportunity. According to her, *"[i]n the future, small units may find it difficult to achieve tightened water quality and environmental requirements, which is why cooperation and consolidation with other cooperatives is a realistic option."* However, such an approach ignores a range of opportunities that are in-built elements of self-organized infrastructures and are ultimately anchored on broad involvement of civil society in dealing with infrastructure issues. An alternative view builds a wider horizon that goes beyond short-term restructuring agenda. It is neither about uncritical acceptance nor categorical rejection of any policy or governance model, but rather about being open to the self-organization of local civil society and empowering local people to look for locally generated solutions. Such a view may be appealing in the future if and when prolonged structural crisis in the Western world will become difficult to mitigate without structural changes.

6. Toward enabling and integrative infrastructure policy

The creation of LTSs is essentially a result of the fairly stable development of advanced societies with a sufficient governing capacity and resource base for investments and maintenance of infrastructures. The increasing complexity and pace of change in technology, economy, politics and culture and especially prolonged economic difficulties are changing the premises of this development and urge us to reconsider the sustainability of the principles on which infrastructure development is based. The gradual weakening of strong state ideology has started to place increasing weight on private sector involvement in infrastructure development. However, mixed experiences with privatization, outsourcing and public-private partnerships (PPP) have, since the 1990s, opened avenues for alternative solutions to infrastructures and publicly funded services, including such alternative models as the Non-Profit Distributing (NPD) model, cooperatives, mutuals, social enterprises, and community buy-outs (e.g., Bailey et al., 2010; Valkama et al., 2013).

6.1 Enabling local authority

The general trend in infrastructure policy seems to be to search for cost effectiveness, innovativeness and the utilization of local capacity, which directs attention to the potential of inverse infrastructures. One of the preconditions for the full utilization of local potentials is enabling and empowering orientation in local governance and policy, which is to stimulate and assist local players to play their part in service delivery and community development (cf. Smith, 2000; Brooke, 1991). Such a turn in infrastructure policy raises many questions. What are the forms of self-organization in infrastructure field that are likely to emerge in the conditions of advanced welfare society? What is the connection of self-organized micro-infrastructures to finance and governance of public infrastructures? What would be the role of local government as the major player in local infrastructure policy? To begin, such a turn seems to require an integrative strategy that takes into account the interdependence of various technical systems as well as the ability to cross over sectoral barriers. At the same time, there is a need to identify the special challenges associated with inverse infrastructures to be able to provide tailored support in their initiation phase and later with maintenance.

Integrative infrastructure policy may create tension, especially if local governments want to dictate the policy lines and terms in the field.

Integrative infrastructure policy has already saw the light of day in Finland in the form of inter-municipal collaboration. For example, in the river valley of Kalajoki a jointly-owned Vesikolmio Oy [inter-municipal company Vesikolmio] provides both water acquisition and treatment and sewage treatment services to six municipalities. This kind of cooperation is a part of national development where certain activities, such as water acquisition and sewage treatment, are concentrated to a few regional operators so that quality product and services can be provided safely and efficiently while also exploiting economies of scale. Another similar kind of case can be found from the Hämeenlinna region, where seven municipalities established a jointly-owned company for regional water and sewage service provision in 2001 (Herrala, 2011, 145). Another form of collaboration is operation and management (O&M) contract, which is used in the provision of some infrastructure services. Concerning water service, a benchmark is the 15-year concession agreement between publicly owned Lahti Aqua Ltd and the municipality of Hollola. It covers all water and sewage services in Hollola and dictates that Aqua Services Ltd, subsidiary of Lahti Aqua, provides services with Hollola's own equipment. This was actually the first model of its kind in Finland (Herrala, 2011, 146). Yet, the overall picture of water policy is that even in cases in which local government has fairly positive view of the overall impact of water cooperatives on local water service, the scope is still narrow and the level of integration modest, dominated by New Public Management (NPM)-oriented LTS perspective.

Ikaalinen represents a small town case in which the local government has been overtly positive toward the establishment of water cooperatives. Thus, it has put the idea of enabling and integrative policy into practice. Herrala (2011, 212) gives the following account of another case of enabling policy, that of the municipality of Pudasjärvi:

> *"Cooperation in the waterworks is not confined to the municipal organisation. If cooperatives operate in the outskirts of the municipality, they are often in close contact with the municipal waterworks so as to arrange and develop the local service provision. Municipalities may also support cooperatives quite*

> *generously if their establishment and operations are in the municipality's best interests. In Pudasjärven vesiosuuskunta [water cooperative of Pudasjärvi], for example, the municipality funded 25 percent of the initial investments when the cooperative was established. In addition to financial support, cooperatives may receive technical assistance or other intangible support from the municipality. Furthermore, neighbouring municipalities' waterworks are encouraged to be in contact to create water and sewage services regional master plans."*

6.2 Prevailing managerialist imperative and LTS paradigm

There are also cases in Finland, most notably among larger cities, which reflect streamlined LTS paradigm and increased managerialism in infrastructure provision. For example, in the public debate on water management in the city of Jyväskylä, a striking feature seems to be the dependence of rural water cooperatives on Jyväskylä Energy Ltd. (the energy company of the city), from which water cooperatives buy their clean water and to which they convey their wastewater. In that case as well, rural water cooperatives were originally supported because local government could not afford to invest in water utilities outside the densely populated city center. Water cooperatives were able to buy water at wholesale price and also received other services from the LTS of the city. However, soon after the merger between the city of Jyväskylä and two of its neighboring municipalities in 2009 Jyväskylä Energy Ltd. announced that local water cooperatives would no longer be able to buy water in bulk at a reduced price (Heinälä, 2012). Päivi Kvist (2012) of Muurame, the neighboring municipality of Jyväskylä, described the situation concerning water cooperatives in the region in her blog as follows:

> *Water cooperatives (which have to buy the service from [Jyväskylä] Energy), are offered ridiculous contracts, which simply profit from water cooperatives. Contracts include unfair clauses, which remove many responsibilities from Jyväskylä Energy, transferring them to water cooperatives. In return, prices are raised to the same level provided to urban consumers, even if water cooperatives cannot afford them. Either inhabitants in rural areas will soon run out of money to pay for clean water and the treatment of wastewater or the*

> *water cooperatives will start to go bankrupt. In this case, responsibility is transferred to Jyväskylä Energy, and the situation will be the same again; that is, prices will be raised so that the people with normal income can no longer live in the countryside. [Translation from Finnish by the authors]*

A similar situation has given rise to a great criticism in southeast Finland. In 2009, three urban governments (Kouvola, Anjalankoski and Kuusankoski) and three rural local govrnments (Elimäki, Jaala and Valkeala) merged to create the new city of Kouvola. Altogether 50 water cooperatives operate in this newly formed city area. Before the merge, the water cooperatives were able to buy water and wastewater services at wholesale prices from the LTSs of each local authority. Wholesale discounts were abolished after the merge, however. Because the total expenses of water services have been considered to be too high and unfairly distributed, the cooperatives united to establish an association for fighting for the reinstatement of the wholesale pricing policy. The association expresses its concern as follows:

> *Cooperatives have been operated by volunteer work so far, but this time has now passed. As cooperatives grow and requirements tighten, the younger generation especially does not want to take on the responsibilities that are the same for small cooperatives as they are for bigger water utilities. The alternative is to utilize outsourcing, which has raised costs so much that many have had to limit their water use. The situation is unreasonable, especially for the families with children, who use water services a lot.* (Kouvolan vesiosuuskunnat ry, 2014)

The abovementioned regional association of water cooperatives sees that as water service is essentially a universal service, the service users should be treated equally within the municipality regarding access and pricing policy. If wholesale pricing were reinstated, cost burdens for cooperative members would become tolerable. The association emphasizes that cooperatives will maintain infrastructure on their own account.

> *The cooperatives have been constructed to a large extent by volunteer work even though the city contributed to the initial construction. In spite of this, connection costs are significantly higher than in urban areas. We have accepted this as we have chosen the place we live.* (Kouvolan vesiosuuskunnat ry, 2014)

These discussions reveal interestingly the tensions that restructuring through mergers and corporatization together with budget constraints and growing tendency towards NPM-oriented managerialism may create in the governance of decentralized systems. We may even hypothesize that local government restructuring through large-scale mergers may simultaneously lead to streamlined and professionally oriented infrastructure policy that supports urban densification rather than reasonably priced services in sparsely populated areas.

7. Conclusions

Small-scale infrastructures exhibit self-organization through micro-level processes that represent reactions to changes in internal and external conditions (van den Berg, 2012). Theoretically, self-organization implies that if conditions change, the entity that is organized through micro processes changes, as well, which suggests that the entity is able adapt to its environment spontaneously. The difference from large-scale infrastructure systems that reflect the official infrastructure policy lies in the fact that the latter aim explicitly to control and govern uncertainties of various types to maintain stability. In this sense, adaptive socio-technical systems, such as water cooperatives, are opportunistic. It is important to learn more regarding the rationale of self-organization and, especially, regarding the conditions under which people organize themselves to create micro-infrastructures, i.e., the necessary and sufficient conditions for the emergence of such systems (Egyedi and van den Berg, 2012; Egyedi et al., 2007). There are many examples of such systems, and their relevance may increase, especially if financial crises and ideological shifts direct local governments' attention to alternative ways of organizing local infrastructures. This situation poses a challenge to local infrastructure policy in the sense that it should be *enabling*, i.e., supportive to the emergence and maintenance of inverse infrastructures, and *integrative* so that it would be possible to ensure that different parts of infrastructure system support collectively set goals, such as cost effectiveness and sufficient degree of functionality.

Based on our theoretical and empirical analysis, we can conclude that the processes within self-organized units and in the multi-sectoral infrastructure governance field are not as antagonistic as one might assume. Rather, we present three instances in which this relationship is rather synergistic, reflecting inherent dialectic features of inverse infrastructures:

- The case of Ikaalinen implies that the establishment of inverse infrastructures is a double-edged sword: it requires both self-organization and at the same time considerable support from the public sector. Here, *autonomy and dependence* go hand in hand, in a synergistic manner, which means that we do not have to view this setting antagonistic. The question is rather about 'controlled autonomy,' hence the importance of both enabling and integrative aspects of infrastructure policy (cf. Dressler, 2007).
- The cooperatives require rules and hierarchies, which determine the role of all actors involved. On the other hand there is the level of flexibility, which is associated with the dominating position of those key figures who have assumed the main responsibility in managing the daily operations of the cooperative. In micro-management *adhocracy and hierarchy* work hand in hand.
- In self-organized systems, order is created through interaction and feedback processes, such as meetings, instructions, proceedings, and rules. Such interaction maintains the organization's dynamics and ultimately determines the degree and mode of self-organization (Haynes, 2003). This calls for a balance between *freedom and formal rules*, or between a legitimate system and a shadow system, as the precondition for the optimal utilization of local creativity (Jackson, 2003; Stacey, 1996).

The case of Finnish water cooperatives demonstrates that inverse infrastructure can be an important part of local infrastructure. However, the case also reveals that there are many challenges that escalate especially when the old generation withdraws from the cooperatives. Theoretically speaking, the local systems may drift away from their equilibrium or 'attractor'. Such a bifurcation point may lead to innovative and creative solutions and the unification of those who stay in charge, but it may also lead to prolonged problems that even threaten the existence of cooperatives. In the case of existing small water cooperatives the tightening economic conditions force to reconsider the fundamental questions relating to the existence of the utility and, in particular, the pros and cons of independence, cooperation, and consolidation.

Concerning resilience, due to various constraints that relate to economic situation, institutional landscape and human resources, small-scale water cooperatives must conduct in a way or another a practical resilience assessment, which increases the understanding of their situation in the current basin of attraction as well as of their navigation options. Under the conditions of late modernity, such self-organized systems may undoubtedly be vulnerable on their own, whereas with the support from local and central governments the width of their basin can be expanded (latitude); resistance to change is likely to weaken; the position in the basin moves away from the edge and thus gets closer to the attractor (precariousness); and lastly, the relationship with local and national infrastructure policies becomes smoother (panarchy) (cf. Walker, 2005).

The increased competence requirements, the pressure to improve financial management and the search for economies of scale where possible through mergers, as illustrated by the case of Finland, pose externally motivated challenges to local water cooperatives. In such a situation self-organization may hold much potential for building and maintaining infrastructures in the future, but its realization has its preconditions. One of the critical aspects of them relates to local infrastructure policy. There is a need to create sector-wise and location-specific understanding of the functionalities, connections and synergies of various infrastructures, but it is equally important to consider the values and visions on which such decisions are based. This translates into the question as to whether traditional LTS-oriented thinking should be replaced by a new paradigm to guide infrastructure policy in a time of economic uncertainty. Our contention is that local infrastructure policy should be *enabling* in order to create preconditions for self-organization, emergence and redundancy within inverse infrastructures, and *integrative* in order to integrate such micro-infrastructures into the infrastructure networks and thus both utilize modularity and enhance 'panarchic' resilience.

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