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An analytical framework for common-pool resource–large technical system (CPR-LTS) constellations

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Abstract: This paper introduces an analytical framework for a special phenomenon: when a common-pool resource (CPR) institution and a large technical system (LTS) are connected and mutually interdependent. The CPR in this case is a node managed by its appropriators within a centrally planned and managed system; here named CPR-LTS constellations. Our framework is empirically derived from two historical investigations of CPR institutions within two LTSs, the agricultural-technical system and the road transport system of Sweden. By comparing similarities and differences it is possible to identify paths to successes and failures. To understand why one survived and the other disappeared we connect Elinor Ostrom's theories about management of CPRs with Thomas P. Hughes's theories about LTSs. We are proposing a framework that can bridge the gap between theories about management of CPRs and LTSs. By combining the two theories it should be possible to better understand how small-scale producers using bottom-up CPRs can be linked to top-down LTSs. We will argue that to fit within an LTS, a CPR needs alignment between different parts or components within the constellation/system and alignment with other systems and institutions in society. We propose three analytical levels to deal with the phenomenon of aligning a CPR project to an existing, large sociotechnical system:

1. Local alignment (CPR): How are CPRs organized and managed at local sites?

2. Sociotechnical alignment (CPR-LTS): How are CPRs connected to the sociotechnical system?
3. Contextual alignment: How are CPR-LTS constellations aligned with neighboring institutions and systems in society?

Our work indicates that for successful management of a CPR-LTS constellation it is important that the CPR be included in legislation and that government agencies support the CPR in alignment with the LTS. Legislators must recognize the CPR-part in the CPR-LTS constellation so that its institutional body is firmly established in society. In this study, we have used the framework ex-post; however, we anticipate that the framework could be a diagnostic tool ex-ante for CPR-LTS constellations.

Keywords: Common pool resources; commons; collective action

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1. Introduction and problem formulation

In this paper we introduce an analytical framework we are developing for a special phenomenon: when a common-pool resource (CPR) institution and a large technical system (LTS) are connected and mutually interdependent. The CPR in this case is a node managed by its appropriators within a centrally planned and managed system. Our framework is empirically derived from two historical investigations of CPR institutions within two LTSs, the agricultural system and the road transport system of Sweden (Larsson 2009; Blomkvist 2010). We studied *summer farms* – periodic settlements for the use of common pastures – and *civic roads* – roads that are managed directly by the road users living nearby – and realized that our CPRs were not isolated or simply connected to other CPR arrangements. Each was in fact dependent on an LTS. They were parts of "CPR-LTS constellations."[1]

[1] Note that most modern road network systems are "pure" LTSs with no part managed as a CPR and that the same is true for most modern agricultural systems.

We also realized that what we call *alignment* is crucial for the functioning and, ultimately, for the survival of a CPR connected to an LTS. Lack of alignment, i.e. conflicting rules and institutions, actors with different interests, mismatching technical standards, etc., needs to be addressed when managing a CPR in a CPR-LTS constellation. In this paper, we argue that alignment is important on three levels: (1) alignment of different parts within the CPR unit, (2) alignment between the CPR and the LTS within the CPR-LTS constellation, and (3) alignment between the CPR-LTS constellation and its environment.

Civic road-keeping still exists in Sweden and is still a CPR-managed institution within the state-controlled road system. Summer farms disappeared when the agricultural system changed in the early twentieth century. To understand why one survived and the other disappeared we connect Elinor Ostrom's theories about management of CPRs with Thomas P. Hughes's theories about LTSs (Hughes 1987, 1992; Ostrom 1990, 2005, 2009). We are proposing a framework that can bridge the gap between theories about management of CPRs and LTSs. By combining the two theories it should be possible to better understand how small-scale producers using bottom-up CPRs can be linked to top-down LTSs.

CPRs like fisheries, irrigation systems, and groundwater basins are man-made and natural resources managed by the actual appropriators (Ostrom 1990, 2005) and are built from technical artifacts, institutions, and actors. A CPR can be any size, but normally a CPR with a well-established common-property regime is relatively small to medium sized with a limited number of users and is managed from the bottom up by its users. It is a widely held opinion that CPR management is a promising source of inspiration when dealing with overuse of natural resources and a possible remedy for the problems behind global warming (Stern 2011).

LTSs – road systems, railroads, power grids, telephone networks, among others – are essential in industrialized nations. We need them for food, transport, communication, power, etc. Modern life as we know it would be impossible without them. Because LTSs are built from technical artifacts (e.g. electricity cables and roads), institutions (formal and informal), and actors (professional and commercial) they are actually sociotechnical systems (Hughes 1987). LTSs are most often centrally planned and managed, leaving users and appropriators with little input. The systems are not easy to change and deeply embedded in society.

In research, road systems are traditionally considered LTSs, whereas agricultural systems have not been perceived as such. In this paper, we leave the debate on what is and what is not a genuine LTS. It is an empirical question at any given time in history to investigate the level of "systematization" (see section 2.2 for a discussion of tightly coupled systems). For our purposes it is enough to state that it is possible to use LTS terminology to analyse both roads and agriculture as being large sociotechnical systems. We argue that an agricultural system can be seen as a sociotechnical system (and a social-ecological system), and like other

sociotechnical systems, the evolution of an agricultural system can be divided into phases: buildup, expansion, maturity, and decline (Hughes 1987, 1992; Myrdal 2006; Larsson 2009, 2012). When an agricultural system is established and has reached momentum, it is difficult and costly to change. All parts in the system fit together – tools and equipment match the jobs to be done, and jobs match the skill of the workforce and are scheduled to match natural conditions. Today, the system character of agriculture is even more pronounced. Many farmers depend on big corporations for tools, machinery, and seeds, and on government subsidies as well as on national and international regulations. Simply put, because of the similarities in system-like features between traditional LTSs and agriculture, it is possible to use theories about LTSs to analyse how agriculture has developed. Thus, in this paper, both civic roads and summer farms in Sweden are seen as CPR-managed, local nodes connected to two distinct sociotechnical systems – the road network system and the agricultural system. We argue that the important factor in these types of arrangements is the alignment between CPR-managed institutions and larger sociotechnical systems. The chance to prosper is greater if the CPR has a strong alignment with its particular LTS.

We follow two CPR-LTS constellations over several centuries and by comparing similarities and differences it is possible to identify paths to successes and failures. We will argue that to fit within an LTS, a CPR needs alignment between different parts or components within the constellation and alignment with other systems and institutions in society. We propose three analytical levels to deal with the phenomenon of aligning a CPR to an existing LTS:

1. Local alignment (CPR): how are CPRs organized and managed at local sites?
2. Sociotechnical alignment (CPR-LTS): how are CPRs connected to the sociotechnical system?
3. Contextual alignment: how are CPR-LTS constellations aligned with neighboring institutions and systems in society?

First, we outline theories about our three analytical levels, starting with CPRs and introducing the design principles for long-enduring CPR institutions, and follow up with theories about LTSs. Next, we analyse two examples of CPRs – summer farms and civic roads – and discuss their local, sociotechnical, and contextual alignments over time using the framework ex post. Finally, we conclude and suggest (briefly) that the framework also can be used ex ante to identify lack of alignment in current CPR-LTS constellations (e.g. wind power in Sweden).

We believe that CPR-LTS constellations will be important institutional arrangements in the future management of natural resources, i.e. energy, transport and agriculture systems, and that a better alignment between CPRs and LTSs could lead to better use of natural resources at the local level and a transformation toward more sustainable modes of production and consumption. Given that CPR-

LTS constellations have not been explored before, this paper offers not a complete investigation of the topic but a framework that serves as a starting point for further research and theory development.

2. Alignment on three levels

2.1. Local alignment

To examine the local alignment of civic roads and summer farms we use the design principles for long-enduring CPR institutions (Ostrom 1990, 90; 2005, 259). The design principles were first introduced in Ostrom's (1990) book *Governing the Commons*. Until the publication of this book, scholars had a negative view of common-property regimes. Gordon (1954, 135) wrote that "everybody's property is nobody's property" and "wealth that is free for all is valued by none." Hardin (1968, 1244) expressed it as "the tragedy of the commons" and concluded that "freedom in the commons brings ruin to all." The prediction was overuse of natural resources, degradation of nature, and environmental damage. Hardin and others proposed privatization or ownership by central governments.

During the 1980s, scholars began to question the wisdom of massive efforts to impose particular institutional arrangements on the users of CPRs. They argued, for example, that Hardin's argument overlooked the important role of institutional arrangements that provided for exclusion and regulation of use (Feeny et al. 1990). In *Governing the Commons*, Ostrom (1990) showed that many social groups have struggled successfully against threats of resource degradation by maintaining self-governing institutions. Although these institutions have not always succeeded, neither has private or state ownership (Feeny et al. 1990; Dietz et al. 2003). Ostrom gives examples of sustainably and unsustainably managed meadows, forests, irrigation systems, groundwater basins, and fisheries. Her conclusion was that successful CPR institutions appear to share certain features. But instead of stating specific rules for success, she developed a set of design principles that characterize all robust CPR institutions, plus an eighth principle used in larger, more complex cases (Ostrom 1990). The design principles describe the broad structural similarities among self-organized systems that have been able to adapt and learn so as to be robust and resilient to many social, economic, and ecological disturbances that occur over time. While earlier studies of human behavior emphasized the individual as a rational actor seeking to maximize short-term instrumental returns (Gordon 1954; Hardin 1968), Ostrom could show that people are able to cooperate and manage natural resources jointly. The "primary role of the design principles is to explain under what conditions trust and reciprocity can be built and maintained to sustain collective action in the face of social dilemmas posed by CPRs. This collective action, in turn, helps prevent the deterioration of a managed CPR" (Cox et al. 2010).

The design principles include: (1) boundaries of the resources and individuals with access rights are clearly defined; (2) appropriation rules/local conditions and benefits/required inputs are congruent; (3) collective-choice arrangements

allow users to participate in modifying the rules; (4) monitors are present and actively audit CPR conditions and appropriator behavior or are accountable to the appropriators; (5) violators face graduated sanctions; (6) conflict resolution mechanisms exist; (7) external government authorities recognize minimal rights to organize; and (8) within larger systems, appropriation, provision, monitoring, enforcement, conflict resolution, and governance of CPRs are organized in multiple layers of nested enterprises (Ostrom 1990). Ostrom has stressed that these design principles cannot be used as a blueprint because there is no panacea when analyzing social dilemmas. We must "[match] the rules of a system to the underlying biophysical world and type of human community involved" (Ostrom 2005, 270).

The design principles were based on empirical findings and have been extensively used. Cox et al. (2010) did a literature review of 91 relevant studies using the design principles and concluded that many scholars believed the design principles characterize robust systems and are well supported empirically. However, some critiques of the design principles argue that they are incomplete and suggest additional criteria for sustainable management. Another critique is whether they can be applied to a wide range of cases beyond those that were used to develop them. Finally, several authors argue for a more constructionist or historically, socially, and environmentally embedded perspective that departs from viewing actors as rational decision makers. Cox et al. (2010) concluded that the critique about the design principles being incomplete is sound. In an increasingly interconnected world, we must consider properties beyond local-level institutions, such as external socioeconomic factors. We agree with this conclusion and will argue that to understand how a CPR could be part of an LTS one needs to consider both sociotechnical and contextual aspects.

Even though the design principles contain some flaws, we will argue that they are easy to correct and do provide an excellent tool to analyse the local alignment of a CPR linked to an LTS. Later in this article we will use the design principles to analyse the development of summer farms and civic roads in a historical perspective and follow them through several centuries.

2.2. Sociotechnical alignment

Above we recognized that Ostrom's design principle number 8 describes how CPRs can be organized in multiple layers of nested enterprises (Ostrom 1990). During the last decade, research about how CPRs are nested or linked in social-ecological systems has been a major topic of research. The study of cross-scale institutional linkages has contributed in an important way to the understanding of the complexity of CPR management. Cross-scale interaction refers to linking institutions both horizontally (across space) and vertically (across level of organizations) where scale is a crucial concept (Berkes 2002; Armitage 2008). Cross-scale linkages have been extensively covered in recent literature and there is an ongoing discussion about their importance (Poteete 2012). In this paper, we analyse scale by focusing on

key elements in theories about LTSs that can increase our understanding of CPR-LTS constellations. Inevitably, cross-scale linkages and what we call sociotechnical alignment sometimes overlap, but theories about LTSs will add important new information about the alignment between a CPR and an LTS.

For theoretical justification of the importance of sociotechnical alignment we turned to the history of technology. A *sociotechnical system* is a concept made known by the American historian of technology Thomas P. Hughes. In his groundbreaking study of the development of the electricity system in the USA and its diffusion overseas to Great Britain and Germany, he established the LTS perspective (Hughes 1983, 1987; Kaijser 1994, 2002; Blomkvist and Kaijser 1998; Blomkvist 2001). Hughes stressed that an LTS must be analysed as a mixture of sociopolitical, economic, cultural, institutional, and technical components, thus not only technical but sociotechnical in nature. We use the acronym LTS in the same way.

The evolution of a sociotechnical system can be described with the classical S-curve and divided into four phases: buildup, expansion, maturity, and decline (Hughes 1987; Blomkvist 2001). A mature system is deeply embedded in society and not easily changed or transformed. Hughes's word for this is *momentum*. The large mass of an LTS, creating momentum, consists of the physical infrastructure (roads, grids, pipes, etc.), the organizations and institutions created for support, laws, and regulations, and the financial and industrial corporations and individuals (engineers, scientists, politicians, etc.) with huge vested interests in the survival and expansion of the system. A mature sociotechnical system is often very conservative and its actors are unwilling to change (Blomkvist and Kaijser 1998).

A system with a high level of momentum gives the impression of autonomous velocity, almost as if the system had its own inertia. System growth seems inevitable. But one cornerstone in Hughes's (1992) perspective is that there is no such thing as autonomous system evolution. Systems are, as any man-made institution, subjected to contingent historical context. The historical origins of most, if not all, infrastructure systems include some form of cooperation among its original users. In Sweden, for example, the development of electrical and telephone systems started as cooperatives or other forms of joint ventures of users who built the networks from the bottom up (Kaijser 1999). Historian of technology Arne Kaijser (2002) describes the same process by using Elinor Ostrom's design principles to analyse the history of the Dutch struggle against floods. He reveals the institutional inertia created by the appropriators' efforts to build CPR-like water control systems and its effect on Dutch political culture. In the end, the Dutch water system, like the Swedish telephone and electrical systems, was transformed into a centrally administrated and controlled, tightly integrated, national infrasystem. Management changed from bottom up to top down. The appropriators lost their influence on the journey from a CPR to a large technical system.

As the sociotechnical system evolves from the local level to a centrally managed top-down system it typically becomes more tightly coupled (Hughes

1987). In a tightly coupled system, the connections among components (technical and institutional) are very strong, specially designed for system purposes, and highly sensitive to disturbance (low redundancy). The system managers are unwilling to make changes and highly aware that all system components must be aligned for the system to function properly, evolve, and grow. It is important to realize that LTS management diligently strives to couple system components more tightly and thereby centralize power over the system; systematization through standardization is typically the most important way to manage an LTS. For this reason, system management, in most cases, has tried to get rid of CPR-like arrangements, cooperatives of users, or other decentralized forms of management (Hughes 1987; Blomkvist and Kaijser 1998; Blomkvist 2001).

We believe that this historical process toward top-down management and tightly coupled systems is coming to an end due to sustainability issues. There are many examples of the need for better alignment between LTSs and CPR-like arrangements where users are invited to manage parts of the system. In the Swedish energy system, for example, one can identify several obstacles on all three levels when trying to connect a local windmill to the centrally managed grid (Blomkvist and Sandberg 2011) (see section 4 for a more detailed discussion). It is also easy to spot similar difficulties in water and irrigation provision and management in developing countries. We refer to the literature on collective action in large-scale water and irrigation systems that are both CPRs and LTSs (e.g. Araral 2008, 2011; Nilsson 2011). Without using our framework, this literature empirically shows our paper's central argument on the need for (1) local, (2) sociotechnical, and (3) contextual alignment for the CPR-LTS constellation to function properly.

Sociotechnical systems are stable and conservative, but they do change – sometimes radically as when gas light gave way to electric light, and sometimes incrementally, as when road networks changed to meet the needs of motorization. Radical change is caused by disruptive forces such as new technology, new or changed market conditions, environmental concerns, policy changes, and institutional innovation or lack of primary products, like oil (Dahmén 1991). In Hughes's (1992) terminology, change in a system occurs with the appearance of a *reverse salient* – a system component (technical or institutional) lagging in development, seen from a pro-systems perspective, and creating incentives to innovate. If the reverse salient is not addressed it can destroy the system. One much debated present-day reverse salient is the battery capacity in electric cars, which affects driving range. For a systems manager it is important to deal with reverse salients to secure the well-being of the system.

In our paper, we use Hughes's concept of reverse salients to analyse alignment between our CPRs (summer farms and civic roads) and their respective LTSs. We argue that the way system management handles reverse salients in the CPR-LTS constellation is crucial for the alignment and thus the survival of the constellation.

2.3. Contextual alignment

Our third analytical level of alignment is called *contextual alignment*. Problems that threaten the development of a CPR-LTS constellation can arise not only from within the CPR or within the CPR-LTS constellation, but also externally. Conflicts and external pressure can stem from collision with other societal institutions, rules, organizations, or systems. The question to ask when investigating contextual alignment is: how does the CPR-LTS constellation align with other institutions and systems in society? Hughes (1987, 1992) uses a similar distinction when he is discussing the delimitations of an LTS, which he calls *environment*.

The factors creating external pressure are not directly controlled by either CPR management or managers of the CPR-LTS constellation, and they are not easy to identify by analysing the CPR or the CPR-LTS constellation in isolation. Sociotechnical alignment is not static. As we show later in the paper, changes in other segments of society can influence the development of the CPR-LTS constellation in ways difficult to discover for the actors involved in its daily management. Such factors can be the building of a national railway system, challenging the contextual alignment in the civic and public roads CPR-LTS constellation or external changes in the textile industry challenging the contextual alignment of the summer farms and agricultural system CPR-LTS constellation.

We realize that external pressure can be caused by a wide range of factors. On the most abstract level, forces of modernization, industrialization, and urbanization create external pressure on all CPRs and CPR-LTS constellations. However, in our third analytical level, our purpose is not to address these types of general and abstract historical trends affecting society over several centuries. We want to keep "context" on a fairly concrete level. When talking about contextual alignment, we analyse external factors directly challenging alignment when interacting with the CPR-LTS constellation in a relatively short time frame.

3. Historical cases – using the framework

We will use examples from two types of CPRs – summer farms (*fäbodar*) and civic roads (*enskilda vägar*). Both are examples of bottom-up processes where users created local organizations for management of agricultural systems and road transport, respectively. The summer farms did not survive the big change in agriculture practice that occurred from the late nineteenth century through the twentieth century. However, civic roads are still an integral part of the Swedish road network system. The larger question is why one disappeared and the other survived. We will start by examining their local alignment using the eight design principles for successful CPR management.

3.1. Summer farms and civic roads

A summer farm was a periodic settlement for the use of common pastures for grazing and processing milk into non-perishable products. It had buildings for

human accommodation, livestock, and the processing of milk. Summer farms were specialized feminine workplaces and functioned within agriculture, i.e. part of a system of arable farming and animal husbandry. Summer farms, which in Sweden were mostly located in forests, were a means of harnessing the extensive outfields for agricultural purposes and formed a kind of transhumance system. They were classed as Alpine transhumance, distinguished among other things by the livestock being kept inside during winter and by much of the summer's labor being devoted to gathering winter feed. The summer farms system emerged in early modern Sweden and reached momentum in the late seventeenth century when it became compulsory for livestock owners in central and northern Sweden to have summer farms. The main animals held on summer farms up to the second half of the nineteenth century were a mix of cattle, sheep, and goats (Larsson 2009, 2011, 2012).

Civic roads are a unique Swedish road category apart from common/public and private roads. These roads are managed directly by the actual road users living nearby. Road users are organized in local road associations and take full responsibility for building and maintenance of the roads. The laws regulating civic roads and the local road associations today have a direct and unbroken heritage from the way civic roads were managed in medieval villages by the landowning farmers (Blomkvist 2010). During a period of 500 years, civic roads were the responsibility of the village council and the landowners using the road. We call this period the pre-modern road regime. The first explicit law on civic roads, enacted in 1907, moved the power from village councils to new local road associations. Civic road-keeping is still a CPR-managed institution even though the public roads are managed by a national, top-down infrastructure system. We call this period the modern road regime.

Today, civic roads account for more than half of the total length of the Swedish road network and they are managed by 34 000 local road associations. About 24 000 of these associations are partly state funded and therefore obliged to keep their roads open for all traffic. Civic roads carry only 4 percent of the total traffic, but it is estimated that one out of every fourth road journey starts on a civic road. The civic roads can be seen as the smallest arteries in the circulatory system of the road network.

3.2. Local alignment

The civic roads in Sweden and summer farms in the parish of Leksand in Dalarna have been examined in detail to look closely at resource management (Larsson 2009, 2012; Blomkvist 2010). In this section, we focus on local alignment by using the design principles developed by Ostrom (1990, 2005)

3.2.1. Summer farms and local alignment

Principle 1. Until the mid-seventeenth century, there were no clear boundaries between summer farms. From the second half of the seventeenth century to around

1730, the commons were divided among summer farm communities and between summer farm communities and villages. It became important to establish the resource area for each user group. This changed the commons from open access to a common-property regime. The local court confirmed the new boundaries. From then on, both the boundaries of the resources and the individuals with access rights where clearly defined. In the second half of the eighteenth century, it became important to protect the boundaries more efficiently by making them more visible, by charging fines when people outside the summer farm community trespassed with animals, or by putting up fences along the boundaries. The evolution of these boundaries was a bottom-up process and very different from the land consolidation reform that took place in the parish around 1830 (see section 3.3.1).

Principle 2. The appropriation rules were enhanced continually from the time summer farms first appeared until the system collapsed. Two time periods are of special interest: (1) In the mid-seventeenth century, general rules about the days when peasants should move their livestock to and from the summer farms emerged. Enforcement of these rules increased around 1700, when the rules became compulsory. The same rules where used over large areas and were decided by the villages. (2) When the utilization of summer farms increased during the eighteenth and nineteenth centuries, due to increasing population and more animals, new ways to protect and maintain the pasture were needed, and each summer farm started to adopt its own rules. The power to decide which day the animals should be moved seems to have switched from the villages to the summer farm communities. The new rules were generally not coordinated with other summer farms; for example, many summer farms did not have a fixed date for moving animals. Instead, they decided every year which day the peasants had to move the livestock. With increased pressure on the pastures from having more animals, it was important to adjust the timing of grazing to local conditions at each summer farm. Written agreements similar to village by-laws became common, with detailed regulations of the use of the summer farms (e.g. number of animals each peasant could bring and how many hours each peasant had to spend improving the pastures).

Principle 3. As the summer farms became increasingly important to the household economy, starting in the second half of the seventeenth century, an institution evolved to manage them – the summer farm community. Within these institutions, the users could influence decisions concerning their summer farms. A summer farm community could consist of just a few or up to 40 or more households. Large summer farm communities could be divided, often in quarters, and some of the decisions about management could be made in these smaller groups if other members were not affected. More important decisions in the summer farm community, such as proposing fines for rule violations, had to be confirmed by the local court. Groups often published a new regulation by reading it out loud at church. This allowed members who had not attended the rule-making meeting to contest it. Summer farm communities sometimes postponed decisions about how the summer farm should be managed if all members were not present at the meeting.

Principle 4. Users monitored their own resources at summer farms. Monitoring was a by-product of tending the animals in the pastures, and the cost of doing it was thus kept low. During the nineteenth century, when utilization of the pastures increased, monitoring changed. It was still possible for the women who tended the animals to keep a watchful eye for intruders from other summer farm communities, but it became even more important to prevent members of their own summer farm community from overharvesting and neglecting their duties. The summer farm communities started to appoint monitors or directors who were paid by keeping a share of the fines from members who violated the rules.

Principle 5. The summer farm community used sanctions against those who violated their rules. The summer farm communities gradually got more and more power to collect fines and, in the nineteenth century, had detailed rules about how much members had to pay if they violated these rules. It is hard for us today to know if the sanctions were graduated since we have no records from the summer farm communities. The written by-laws for the summer farm communities mention only how large the fine should be for violating the rule. It is likely that they first used more refined ways to make a member aware that he or she was breaking a rule, but we do not know for sure.

Principal 6. There were two arenas for resolution of conflicts related to summer farms – the summer farm community and the local court. Both were low-cost arenas, and the local court was where peasants and their organizations could bring cases and solve problems that were impossible to solve within or among the summer farm community; for example, a dispute regarding the boundary between two summer farms. We can conclude that during the eighteenth century and the first half of the nineteenth century the local courts acted to maintain an agricultural system and facilitate the economic development of the households. The role of summer farm communities in solving problems they faced developed from the late seventeenth century and agreements similar to village by-laws became more common for this purpose.

Principle 7. There are no indications that the Swedish central administration or government had anything to do with the establishment of summer farm communities. The peasants could organize the management of their summer farms based on their own best knowledge.

Principle 8. It is hard to argue that summer farms were nested enterprises in the same sense as many irrigation systems around the world (Ostrom 1992). Some of the big summer farms were divided into sections and these sections were nested within the bigger summer farm community, but there was no overarching organization for summer farms on a local or regional level.

3.2.2. Civic roads and local alignment

Principle 1. A civic road is a CPR in that it has clear physical boundaries that distinguish it from other types of land use. But the boundaries are not easy to enforce. It is difficult to prevent a non-authorized person from entering the road, i.e. to fence the road is not effective or even possible. But during the pre-

modern road regime this was not a big problem. Traffic was mostly local, and the boundaries of the road and the appropriators were easy to identify. Local farmers and landowners used the civic road as a utility in their daily business, and the occasional traveler without formal access rights, usually walking, did little harm to the resource. Traffic demands changed during the modern road regime. Long-distance travel increased, the mechanization of agriculture adopted to meet a more pronounced market economy put heavier demands on the roads, and new groups of users, such as industrialists, began to exploit the roads without paying for their usage. From a CPR-management point of view, all of this created problems in identifying boundaries and individuals with access rights. From around 1850, when this process started, to 1907, the civic roads gradually lost their standing as the power of the village council was eroded. But with the new law of 1907, civic roads regained their former status and Ostrom's first design principle was re-established. During the twentieth century, boundaries and access rights were challenged by mass motorization and changes in housing patterns following urbanization and industrialization. But to this day, the institution of civic road-keeping has managed to respond and safeguard its CPR character, and Principle 1 is still valid as a description of how civic road associations operate.

Principle 2. During the whole history of civic road-keeping, Principle 2 has been strongly upheld. The village councils and later the road associations have always adjusted to local conditions. One example is that the allotment of road maintenance work was based on both actual benefits, i.e. more use because of the size of the farm, and the amount of work needed to take care of the road (grading). Road building and maintenance have always been related to the direct benefit obtained by each and every landowner, and the same goes for the work or capital required from all appropriators. In fact, one of the qualities distinguishing civic roads from public roads is the principle of objective valuation of actual benefits each actor can get from the road and the direct relationship of benefits to inputs required. Today, each member of a road association pays a fee according to actual road use. Public roads did not (and do not) have this direct connection between input and benefits.

Principle 3. In the pre-modern regime, the village and the village council had the power to manage the roads. We do not know the exact decision procedures, but it is fair to assume that every landowner had a vote according to the size of his or her property. The village council, in their yearly meetings, made decisions on allotments and matters concerning the management of roads and other common works, such as crops and time for harvest. Each village had its own by-laws as a basis for decisions. In modern times, the road associations gradually took over and copied the function of the village council, and every member can participate in modifying the rules to meet local conditions, according to each individual allotment and within the rules stated by the prevailing civic road legislation.

Principle 4. The village council and its board had the explicit task of monitoring appropriator behavior and CPR conditions. The chair of the village board, the village eldest, had the power to issue fines if an appropriator did not follow the rules. The fines were divided into three equal shares for the council,

the poor, and the village eldest. In the modern road association, the board, its chair, and members have the same roles. Board members cannot issue fines and put the money in their own pockets, but they can raise the fee each member has to pay if for some reason road use increases or if the member causes damage to the road. It is clear today, and was even more so in historic times, that the most effective monitoring comes from the fact that all members of the road association, the appropriators of the CPR, live near the road. Social control by all members is very important in day-to-day management of civic road institutions.

Principle 5. As touched upon above, the village council and its head, the eldest, could issue fines corresponding to the seriousness of the violations. The same is true in the road associations of the modern regime. But in one aspect the modern road administration has even greater power. If a member refuses to pay the yearly road fee, the board can go directly to the tax reinforcement office, and have them issue an order of payment. Thus, the state has delegated the right of taxing to a private enterprise, the civic road association, an action not common in Swedish state administration. If the member still does not pay the fee, the road association has the right to sell the landowner's property in an "executive auction" to get its money.

Principle 6. As with summer farms, there were two arenas to resolve conflicts in civic road-keeping in the pre-modern regime – the village council and the local court. In the courts, all complaints were treated as civil cases. Today, disputes over allotments, fees, and other subjects are brought to the district court if a road association cannot settle them.

Principle 7. As has been shown, the government support of civic road-keeping has been massive. In a sparsely populated country with long distances between settlements, civic roads were an absolute necessity. The high proportion of small landowning farmers and the low proportion of great estates (a small aristocracy) made the civic roads vital for the whole road transportation system. When the public roads developed into a state-controlled and tightly integrated infrastructure system, civic road-keeping kept the principles of CPR management supported by modernized legislation built on a century-old practice.

Principle 8. As a consequence of the positive attitude from the Swedish government throughout history, civic road-keeping has been more or less organized in multiple layers of nested enterprises. However, there was no actual cooperation or contact between the various local road-keepers, village councils, or road associations until 1949. That year, a national civic road federation (REV) was formed to coordinate local road-keepers and facilitate contacts with the regional and state road administrations (public road-keeping had been nationalized in 1944). REV has about 10 000 member associations, about one-third of the total associations, and is an important partner in all discussions concerning civic road-keeping.

3.2.3. Summary of local alignment

The management and organization of the summer farms was a bottom-up process and was supported by the local court. As exemplified by the material

from Leksand, peasants with summer farms solved the problems they faced, and the management institutions changed over time to solve new problems. By using the design principles, we have shown how summer farm users built a robust governing system at the local level. By the second half of the nineteenth century, the peasants had an adequate organization for management of their CPR and had created a strong common-property regime. The question is why the system started to collapse in the last decades of the nineteenth century when the local organization seemed to be so robust. At the local level, one reason for the collapse could have been that the number of animals each peasant was allowed to bring to the summer farm had decreased during the nineteenth century, thus increasing the transaction costs for the summer farms (Larsson 2009, 2012). But it is more likely that factors outside the local level were behind the rapid abandonment.

Civic road-keeping has been managed by the appropriators for many hundreds of years. Ostrom's design principles fit very well in describing the history of civic roads. There has been pressure on the institutional setup, for example the change of authority from the village council to the modern road association. But the Swedish government has been willing to modify rules and institutional arrangements to keep CPR-managed civic roads as a vital part of the total road transportation network. All in all, the CPR institution has survived.

Both the summer farms and the civic roads could facilitate arenas where appropriators met, discussed, and made decisions, thereby building trust and reciprocity among users so they could sustain collective actions in the face of social dilemmas (Ostrom 2005).

3.3. Sociotechnical alignment

3.3.1. Summer farms and sociotechnical alignment

During the seventeenth and eighteenth centuries, summer farms were part of an agricultural system with good sociotechnical alignment; during the nineteenth century, this alignment became weaker. We discuss sociotechnical alignment of summer farms in relation to property rights, changes in farming practices, mechanization of agriculture, and introduction of the dairy industry. These factors made the summer farms lag behind, making the summer farms reverse salients in the new agricultural system that took shape during the nineteenth century and early twentieth century.

Until the land consolidation reforms, Swedish law (Sveriges Rikes Lag [1780] 1984) protected the right to use the commons for grazing and harvesting timber, firewood, fence wood, leaves, birch bark, etc. for the subsistence of the household. All peasants had the right to extract natural resources from the commons. At the summer farms, the vast forests were usually commons, and to protect a forest from overharvest, peasants divided it into management units as discussed earlier. Before they were divided (section 3.2.1, Principle 1), they were de facto open access. The division transformed them to CPRs where members could develop

institutional mechanisms to address questions of excludability and subtractability. The common-property regime that the summer farm communities developed can be understood as a way to privatize the rights to goods without dividing the goods into pieces (McKean 2000). This type of land tenure was common where the natural resources had certain features; for example, the value of the production per unit was low, the area required for effective production was large, and the labor- and capital-investing groups were large (Netting 1976).

From the 1750s to 1827, three consecutive land consolidation reforms were introduced that transformed the bulk of Sweden's agricultural land, including commons, through 1880. The purpose was to reduce the fragmentation of many village fields and to reduce the vagueness of collective property rights by dividing the commons into private lots (Gadd 2011). When the land consolidation reform in Leksand was complete, around 1830, the former commons they had used as grazing land for their livestock was divided into many small, individually owned pieces. Each piece was too small for grazing. Since the peasants in Leksand were still deeply dependent on animal husbandry and needed summer farms and pastures in the forest, they were given the right to use the forest as pasture the same way they had used it before land consolidation.

In the long run, the main problem with the land consolidation reform for the summer farms was that ownership of the land and the right to use it was divided. As long as all peasants needed summer farms, the system still worked. But when some farmers started to leave the summer farm communities, the farms became weaker and fell apart. Every owner of land had his or her privately owned forest, and at the same time the summer farm communities used this land for grazing and collecting leaves for winter fodder. The clearing of the forest for grazing could come in conflict with logging. As we discuss later, the competition for forest resources increased from the second half of the nineteenth century when timber became a main resource. The result of the land consolidation reform was that the linkages between how the peasants conducted animal husbandry and the legal ownership of land changed. The law had earlier favored the use of outlying land as commons but later stressed the importance of private ownership. With weaker linkages between the local level and the national level, the summer farm became a reverse salient in the agriculture system and was lagging behind.

Agriculture transformed in the second half of the nineteenth century, and the most important changes for summer farms were the introduction of crop rotation and mechanization. The introduction of crop rotation made it possible to graze and grow feed on the same arable land, and forest grazing was phased out (Larsson 2011). The mechanization of agriculture was more favorable for larger farms and farms with arable fields close to the homestead. Most summer farms were part of smallholdings with low incomes and were located in remote areas, so as the agriculture system became more tightly coupled, they could not take advantage of mechanization to the same extent as the larger farms. Following Hughes (1987), the mechanization of agriculture made the summer farms reverse salients in the new system.

The pattern of dairy produce consumption changed under the influence of industrialization and urbanization. The dairy industry that evolved became the antithesis of the summer farm, also making the latter a reverse salient in the new system. When milk came to be processed by dairies, many summer farms were abandoned due to the difficulty of carrying milk along footpaths to passable roads, but also because the demand for summer farm products decreased. A shift also occurred in the economics of the bigger farms, with production of cow's milk growing progressively more important, at the expense of milk from goats and sheep (Larsson 2011).

3.3.2. Civic roads and sociotechnical alignment

During the pre-modern road regime, alignment problems arose gradually as the separation between public and civic roads became more prominent. From the middle of the nineteenth century, civic roads were lagging behind in both a technical and an institutional sense compared to public road-keeping. Reverse salients began to appear in the CPR-LTS constellation more regularly and with greater impact as public roads evolved into a tightly coupled system used for commercial and industrial heavy transport and eventually mass motorization.

First, industrialization and a commercially orientated agriculture put heavier demands on all roads, which affected durability, carrying capacity, and geographical tracing. The state road board and its regional offices met these demands by new road-building technology and organizational innovations for better roads adapted to the new forms of traffic. Business organizations from Swedish industry also joined forces with road engineers to tackle the task of "industrializing" the Swedish road network" and to change the road administration into a "technically rational" bureaucracy, all efforts leading to the "technification" of Swedish road-keeping (Blomkvist 2001). But in this wave of standardization and modernization, the civic roads were left behind. The focus was on the public part of the road network: civic road-keeping had become a reverse salient in itself during the first decades of the twentieth century.

After almost a decade of no action, focus was put on the civic roads to remedy the reverse salient and to create better alignment between the LTS and the CPR parts of the constellation. The 1907 law on civic road-keeping mentioned earlier was a first step. Its most important statue was that not only individual landowners but also commercial interests and industrialists had to contribute to civic road-keeping. Thus all actors using the roads were forced to pay according to usage. At the same time, the state road administration began to take interest in the technical standard of civic roads. They appointed regional road engineers to give advice on pavement, durability issues, and so forth. Altogether it strengthened the linkages between organizations on different levels. In 1918, the government decided to fund civic roads of particular importance for industry and commerce. The road associations managing these roads received cost coverage on some parts of their maintenance if they promised to keep the road open to all traffic. Funding is still an important tool the state uses to convince road associations to cooperate.

In the mid-1930s, however, civic road-keeping was contested, and acute reverse salients began to surface. Private automobiles began to invade the countryside, and civic roads were used for recreational purposes. The civic roads' connection to utility and agriculture weakened. The private car also demanded straighter roads due to its speed. Because of development in the public road system (the LTS), pressure was put on civic roads (the CPRs) to adopt new standards and align with the larger system. In 1939, renewed legislation on civic roads was passed that reinforced the power of the road associations but also required tighter alignment with the state road system. The state road administration got a firmer grip on deciding technical standards, and the surveyor bureau (*lantmäteriet*) was instructed to monitor the road associations and their boards on land permits, accounts, and allotment of road responsibility among members. The linkages between organizations on different levels became stronger.

At the local CPR level, these system changes originating in the LTS created real problems. After World War II, when mass motorization exploded and Swedish people got the appetite for and the means to have recreational homes in the countryside, civic roads were reaching maximum capacity. First, because of the sheer number of cars that deteriorated the road structure, and second, because the new recreational inhabitants were not members of the original road associations and thus used the road without contributing to its sustainability. Civic road-keeping was at the brink of "the tragedy of the commons." In this novel situation, due to changes in the LTS, road-keepers had a hard time upholding Ostrom's principles 1–4 (see section 3.2.2). The solution was a rise in state subsidies and the introduction of better cooperation in road maintenance technology between the state road administration and the road associations through the creation of the regional road offices focused on civic road-keeping. The road associations also obtained a stronger mandate to close down their roads without the risk of losing state funding in case of damage risk to the road. Recreational residents were forced by legislation to join the road associations and take full responsibility. Another institutional arrangement was the government-initiated creation of REV to coordinate and assist local road associations. Increased traffic also put pressure on the civic road-keepers to align with the LTS standard of road signs, traffic rules, and speed limits. When the Swedes changed the driving side of the road from left to right in 1967, the civic roads had to follow suit.

Presently, one of the biggest problems facing civic road-keepers is the reorganization of the state road administration, which happened in 2010. Road, railroad, air, and sea traffic administrations were merged into one gigantic organization – "Traffic Administration" (*Trafikverket*). Even though civic road associations had often complained about poor alignment with the old state road administration, this new reform has added to the difficulties. One stress factor, a reverse salient, is the division of state funding and monitoring of civic road-keeping into seven different bureaus and administrations on state and regional levels within the Traffic Administration. This new organization effectively precludes all efforts to create overview and alignment.

3.3.3. Summary of sociotechnical alignment

During the nineteenth century and the beginning of the twentieth century, summer farms lost their sociotechnical alignment to the agricultural LTS they were part of. When a new agricultural system evolved, summer farms lagged behind and became a reverse salient within the system. Important factors to consider in the new sociotechnical system and the reasons behind the decline of summer farms include changes in property rights, the introduction of crop rotation, mechanization of agriculture, and the introduction of the dairy industry. To solve the problem, peasants could change the summer farms to fit into the new system or abandon them (Hughes 1992). History shows that the peasants chose to do the latter, and the result was a swift decrease of summer farms (Larsson 2009, 2012).

Civic road-keeping faced many obstacles when the public road network changed to a centrally planned infrasystem designed for heavy traffic and the private car. Technical and institutional mismatches were more the rule than the exception. But, in most cases, the road associations kept their influence over civic roads because they were able to adjust to the development in the LTS. All in all, the history of civic road-keeping, especially after 1945, is the story of the regular appearance of reverse salients due to bad alignment in the CPR-LTS constellation. But the principle of CPR-managed road-keeping in the nodes of the LTS has prevailed. Civic roads as a CPR institution have survived because great efforts have been made to resolve reverse salients in the CPR-LTS arrangement. One such effort was improvement in the linkages between different governing levels during the nineteenth century when the civic roads were under stress. The appropriators clearly understand that there is no realistic alternative, and the government knows that it would be impossible to incorporate the civic roads into the public road network. According to experts, the price tag for maintenance of CPR-managed civic roads is only half the cost of maintaining equivalent roads under public management (*SOU* 2001). Civic roads are good business for the Swedish state.

3.4. Contextual alignment

3.4.1. Summer farms and contextual alignment

To fully understand why summer farms disappeared when a new agricultural system evolved, one also needs to consider their contextual alignment. Important changes for the summer farms were the new value placed on forest resources, the importance of roads and trucks, and changes in the textile industry. It is sometimes hard to distinguish sociotechnical alignment from contextual alignment, but the main difference is that changes in the contextual alignment occur outside the CPR-LTS constellation but affect it.

When the agricultural system that the summer farms were part of was in its momentum, there were few contradictions between using the forest for grazing and other uses. For example, killing predators like wolves and bears was encouraged by the law (Sveriges rikes lag [1780] 1984). Charcoal burning and firewood collection improved the pastures. Even though permission was required to use

fire in the forest to improve the pastures or establish a temporal field and the central government tried to limit the use of fire, it was a well-established practice. Peasants had the political position to change the constitutional rules and ease the restriction during the eighteenth century (Kardell et al. 1980; Bäck 1984; Larsson 2009). During the nineteenth century, views of the forests changed and the main resource became timber; use of forests for grazing was viewed as a threat to successful timber management. Legislators, forest industry, national authorities, and agricultural interest organizations shared this view of forest grazing, and in the long run public opinion about the purpose of forests changed. Campaigns and propaganda against forest grazing became intense during the second half of the nineteenth century. However, for many farmers, especially in the northwest parts of Dalarna and Jämtland counties, it was not possible to abandon forest grazing as quickly as the authorities wanted due to lack of arable land in the villages (Larsson 2011). To protect forests from grazing, the Swedish parliament passed a law in 1867 to tighten restrictions on grazing rights for goats and sheep (Hahr 1906). However, large parts of the summer farm area were exempt from the new law, because goats and sheep still played an important role in agriculture and local economies (Larsson 2011). The important point here is that the law viewed goats and sheep as pests, undesirable in timber forests.

The view of forests changed between the eighteenth and twentieth centuries from being an intrinsic part of agriculture to being a natural resource that should be protected from agriculture. At the same time, the introduction of crop rotation made it possible for farmers to abandon forest grazing. When the forests lost their role as important for grazing, the agricultural system of the summer farm area lost its leverage and started to decline (Larsson 2009, 2012). It was not possible for summer farms to assimilate into the new system because they were considered threats to the forests.

Other causes for the decline of summer farms were changes in the textile industry and new clothing habits. There was a steep decline in the demands for products from sheep and goats after 1850. In the textile mills, cotton had become the staple raw material, and much of the wool was being imported, thus the numbers of sheep and goats decreased sharply. Since the increase in goats and sheep had been a reason to establish summer farms in the first place (Larsson 2009), the decrease was a reason to abandon them.

When the public road system developed in Sweden and transportation by truck and cars became more important for the new agricultural system, summer farms lagged behind because they were usually located in remote areas far from roads. However, the expansion of forest roads for harvesting timber in the 1930s delayed the abandonment of summer farms still used by households in some areas (Larsson 2011).

3.4.2. Civic roads and contextual alignment

In this section, we discuss three external processes that influenced and put pressure on civic road-keeping (and the whole road system): land consolidation reforms

already mentioned, the evolution of the railway system starting around 1850, and the present-day example of the expansion of towns into areas originally intended for summer houses. These processes changed the environment for civic road-keeping and created bad contextual alignment that had to be repaired for the CPR-LTS constellation to function properly. Note that the land consolidation reform, for example, was analysed as an internal component of the CPR-LTS constellation (the agricultural system) above. From the civic road point of view, the same process is analysed as being external, part of the constellations environment.

Land consolidation reforms affected civic road-keeping in two distinct ways. First, and most directly, with the division of land into private lots, many civic roads became redundant. Civic roads were most often built on common land and stretched along the borders of fields in the village. When the map changed, some roads ended up on private property. Also, the establishment of new households outside the village centre required new roads to be built. Villages going through land consolidation reforms received assistance from land surveyors in establishing new road maps, and the government issued a regulation stating that all parties of the reform were to pay equally if new roads had to be built. Second, the land consolidation reform affected civic road-keeping in a more diffuse way. In the old property regime, the village council had a powerful position in the management of local roads and other CPR-like arrangements in the village. After the reforms, the village council and the village eldest gradually lost their positions of authority, and the principal oversight of civic roads slowly disappeared. For nearly a decade, farmers appealed to the Parliament, but government was hesitant to do anything to solve the problems of bad alignment. It was not until 1907, when the absence of village councils became apparent due to declining road quality, that legislation finally resolved the bad alignment and institutionalized the local road associations. Then 30 more years passed before a firm grip was taken on civic road-keeping by the law of 1939.

The second factor was the evolution of the railway system starting around 1850 and basically ending in the 1920s. This process had a direct effect on the whole road system, public and civic roads alike. The railway is a more tightly coupled system than the roads. When railroads and roads meet, the railroad takes precedence. Crossings had to be built so the train had the right of way. The railroad system's explicit demands on security and technical standardization had to be met. This was a challenge for the public road administration, and the two "system builders" – the state railroad and road administrations – worked together to solve the alignment problems. But the civic road-keepers were left behind. Local road associations and village councils had no influence when the railroad crossed their roads. They had to adjust and adhere to demands of the stronger, tighter system.

The last example has to do with urbanization in Sweden today. The big cities, especially Stockholm, are growing exponentially, and shortage of accommodation makes former areas of recreational houses attractive for permanent residence. In most of these recreational areas, road-keeping is managed by local road associations. When you buy a house you are forced to join the road association and pay fees,

and when demographics change, the traffic increases. Roads originally built for recreational purposes are now used all year and by more intense, work-related traffic. This leads to higher maintenance costs, including the cost of keeping roads free of snow during winter. But stress is put not only on the physical road structure. Local road associations report difficulties integrating their new members, who are often unaware of the existence of civic roads and the special responsibilities in civic road-keeping. They are used to the same standards, i.e. pavement and lighting, as offered in the public road network managed by municipalities or the state. Furthermore, these new inhabitants, allegedly, are not willing to pitch in and contribute to the road association (Blomkvist 2010). The lack of alignment in this area is discussed extensively within REV, but solutions are hard to find. Perhaps this process will ultimately change civic road-keeping near large cities by incorporating the roads into the public network. If so, civic road-keeping will again become a truly rural phenomenon.

3.4.3. Summary of contextual alignment

Summer farms lost not only their sociotechnical alignment during the decades around 1900. They also lost their contextual alignment. Three examples have been given for how changes outside the summer farms and their agricultural system affected them: changing views of forest use, changes in the textile industry, and changes in the transport sector.

Civic road-keeping and its contextual alignment have been challenged many times. We have given three examples of contextual pressure: land consolidation reforms, the evolution of the railway system, and the trend of new owners living permanently in former recreational houses in what has now become the outskirts of large cities. In the first two, action has been taken to successfully solve the problems and to regain contextual alignment. The third misalignment is not yet solved, and many actors in the road sector argue that this trend is a real threat to the CPR character of civic road-keeping.

3.5. Conclusion: using the framework ex post

Summer farms and civic roads both had deep historical roots as CPRs when big changes in society took place around 1900 and agriculture and roads evolved into new LTSs. Summer farms lost their connection to the agricultural system and were abandoned. Civic roads became an intrinsic part of the new road system. We have shown that it is useful to use our framework to understand the dynamic of CPR-LTS constellations. Local, sociotechnical, and contextual alignments are tools to analyse and categorize historical processes on three different but connected levels.

Important for civic roads was the law that replaced the village council as the governing institution with the road association as a collective-choice arena. With that change, the local alignment for civic roads was improved. But good local alignment was not enough for the functionality of the CPR-LTS constellation. The

Swedish government also took action to improve the sociotechnical and contextual alignment – i.e. by actively incorporating CPR-managed civic road-keeping in the expanding LTS of motor roads and by facilitating contextual alignment of the CPR-LTS constellation.

The opposite occurred for the summer farm. The Swedish government did not change or introduce new constitutional rules to improve the local alignment of summer farms within the new agricultural system. The collective-choice arena, the summer farm communities that had been used before, disappeared. At the sociotechnical and contextual levels, government action made things worse for summer farms. It is easy to see the disappearance of summer farms as inevitable in the industrialized Western society. However, in Switzerland for example the summer farms (*Alpwirtschaft*) had struggled through much of the 1900s but with agriculture policies introduced by the Swiss government, changes in the local governance system, and adaption to the tourist industry they were able to respond to these challenges (Baur and Binder 2011).

The government's lack of incentives to maintain summer farms in Sweden and actions opposing them were not the only reasons they disappeared, but compared to how the government helped civic roads, the difference between the two is very distinct. Two conclusions can be drawn. First it seems that for a successful alignment between CPRs and LTSs, government action and constitutional rules are especially important. Second we argue that all three levels of alignment – local, sociotechnical and contextual – must be taken into account for sustainable management of CPR-LTS constellations.

4. Discussion

We argue that to analyse a CPR-LTS constellation it is important to investigate alignment on three levels: (1) local, (2) sociotechnical, and (3) contextual. First, to get a good local alignment one needs to build trust and reciprocity among members so they can sustain collective action in the face of social dilemmas. One way of building trust and reciprocity is to create arenas where appropriators can meet, discuss, and make decisions – the same way the road associations replaced the old village councils to handle civic roads. A way to examine if a constellation is robust on the local level is to use Ostrom's design principles and the theories behind them. Elinor Ostrom suggested that the design principles can be translated into a series of questions that address the sustainability of a CPR system. For example, "How can we better define the boundaries of this resource, and of the individuals who are using it, so as to make clear who is authorized to harvest and where harvesting is authorized?" (Ostrom 2005, 271). Similar questions have been formulated for the other seven design principles. Second, as we have shown for CPRs that are part of an LTS or other larger system, one also needs to analyse alignment on the sociotechnical level. Thomas P. Hughes (1987, 1992) argues that a mature, large technical system is deeply embedded in society and not easily changed or transformed. Change in such systems occurs with the

appearance of a reverse salient. It is possible to formulate analogous questions to investigate sociotechnical alignment to discover possible reverse salients creating misalignment. Third, to get a CPR-LTS constellation to function properly, one also needs contextual alignment, i.e. what Hughes describes as the relationship between the system and its environment.

Our work indicates that for successful management of a CPR-LTS constellation it is important that the CPR be included in legislation and that government agencies support the CPR in alignment with the LTS. Legislators must recognize the CPR so its institutional body is firmly established in society. In this study, we have mainly used the framework ex post; however, we anticipate that the framework could be a diagnostic tool ex ante for emerging CPR-LTS constellations. In Sweden today, the process of building relatively small wind power plants (CPRs), connected to the nationwide electrical grid (LTS), could surely benefit from better alignment on all three levels – local, sociotechnical, and contextual. At the local level, a windmill affects the living environment for many, but just a few landowners normally gain economically, i.e. externalities (positive and negative) are distributed unevenly. One main obstacle is that if one landowner puts up a power plant it reduces other landowners' ability to exploit their land. Another obstacle is that access roads to the plants often go through adjacent landowners' properties. Together with other problems, the consequence is that it is hard to achieve local alignment for wind power projects in many communities. Sociotechnical aspects are also misaligned: the Swedish electricity system has been designed as a distribution system from the center to the periphery, whereas wind-powered electricity is small scale with decentralized production plants. There are also difficulties in billing due to the contingent nature of the wind as well as the fact that institutions, regulations, organizations, and markets are designed exclusively for a distribution system with large central production plants.

One surprising contextual alignment problem appeared when the communal income tax law from 1928 was "rediscovered" by the tax authorities. It was originally aimed at farmers' private use of surplus goods, e.g. milk, meat, and eggs, and the tax law postulated a stereotyped tribute adding the value of the benefits in kind to yearly income. In 2008, according to the central tax authority, the same rules were to be imposed on wind power. Members of cooperative societies owning shares in a windmill must pay tribute if they are able to produce their own electricity at a lower cost than the market price. The direct result was a 90% decrease in jointly owned windmill projects (Blomkvist and Sandberg 2011). A more in-depth analysis of the CPR-LTS constellation of wind power would give a deeper understanding of the challenges and advantages that CPR-managed windmills face and can provide diagnostic tools to find better alignment.

The three levels of alignment could be described as a framework or a diagnostic approach for how to relate CPRs to an LTS. Without analyses at these three levels, the complex mix of problems of and solutions to connecting a CPR to an LTS will remain unknown. For a scholar or policy maker interested in connecting CPRs and LTSs, it is important to identify problems at all three levels to avoid technical and institutional mismatches. Without analyzing the three levels, only some of the

problems the constellation faces will be known, attempts to solve them will be a patchwork, and the constellation will still be dysfunctional. However, we do not see our framework for analyzing CPRs connected to LTSs as a panacea; it will not solve all problems. This framework identifies on what levels the problems exist. Are they at the local level, the sociotechnical level, or the contextual level? Once this is determined, one often must dig deeper into the problem by using other theories, frameworks, or methods. But, as we have shown in this article, the first step in revealing technical and institutional misalignment is to analyse a CPR-LTS constellation using our framework's three levels.

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