Krigsholm, Pauliina; Riekkinen, Kirsikka; Ståhle, Pirjo

Pathways for a future cadastral system : A socio-technical approach

Published in:
Land Use Policy

DOI:
10.1016/j.landusepol.2020.104504

Published: 01/05/2020

Document Version
Publisher's PDF, also known as Version of record

Land Use Policy 94 (2020) 104504

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Pathways for a future cadastral system: A socio-technical approach

Pauliina Krigsholm[a,b,*], Kirsikka Riekkinen[a,b], Pirjo Ståhle[b]

[a] Finnish Geospatial Research Institute, National Land Survey of Finland, Geodeetinrinne 2, FI-02430 Masala, Finland
[b] Aalto University School of Engineering, Department of Built Environment, P.O. Box 12200, Aalto, Finland

ARTICLE INFO

Keywords:
Land administration
Cadastral systems
Future
Pathways
Socio-technical transitions

ABSTRACT

A vast array of trends and innovations, such as drones and person-to-person trust solutions, have been proposed to revolutionize the task of recording land and property rights. There is, however, a gap in current research regarding how to approach systematically the future(s) of cadastral systems. This paper introduces socio-technical transitions theory and multi-level perspective (MLP) framework in particular as a way to structure potential pathways for cadastral systems. The approach emphasizes the role of institutional rules of the game – the regulative, normative and cognitive institutional elements – in socio-technical transition processes. Using the Finnish cadastral system as a case study, we illustrate the approach by forming three alternative transition pathways: (1) a cadastral system under digital transformation, (2) differentiating urban and rural cadastral systems, and (3) a cadastral system facing new data management challenges. After describing each transition pathway with a narrative storyline, we reflect them in light of previous discourses of the cadastral domain. Thereby, the study provides new insights into discussions about the future of cadastral systems and land administration in general.

1. Introduction

In parts of the world where cadastral systems exist, they are often based on a model of centralized recording of land and property rights, restrictions, and responsibilities (RRRs). The status quo is, however, increasingly challenged both by the academia and industry. For instance, the technological potentials of blockchain technology and volunteered geographic information (VGI) in recording land rights have been under vivid discussion lately (e.g. Anand et al., 2016; Rahmatizadeh et al., 2016). Further, anticipation should not be limited only to new potential technological solutions. Social aspects should be included into the discussion as well: How do changing demographics affect land use, and in turn, land administration operations? What kind of (public) services are expected in the coming decades? When all these questions are asked simultaneously, understanding the associated dynamics becomes a key issue. Hence, we believe, it is meaningful to explore in a more detailed manner alternative future pathways for cadastral systems and try to better understand their connections to the current day.

This study seeks to understand potential future pathways for cadastral systems, and therefore, to help to prepare for the uncertainty related to future. The study is explorative by nature and envisions how the future cadastral system might evolve going forward in time. Thereby we also provide new insights, perspectives and ideas to discussions about the future of cadastral systems and land administration in general. The study focuses on long-term, narrative explorations of futures (i.e. explorative scenarios, see e.g. Börjeson et al. (2006) or Banister and Hickman (2013) for a typology of scenarios). It adapts a 10 to 15-year time horizon to leave enough room for consciously different choices and directions of development. Exploratory scenarios are often constructed within a two by two matrix, where after the recognition of axes the process continues by filling the storylines in each quadrant of the matrix[1] . Critics have argued that these kinds of typical scenario techniques are too simplistic and linear and "lack attention for actors, their decisions, interactions and learning processes, and the way these shape twisting transition paths" (Hofman et al., 2004). To better account for this kind of endogenous dynamics of transitions, the approach taken here is instead based on insights from socio-technical transition theory.

While not much research has been done in this area, we connect to the work by Ottens and Stubkjaer (2008), who have proposed that cadastral systems can be described and analysed as a socio-technical system. They have described cadastral systems followingly: "on the one hand they are technology-based representations of land units, but on

* Corresponding author at: Finnish Geospatial Research Institute, National Land Survey of Finland, Geodeetinrinne 2, FI-02430 Masala, Finland.
E-mail address: pauliina.krigsholm@nls.fi (P. Krigsholm).

[1] This kind of approach for explorative scenario building was recently applied also in the context of land administration by Zetterqvist (2019).

https://doi.org/10.1016/j.landusepol.2020.104504
Received 3 October 2019; Received in revised form 9 December 2019; Accepted 29 January 2020

the other hand they are part of the institutional arrangements relating to land and its functions within the societies they serve". Other authors have also advocated adopting a systemic view in describing and analysing systems of land registration (e.g. Zevenbergen, 2004). Moreover, we find a connection to the work by Ho et al. (2013, 2015) who have explored institutional issues within the land administration sector and especially regarding a 3D cadastre and suggested that institutional elements underpinning the cadastral system might be the key for better understanding cadastral innovation. Most importantly, our study links to future-oriented studies conducted within the cadastral domain (Riekkinen et al., 2016; Krigsholm et al., 2017), as these studies provide a starting point for understanding the driving forces of cadastral systems.

A well-known heuristic approach, the multi-level perspective (MLP) framework[2] (Geels, 2002), is used as a conceptual and theoretical starting point here. In the MLP a socio-technical system consists of three analytical levels: landscape, regime and niche levels (see Fig. 1 in Section 2 for a graphical description of the MLP framework). The landscape level presents the broader political, social and cultural processes of society that are expected to change slowly and outside the control of socio-technical regimes (Smith et al., 2010). The regime level presents the stable and dominant way of realizing the societal function that the particular socio-technical system aims to fulfil (Geels, 2011). The socio-technical regime consists of actors, systems (resources, material aspects) and formal, cognitive, and normative rules (van Bree et al., 2010). These highly institutionalized yet not necessarily coherent rules orient and coordinate the activities of the actors that reproduce the various elements of socio-technical systems (e.g. Fuenfschilling and Truffer, 2014). The niche level completes the framework and its role is to "provide 'protective spaces' for path-breaking, radical alternatives whose performance may not be competitive against the selection environment prevailing in the regime" (Smith et al., 2010).

The MLP posits that regimes are subject to influence by pressures stemming from both the niche and landscape levels. Interactions between the levels may result in a system transition, when transition is defined as a change from one sociotechnical regime to another. The main objective of this study is to illustrate how the MLP heuristic and related concepts can be used as an alternative way to help to understand in which direction the land administration sector and cadastral systems in particular could be heading. By setting up a case study of the Finnish cadastral system – an example of a reliable and well-functioning cadastral system (WB, 2019)– this research answers two questions. First, how is the regime described in the case of the Finnish cadastral system and which niche and landscape level factors are challenging the regime? Second, based on the MLP analyses, what kind of alternative pathways can be recognized for the Finnish cadastral system?

The rest of the paper is structured as follows. Section 2 reviews briefly the theoretical and conceptual grounds. In Section 3 we present the research process, methods used for material collection, and the case study subject. In Section 4 the landscapes and niches of the Finnish cadastral system are reviewed, followed by a description of the Finnish cadastral system regime and a formulation of three alternative pathways for the system in Section 5. Then, in Section 6 we discuss the drafted pathways in comparison to previous cadastral literature. The paper concludes with a summary and proposals for future research.

2. Conceptual and interpretive frame: the multi-level perspective and socio-technical change

This study draws theoretically on the MLP framework (Geels, 2002) around which an extensive branch of research has developed during the past decade or so (Genus and Coles, 2008; Smith et al., 2010). The MLP heuristic (Fig. 1) helps to structure societal dynamics into 'levels' that put pressure on the socio-technical system. The regime level forms the backbone of stability for the socio-technical system through dominant cultures, structures, and practices embodied in both physical and immaterial infrastructures (such as routines, actors, networks, regulations, et cetera). It is often described as 'dynamically stable', referring to the path-dependent yet over time gradually changing nature of the regime (e.g. Genus and Coles, 2008). On the landscape level dominant trends and evolutions that are extremely difficult to deviate from and nearly impossible to change, put external pressure on the system in place. Both slow-changing trends and exogenous shocks like wars and economic crises are considered landscape developments (Geels, 2018). Finally, the niche level describes narrow, protected segments of society where novelties (new technologies, rules, organizational arrangements, or their combinations) are created and tested. These novelties challenge the stabilized way of realizing the societal function, though many of them never break through to the regime.

2.1. The socio-technical regime and the institutional rules of the game

The socio-technical regime – the 'deep structure' that accounts for the stability of an existing socio-technical system - is a key concept in the MLP framework (Fuenfschilling and Truffer, 2014). The regime ultimately determines the pace and direction of transition processes (van Welie et al., 2018). This, as Konrad et al. (2008) propose, makes the regime a particularly appropriate subject to analyse 'co-evolutionary transformation processes'. We also note that both the niche and landscape levels are defined in relation to the regime and can be thus seen as derived concepts in the MLP (Geels, 2011). It has been noted, however, for instance by Fuenfschilling and Truffer (2014) that empirical studies often present the regime as homogenous and coherent, which in the majority of cases does not match reality. To avoid this pitfall, we zoom in on the regime concept next.

The socio-technical regime consists of (1) a network of actors and social groups, (2) rules that coordinate and structure the activities of actors, and (3) material and technical elements (Verbong and Geels, 2007). The rules can be further divided into regulative, normative, and cognitive ones, following the well-known 'Three pillars' framework' of Scott (1995, 2001). In this literature, rules equal institutions in which technologies are embedded (Sutherland et al., 2015). Geels (2004) for instance explains that he prefers to use the word 'rules' to avoid confusion between institutions and (public) organizations. Further, it is good to keep in mind that socio-technical studies mostly borrow the concept of institutions from neo-institutional economics, where institutions consist of formal rules (hard institutions), informal constraints (soft institutions), and their enforcement characteristics (e.g. North, 1990, 1994). Both formal and informal institutions are considered part of the regime.

The MLP literature commonly recognizes five regime dimensions or 'sub-regimes' – technology, science, policy, socio-cultural, and user and market regime – that each have their own set of rules and trajectories for those rules (Geels, 2002, 2004; Ghosh and Schot, 2019). While the sub-regimes have their own dynamics, they also co-evolve together (Geels, 2011). The regulative rules include explicit regulatory processes such as laws, formal rules, policies, and standards. In the case of cadastral systems, formal regulations of technology, technical standards like LADM (ISO 19152, 2012ISO 19152, 2012), and competition rules are examples of regulative elements. The normative pillar comprises rules like values, expectations, norms, responsibilities, and duties. Therefore, normative rules prescribe what is considered as appropriate behaviour, but they are not necessarily formalized in written documents (Raven et al., 2019). Instead, they internalize in the behaviour of actors through social interactions. For instance, expectations of technological development and actors' role perceptions are considered as

[2] MLP studies are part of larger body of socio-technical studies literature that focuses on the joint development of technology and society. Other branches of socio-technical literature include strategic niche management and technological innovation systems.

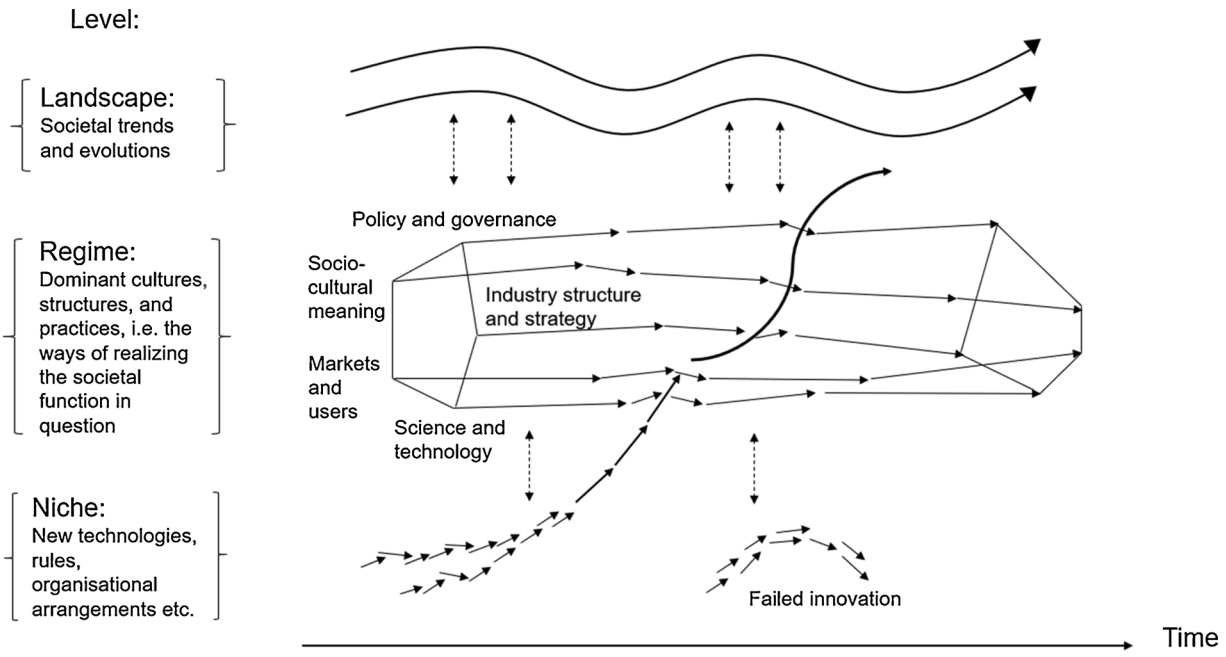

Fig. 1. The multi-level perspective (MLP) framework, following Geels (2002).

normative rules. The cognitive pillar refers to rules like shared conceptions, guiding principles, symbols, and paradigms. Perhaps the most obvious example for cadastral systems is the prevailing 2D paradigm, i.e. that maps, drawings and surveying practices support the 2D representation of cadastral units. The actors might not even be aware of the cultural-cognitive elements, but they are fundamental and constitutive to social life. Though there is no definitive hierarchy for the rule types, regulative rules can be seen as less fundamental than cognitive and normative rules in the context of socio-technical change (Ghosh and Schot, 2019). Further, we note that the rules of the normative and cognitive pillar are not tied to the trajectories of particular sub-regimes but instead often guide the operation of the whole regime.

2.2. Socio-technical change

When shifting the discussion from the MLP framework and related concepts to future socio-technical systems, it is necessary to define first some of the most important terms. As mentioned, in the MLP literature transitions denote shifts from one socio-technical configuration to another over time[3] . Pathways, then, conceptualize the complex processes and patterns involved with transitions (Rosenbloom, 2017). Though the majority of the MLP studies focus on the analysis of historical transitions, the framework has also been applied to the exploration of future transition pathways for domains like electricity (e.g. Elzen et al., 2004; Foxon et al., 2010) and urban mobility (Moradi and Vagnoni, 2018). The theoretical considerations of the forward-looking studies are often formulated in a way that they are in line with elements familiar from foresight and scenario methods, such as uncertainty, surprise, and presentation of alternative futures (Markard et al., 2009).

Foxon et al. (2010) present an approach for outlining transition pathways that is highly cited and indeed a good starting point for building qualitative pathways (Fig. 2). Their approach, in short, builds on three steps: (1) characterization of the existing regime, its internal tensions and landscape pressures on it, (2) identification of dynamic processes at the niche level, and (3) specification of interactions giving rise to or strongly influencing transition pathways. It is also more widely acknowledged that socio-technical storylines should be guided by a logic that draws on socio-technical theories such as the MLP (e.g. Pathways project, 2016). Moreover, there should be an endogenous logic for the transition pathways that is based on the choices, decision, strategies, and beliefs of the actors (ibid). This means that a pathway does not emerge out of the blue – instead, there should be a clear reasoning available to *why* it develops.

Ghosh and Schot (2019) provide a slightly different perspective on socio-technical change and regime change in particular, which builds on the regime dimensions and rules. They note that three types of regime change exists: (1) regime optimization, (2) regime transformation, and (3) regime transition. In all cases regime change starts from within, i.e. a regime becoming less coherent and susceptible to tensions between actors. Regime optimization is characterized by changes in regulative rules within one or two regime dimensions. The latter two, in contrast, depict a deeper impact on the regime, and include changes also in cognitive and normative rules. What should be noted as well is that, by definition, the trajectories of different regime dimensions are aligned and connected with each other under regime transformation and transitions (ibid).

To summarize, we conceptualize the socio-technical change occurring through interactions between the landscape, regime, and relevant niches. The interactions take place between the rules, actors and networks, as well as the technologies of the regime and niches. Opportunities for transition may come either from landscape pressures or new radical innovations breaking through to the regime. The regime must be, however, receptive to change in both cases.

3. Research context and methods

The empirical findings of the paper are based on a case study. In this section the research process and methods used for material collection are explained, followed by characterization of the case study subject, the Finnish cadastral system. It should be emphasized that the findings presented in this study are illustrative and oriented towards presenting narratives of a few possible transitions. Hence, we cannot provide an exhaustive assessment of all imaginable change processes that cadastral systems might face in coming years.

[3] Hence, socio-technical transitions differ profoundly from technological transitions since they include, in addition to technological dimension, changes in user practices and institutional structures (Markard et al., 2012).

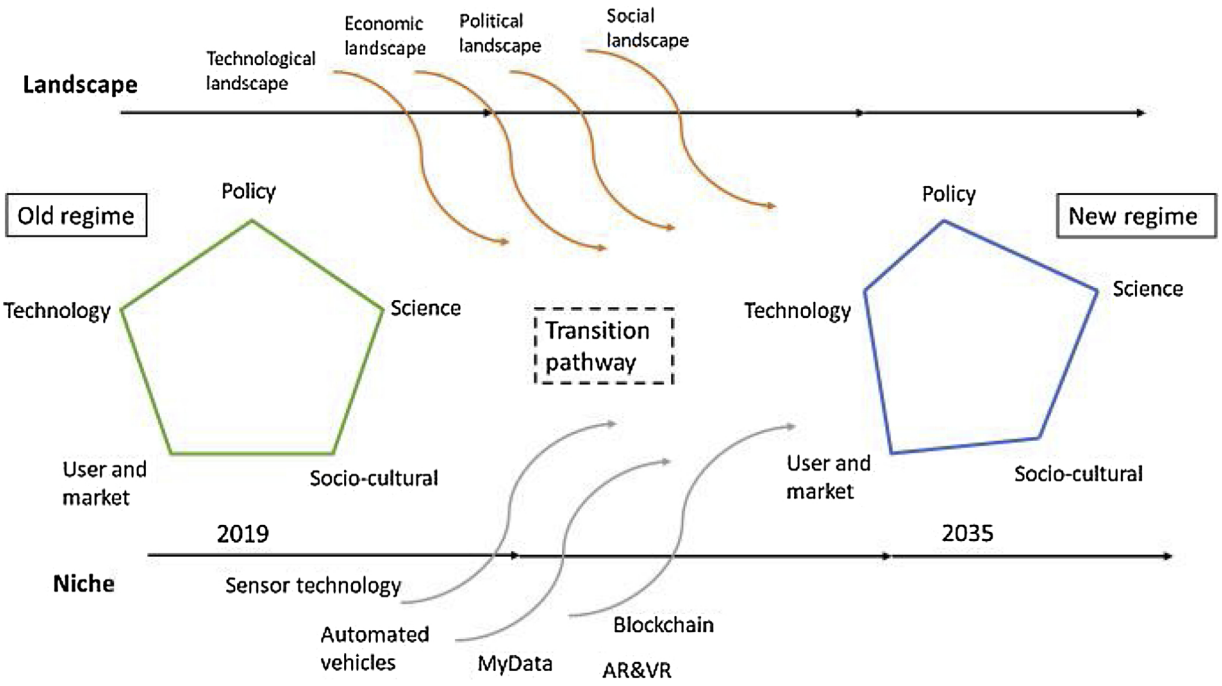

Fig. 2. Transition pathways in the MLP framework illustrated, modified to fit the context of this study, original source Foxon et al. (2010). Note that niche innovations that appear in the Figure present only fraction of the potential innovations.

3.1. Research process

The main objective of the paper is to test how the concepts of MLP framework and socio-technical change can assist in the challenging task of understanding the future(s) of the Finnish cadastral system. To accomplish that, we set up a process consisting of following steps: 1) review of landscape pressures and niche level innovations, 2) characterization of the regime and its dynamics, and 3) formation of alternative pathways (Table 1).

The empirical data is collected through literature (reports, peer-reviewed publications) and two focus group discussions. For identification of 'cadastral system relevant' landscape and niche level factors we rely on literary sources, whereas the focus group discussions were targeted to (1) build understanding of the current cadastral system regime and its dynamics and (2) support the formation of pathway variants (see Table 1 for further details). Following the principles of focus group methodology (Stewart et al., 2007), the group was purposely selected and consisted of four land administration professionals with extensive experience within the domain. It should be stressed that the sampling follows the principle of segmentation that ensures more fluent facilitation of the discussions as the participants share similar features (Morgan, 1996), in this case shared professional background in the field of land administration. One participant has professional background in research and particularly in remote sensing applications, the second one also in research but with specialism in land policies and real estate valuation, the third one in cadastral surveys and in leading the productional processes of the cadastral agency, and the fourth one in governance and land administration jurisprudence. Therefore, the aim was to compensate the rather low number of participants by gathering together professionals with different backgrounds. Since the expertise of recruited participants covered the regime dimensions reasonably well, no additional candidates were contacted. Adding a collaborative element to pathway development was motivated by the premise of building a broader and more integrated perspective of the potential transitions. Before the discussions, the participants were introduced to the basic concepts of the MLP framework and especially the socio-technical regime and its five dimensions. The discussions were recorded as well as documented by writing down the notable aspects brought up during the session. Both sessions lasted approximately three hours.

3.2. The Finnish cadastral system characterized

Like in many western countries, in Finland the cadastral system has evolved from a fiscal to juridical system, and further towards a multipurpose one during the past rough four hundred years. In addition, Finland provides a good example of a country that has a well-established and reliable land administration (WB, 2019).

The current form of cadastral system in Finland can be summarized

Table 1
Research process summarized.

Phase	Method	Main contents	Outputs
Step 1: Landscape and niche level scanning	Literature review	Review of literary sources to conduct lists of relevant landscape pressures and niche innovations	Four landscape developments and twenty-one niche innovations
Step 2: Current regime and its dynamics, factors challenging the regime	Focus group discussion	Discussion on regime dimensions, main drivers and challenges	Cadastral system regime description Key landscape and niche level factors identified Preconditions for alternative pathways formulated
Step 3: Formation of pathways and a round-up	Focus group discussion	Discussion on pathway variants and their plausibility, complementing and finalizing pathways	Three alternative pathways for the Finnish cadastral system

as follows: public authorities (NLS and municipalities) maintain comprehensive registers (cadastre and land register) as well as the cadastral map and perform the cadastral surveys. Hence the Finnish system follows the German type of cadastral system, where the land register and cadastre are closely connected. Real property rights are allocated into either the cadastre or the land register component[4] . The land register enjoys full positive and negative faith and credit. The cadastre, in contrast, does not have the same level of faith and credit due to known shortcomings, e.g. unreliable accuracy of boundary marks and differences in practices of registering rights of use, easements and restrictions. Land parcel is the basic spatial unit (a real property unit can consist of several parcels) of the Finnish cadastral system, and built properties are currently not listed in the cadastre. In this study cadastral surveys are considered a part of the cadastral system as well. Subdivision is by far the most common cadastral survey procedure in Finland. Some 12 408 subdivisions were carried out in year 2018 and the average duration was 0,41 years (NLS, 2018). The Finnish land information system (FLIS) is the main deliverable of the above registers. FLIS information is used for instance to support land use planning, exchange of real properties and several type of juridical decisions (Krigsholm et al., 2018).

4. Landscapes and niches of the Finnish cadastral system

In this Section we review the landscape and niche levels of the Finnish cadastral system. Considering the future-oriented perspective taken in the study, it is reasonable to utilize recent megatrend studies and reports for the identification of land administration relevant landscape developments. Krigsholm et al. (2017) have studied megatrends in the context of the Finnish cadastral system (original source of megatrends Z punkt, 2016). According to the definition of a megatrend (Mittelstaedt et al., 2014), each respective megatrend should appear as long-standing and influential as observed today. Hence, even though we cannot state future landscape developments with absolute certainty, using widely recognized trends that previous evidence supports as particularly relevant for cadastral systems seems like a justified approach here. To reduce the complexity of study in Section 5, we compress the eight megatrends that are considered to be of key importance for the Finnish cadastral system (Krigsholm et al., 2017) under four landscape developments: (1) technological landscape, (2) economic landscape, (3) political landscape, and (4) social landscape (see Table 3). To validate the relevance of the aforementioned megatrends, we go through recent grey literature on trends and megatrends (e.g. EY, 2018; EEA, 2015; KPMG, 2014) and list the supporting sources in Table 2 as well.

To describe promising niche innovations is a greater challenge. A large variety of alternatives is developed simultaneously and each of them provides some sort of promise to break into the regime level, but it is impossible to predict upfront which alternatives work in practice. Nevertheless, some sort of selection mechanism is needed for choosing the most potential niche innovations. Since the geographical focus of the study is in Finland, we use publications of the Committee for the Future of the Finnish Parliament that focus on foresight and especially on technology anticipation (TuVJ, 2014, 2016, 2018). These reports have been conducted by futures studies professionals and they reflect the expectations of a large pool of experts and therefore summarize a broad view of future technologies and innovations and their anticipated impacts on the society. For the purpose of our study, however, a list of hundred innovations is too long. Thus, we need some criteria to cut down the list. The reports are structured under 20 value-producing networks, and we looked for value-producing networks that share some similarities with the land administration sector. Particularly, similarities in industry characteristics (e.g. the level of regulation, type of services provided), in nature of work (e.g. the average level of required expertise), and in societal impact of the value-producing network were looked for, and as a result, we focused on innovations that were listed under the following value-producing networks: (1) Work and earnings, (2) Built environment, (3) Exchange, (4) Observations and knowledge, (5) Safety, (6) Power structures, (7) Ability to co-operate, and (8) Know-how and its demonstration.

A second criteria used here is the so-called ‘general impact’ score calculated in TuVJ (2018) that aims to condense the expected breadth and extent of impact for each innovation. We include only innovations that receive the highest or second highest score (on a scale 1–4). Using these criteria, a list of nineteen niche-level innovations was compiled (Appendix). The list includes many innovations and technologies familiar in cadastral discourse, like quadcopters and drones, sensor technologies, virtual and augmented reality, and person-to-person trust solutions, but also some more surprising innovations such as gamification of collaboration and society.

5. Towards transition pathways for the Finnish cadastral system

This section presents the findings of focus group meetings. In the first focus group meeting, outputs of the landscape and niche level scanning phase were used as a source material. First, all five regime dimensions were discussed, and their key characteristics were identified (Section 5.1.). Simultaneously, the linkages between dimensions were discussed. The main goal of the first focus group session was to (1) identify the key drivers at both landscape and niche level, and (2) collect their potential impacts across the regime dimensions. These results are reported in Section 5.2. At the end of the session, the preconditions for alternative pathways for the Finnish cadastral system were determined, i.e. the focus group participants decided which landscape and niche developments were considered as main drivers for the pathway variants.

In the second meeting the focus was on the formation of pathway variants. Based on the findings of the first focus group meeting, initial drafts of the pathways were formulated before the session. The drafts acted as guidelines for the discussion, and the focus was on enriching and complementing the alternatives. Hence, the pathway narratives are results of group discussions, not participants’ or researchers’ individual perceptions. The goal was that, by the end of the second session, three alternative pathways with logical and coherent storylines were drafted that all participants agreed upon. The pathway variants are described in Section 5.3.

5.1. The current regime and its dynamics

The focus group discussions indicated that in the case of the Finnish cadastral system it is more reasonable to handle technology and science as a one instead of two separate regimes. Characteristic for the science and technology regime (hereafter ST regime) is to create new knowledge and research used to develop and justify technological decisions. In particular, it is crucial that these decisions enable the realization of quality requirements coming from the user and market regime. Further, the (dis)proportionality between technology-oriented studies and legal or social-oriented cadastral system studies were brought up in the discussion. The ST regime and policy regime have a prevailing connection as policy directions can either hinder or advance the deployment of new practices developed within the ST regime. For instance, in Finland geoinformatics – both research on geoinformatics and practical applications – has been heavily on the policy agenda during recent years (MMM, 2018). This is just one example of a policy goal arching the two regimes. The policy regime also produces the formal regulations (laws,

[4] Using the legal cadastral domain model classification of rights and restrictions regulating the ownership of real property (Paasch, 2012), other than person-to-property rights are registered in the cadastre, whilst person-to-property rights are registered either in the cadastre or the land register (Niukkanen, 2014).

Table 2
Landscape developments and their origins explained.

Name	Megatrend	Supporting sources	Summary
Technological landscape	Digital culture	Sitra, 2016	A new generation of digital natives as well as new forms of social communication, participation and organization emerge. In parallel differentiation in digital lifestyles grows. Technology stretches to every aspect of life, as we witness for example transition towards cloud-based IT, new interfaces and intelligent environments, emergence of the Internet of Things, artificial intelligence solutions, and P2P-trust solutions.
	Ubiquitous intelligence	Sitra, 2016; KPMG, 2014; PWC, 2016; EEA, 2015	
Economic landscape	Knowledge-based economy	KPMG, 2014	Higher level of education globally, innovations as a key driver and competition factor, data and knowledge-based value creation, and lifelong learning form the core of knowledge-based economy. New value-chain partnerships and platforms become more common. In a complex and networked world system innovations, management of complexities and shared values grow in importance.
	Business ecosystems	EY, 2018	
Political landscape	Increasing trend towards transparency, accessibility, and open data	KPMG, 2014	Citizens expect increasing transparency and accessibility from authorities, but simultaneously the lack of trust towards them grows. Global risks like growing vulnerability of technical and social infrastructures worry people, as do global organized crime and cybercrime, as well as monitoring of actions. Risk of asymmetric conflicts grows.
	Global risk society	KPMG, 2014; PWC, 2016	
Social landscape	New patterns of mobility	EEA, 2015	Global mobility (incl. mobility of human population) increases, and different modes of transportation become frequent. Automated vehicles enter transport. Urbanization and the growth of populations centres continues. Simultaneously rural areas face structural problems (declining population etc.). Customized infrastructure solutions and sustainable city development evolve. New forms of living and property ownership are witnessed.
	Urbanization	EY, 2018; KPMG, 2014; PWC, 2016; EEA, 2015	

decrees), and this function makes it connected to all other sub-regimes. It should be noted, however, that in the case of the Finnish cadastral system the formal regulations control only the content of the cadastre and land registry, not the technological solutions.

The socio-cultural regime (SC regime) lays the ultimate foundation for the cadastral system: rules such as acceptance and reliability of cadastral information, and perceptions of land and land ownership in the society have an impact on the willingness to invest in land and property. Hence, the rules of the SC regime contribute to the prosperity of the whole economy and make it less prone to frictions. Moreover, the taxation of land and property and perceptions related to it are considered a feature of the SC regime. Regarding the user and market regime (UM regime), the question of what the market in the case of the Finnish cadastral system in the first place is, was discussed. The discussion did not lead to an unambiguous definition for the market of the Finnish cadastral system, but it should be clarified that in the rest of the paper the market is understood as any structure where the exchange of goods or services is somehow connected to cadastral information. Therefore, in addition to real estate transactions for instance many public services such as land use planning or environmental protection are part of the market. We can say with certainty, however, that the high volume of the Finnish real estate and property market (9,3 bn euros in total in 2018 according to KTI, 2019) translates to high expectations about the quality and reliability of information and the convenience of services in land administration. What comes to connections to other sub-regimes, there is the already mentioned linkage to the policy regime and the formal regulations enacted within it. In addition, the focus group participants highlighted the connection to the SC regime, as rules like perceptions of what 'the market' wants ultimately depend on society-level values and developments.

Overall the policy, the SC, and the UM regime were considered the 'key' regime dimensions in the case of the Finnish cadastral system. This standpoint is based on an outlook that science and technology are seen more as supporting and enabling dimensions in the case of the cadastral system, whereas the real urge for the existence of such system stems from the society.

5.2. Characterization of drivers and barriers at landscape, regime, and niche levels

Next, we are particularly keen on understanding the potential changes taking place along the regime dimensions. Leaning against the MLP framework the focus group considered how the landscape developments (Section 5.2.1.) and new radical innovations from the niche level (Section 5.2.2.) challenge the current regime, to gain more understanding of what the most significant drivers and barriers for the potential transitions are.

5.2.1. Landscape-regime anticipation

First the potential changes to regime dimensions deriving from the relevant landscape developments (Table 2) were considered. Table 3 lists the potential changes identified during the focus group discussion and denotes the related regime dimension with a letter or a letter combination. The role of the third column in Table 3 is to demonstrate how widely the potential implications affect the regime.

The pressure from the technological landscape was assumed to lead to multiple changes. First, stricter requirements for quality and accuracy of information were supposed. Although the Finnish cadastral system performs well in international comparison in this respect, for instance the forest sector already in present day would benefit from reliable, higher accuracy information of the property division. Related to new frontiers created by technological development, a coordinate-based cadastre challenging a boundary-marked cadastre paradigm was seen as a potential change. A more digitalized environment could lead to an emergence of new service chains and a more networked register authority. In addition, mobile services being preferred over electronic services and the end of traditional transaction services were considered changes affecting user practices and preferences. Finally, a requirement of automated upkeep of registers was seen as a likely new policy goal.

Economic landscape developments and their potential impacts were considered a more difficult subject of speculation. Just two potential shifts were brought up, though both could induce grand implications to the cadastral system regime. First, the emergence of a new ecosystem type of thinking was seen as a possible outcome, though the conservativeness of actors causes some uncertainty on the scope and pace of this change. Furthermore, the focus group emphasized that the emergence of business or service ecosystems is linked to technological development as well, even though here they are categorized under the economic landscape. Second, one very likely development related to the management of complexities in the context of cadastral systems is the increasing complexity of commodities market. This would imply that real estate transactions turn into asset transactions or something similar. It should be noted, however, that the Finnish real estate market is polarized (e.g. BoF, 2018), and the new transaction types are likely to

Table 3
Landscape-regime anticipation summarized. ST = Science and technology regime, P = Policy regime, SC = socio-cultural regime, UM = user and market regime.

Landscape development	Potential implications	Related regime dimensions
Technological landscape	Strict requirements for quality and accuracy of information;	ST
	Mobile services preferred over electronic services;	UM
	Boundary-marked cadastre paradigm challenged;	SC, ST
	Traditional transaction 'services' challenged;	UM
	New service chains and more networked register authority;	SC
	Automated upkeep of registers	P
Economic landscape	Emergence of ecosystem type of thinking;	UM, P
	Real estate transactions turn into asset transactions	SC, UM
Political landscape	Technical protection mechanisms: the information needs to remain unchanged;	ST
	Role of cybersecurity must be emphasized;	ST, P
	Increased requirements for both openness and personal data protection;	P
	Government must adapt the role of service provider	P
Social landscape	Increasing popularity of new forms of land and property ownership;	SC
	Higher responsibility of the legality of official actions;	P
	'Professionals' as customers;	UM
	Register keeping concentrated to a government authority	P

develop at those areas where the real estate is valuable.

The pressure from the political landscape was thought to have implications especially on data protection. The participants anticipated that new technical protection mechanisms are needed to secure that the information in registers remains unchanged. Continuing with the security issue, the role of cybersecurity must be acknowledged to be much stronger in the future – considering that the cadastre data in Finland is already digital apart from historical records. The increasing – yet somewhat contradictory – requirements of both higher open data access and personal data protection are changes already taking place in the context of land administration. Their impact and importance are expected to increase in the future. Moreover, there was a consensus among the group that the government needs to adapt the role of service provider, i.e. learn to act in a more agile and customer-friendly manner.

Social landscape discussions mainly focused on the urbanization-led changes to the regime. The share of urban population is growing in Finland (OSF, 2019a), and if this trend continues during next decades, it is apparent that real property owners (i.e. owners of land used in agriculture of forestry, or other type of inherited property) will live in the city as well, thus managing their property from distance Longer distances to owned property could mean looser emotional ties to land, which could lead to lesser active management interests and increasing popularity of new forms of land ownership such as jointly owned forests and real estate investment funds. This in turn would mean that users of cadastral information are more often professionals in the field of real estate rather than individual landowners. This would have twofold implications. First, with the changing customer type also the requirements of customer service would change, and second, the responsibility of an official for the legality of his actions is emphasized as the owner no longer has contact to the cadastral system and the authority. Finally, the current predicted demographic changes in Finland indicate a drastic decrease of working age population. Hence it is reasonable to ask, whether the economic rationalization objectives will force the municipalities to cut out operations like keeping of a cadastre. If that is the case, it is likely that the register keeping duties concentrate to a government authority.

5.2.2. Niche-regime anticipation

We complement the above discussion by considering a group of niche innovations relevant for the Finnish cadastral system. From the anticipation point of view, the relevant questions related to niche-regime interaction are: Which innovations show most potential to disrupt the regime? And more importantly, what will they do to the regime? A list of nineteen niche innovations (Appendix) was presented to the focus group. First each participant was asked to individually pick the five most influential innovations, after which those innovations that were mentioned at least twice were discussed more closely as a group. The following six innovations were selected by more than one expert but were also collectively agreed upon before the discussion on niche-regime anticipation was opened: MyData and GDPR, quadcopters and drones, augmented reality and virtual reality, P2P-trust solutions, encrypted and anonymous communications, and imaging and positioning through sensor technologies.

There was a strong consensus among the participants that four out of six innovations; quadcopters and drones, augmented and virtual reality, P2P-trust solutions, and imaging and positioning through sensor technologies were seen primarily as enabling innovations or technologies. For instance, quadcopters and drones were seen as a means to provide reliable information cost-efficiently – limiting the impacts to regulatory and normative rules of the regime. The impact of P2P-trust solutions (including blockchain technology), was considered to be limited only to transactions, not to the cadastral system as whole. Augmented and virtual reality and imaging and positioning through sensor technologies, respectively, were accounted as probable technologies to break through to the regime level, but they will likely contribute to regime optimization rather than transformation or transition. Overall, the focus group participants strongly emphasized that the above innovations may provide possibilities to new services as well as to new ways of organizing production processes. They were seen, however, as means to enhance the current processes rather than as factors that have the potential to shift the whole course of the Finnish cadastral system.

The remaining two innovations, MyData and GDPR, and encrypted and anonymous communications, generated a different kind of speculation among the focus group. Their potential impacts to the Finnish cadastral system were considered as more profound. MyData and GDPR, in particular, was rated as a potential re-former of the underlying normative and cognitive rules of the cadastral system regime. The central notions of this innovation, a right to be forgotten and a right to control personal information to be stored (more about MyData: LVM, 2018), bring up many interesting aspects to speculate. As stated above in the discussion about the political landscape, already now it is evident that growing calls for open (government) data and personal data protection on the other hand create contradictions. The MyData concept as a human-centric approach to the managing and processing of personal information takes this development much further and makes the current logic of personal information management of public register authorities no longer functioning. Encrypted and anonymous communications could, in an extreme case, shake the very core of a cadastral system and make its reliability and credibility questionable. The core issue is the safety of the system as weaker telecommunications imply more hacking attempts.

Table 4
Pathway characteristics summarized.

Pathway aspect:	Pathway 1: Cadastral system under digital transformation	Pathway 2: Differentiating urban and rural cadastral system	Pathway 3: Cadastral system facing new data management challenges
Key changes	A shift towards (digital) service ecosystem; Automation of decision-making and cadastral survey proceedings;	Asymmetrical development of urban and rural cadastral systems; Adaption to new forms of land tenure	Increasing importance of cross-national regulation; Cross-national back-up mechanism; Users with stronger control (or interest of having control) over their own data
Key concepts	E-government and integration; cloud services; AI and smart contracts; networks and business ecosystems	Urban-rural dichotomy (for instance position accuracy requirements); 3D/4D cadastre; smart cities	International co-operation and coordination; Safety and data management
Actors	Incumbent regime actors, possible new entrants but also exits when ecosystems start forming (hard to pinpoint more exactly)	Regime actors concentrate in (a few) urban areas; Customer base becomes more professional;	Incumbent actors and some new ones: Safety producing actors (e.g. cyberthreat experts); MyData experts; International actors
Examples of design and operation aspects	Controlling increasing diversity; Reliability of technical solutions; Knowledge of networks and business ecosystems needed; Maintenance (of the system) in a key role	Targeting resources to areas where they are needed; Responding to increasing complexity; Responding to interoperability requirements (with e.g. BIM models)	Decentralized solutions; Increasing maintenance costs
Key challenges	Understanding the effects of digitalization on all processes; Policymakers in a key role in recognizing relevant niche innovations; Traditions and other lock-ins; System resistance and maintenance of trust; Finding a shared vision within/for the network	Increasing complexity and volume of RRR's (in urban areas); Anticipating the pace and scope of changing customer base; Dependence on political decision-making (regional politics etc.); Integrating properties and buildings as part of the cadastral system	Risk management; Controlling the controversy between openness and personal data management; Lack of expert knowledge; Communications during crisis; Widespread effects in an increasingly networked environment

5.3. Transition pathways for the Finnish cadastral system

Next, storylines for three transition pathways for the Finnish cadastral system in light of the priorities and challenges identified above are developed. The presented storylines are an outcome of focus group discussions and following aspects were considered for each pathway: (1) What are the key changes overall? (2) Which concepts relate to these changes? (3) Who are the key actors, and what are their roles and interactions? (4) What are the major implications to the design and operation of the Finnish cadastral system? and (5) What are the key challenges to the realization of the pathway? The aspects stem from the theoretical background and their main role is to assist in structuring the storyline and to ease the comparison of pathways. Each pathway is presented in a narrative form and Table 4 sums up the key aspects of the three alternatives. It should be stressed that the goal here is to explore developments, not to state the course of the future or to make predictions based on past evidence.

Pathway 1: Cadastral system under digital transformation

The first pathway variant develops under a strong pressure from the technological landscape and digitalization in particular. Some substantial steps towards a more digital and automated cadastral system have been already taken in Finland. For instance, the purchase of real estate can be done electronically, and the process for a registration of title to a property starts automatically after a property is transferred from one owner to the next. Eyeing forward in time, this kind of development is expected to increase incrementally further – and to extend to a full automation of (at least the relatively simple) cadastral survey proceedings. In addition, the pathway envisions a shift towards the management of a wider digital ecosystem where the governmental authority produces and stores the cadastral data, on top of which (private) service providers create different kind of services. This kind of shift to an ecosystem type of thinking requires that all current actors first of all consider what is their own role as part of the platform and put the functioning of the whole 'entity' before optimizing their own processes. It is crucial that also the service providers see the benefits of investing in the digital platform, as the goal is to find a workable funding mechanism.

Defining the actors and their roles in the ecosystem up front is challenging and requires new openings in public-private interface. In the focus group discussions, the general view was that some new entrants like service providers may emerge, but on the other hand some others may exit the regime. Considering the design and operation of a cadastral system, more attention to management of diversity is needed – after all, the main feature of this vision is the shift to a substantially more networked environment. Also, the reliability of the technical solutions will face higher requirements. Before any drastic reconfigurations can be made, some extensive knowledge on networks and the new business ecosystem environment is needed. This could imply for instance a full account of the economic and technical requirements of the digital service ecosystem. Finally, compared to the current situation, more resources need to be directed to the upkeep of the system.

The greatest challenge related to the above described shift to a new era of closer networks and business ecosystems must be to overcome the actors' perceptions of their own roles and a need to hold on to traditions and established practices. This kind of 'system resistance' might be difficult to overcome. Another challenge, considering this is the most technologically-oriented variant of the pathways, might be recognizing the relevant niche innovations from a large pool of emerging innovations. Even currently we can list a plethora of innovations, starting from virtual and augmented reality that could potentially enhance the digital transformation of cadastral systems. Further, in the discussions it was stressed how the challenge lies in recognizing the effects of digitalization in all processes, not just on the obvious ones like optimizing the workflow or digitizing the old archives.

Pathway 2: Differentiating urban and rural cadastral system

The second pathway originates from more comprehensive changes in social structures and development. In the discussions, it was expected that an increasing share of the population concentrates in a few larger cities, which would denote an increasing intensity of land use for these areas. This, in turn, denotes a diverging development of property prices, i.e. decreasing or even negative property values in remote locations and rising values in those where people accumulate (this kind of price development is already evident in Finland, OSF, 2019b), as well as an emergence of new more complex land and property interests (RRR's) to record in urban areas. Due to the increasing complexity, data models of land administration need to be updated as well. As sort of a branching point for this pathway we assume that the described divergence leads to dual development for the cadastral system as well. For urban areas, more accurate position information is produced and also the available information content is wider to answer the needs of more intense land use. For rural areas, where lower financial interests fall upon the land and property, the accuracy and 'breadth-of-content' requirements are not on the same level.

Besides the urbanization development, this pathway connects to a

call for more efficient use of public finances, which seems inevitable considering the ageing population and declining number of taxpayers. Hence, this vision demands some recasting of financial and human resources. They need to be targeted to the areas where the cadastral information is most valuable. It should be noted, however, that the objective is not to diminish the level of services for any areas – rather to be more cautious about the sufficient efficiency of the use of resources. Considering these changes together, it seems apparent that also the customer base will look different compared to the current day. It is anticipated here that the percentage of so-called professional customers will increase as more of the owners or right holders will either live far away from their holdings or for other reasons choose a jointly owned forest or similar as the form of ownership. Overall, the 'connectivity' to land and owned property is assumed to decrease.

Responding to increasing complexity is the key task for design and operation: in addition to data models that are able to handle the complexity of RRR's, also the interoperability with BIM and other models used in sectors intersecting with land administration should be acknowledged. A more specific issue related to the Finnish case is the manner of integrating properties and buildings as part of the cadastral system as currently this information is collected and maintained by a different authority. Challenges include, besides the complexity and its management, anticipating how fast and broadly the land ownership norms change. Presumably it takes some time before new forms of tenure become more common, and the 'professionalization' of the customer base sets out. High dependence on political decision-making is, still, probably the biggest a challenge/uncertainty: regional politics and the political atmosphere in general have a strong control over the reallocation of resources – which is in a major role in this pathway.

Pathway 3: Cadastral system facing new data management challenges

The rationale behind this vision is that the current rules of data management hold no longer in the future. They are challenged both by the increasing threat of cyberattacks, and citizens' increasing interest of having control over their own data, manifested by the MyData movement. These developments have apparent impacts on the cadastral system, since information management is one of the main functions of land administration (Dale and McLaughlin, 1999). The key changes in this pathway are the increasing importance of cross-national co-operation and responding to the growing importance of personal data management. Co-operation presents itself in the form of European Union level regulation as well as creation of a safety backup mechanism. Hence, this vision presents that the conception of cadastral systems as national registers changes. Also, the perception of customers as users of pre-defined services and applications alters if individual empowerment, one of the MyData principles, is realized.

The central issue in this pathway is to find options for administering data in a way which maintains the security of cadastral information and thereby, the trust of the public. MyData and GDPR principles such as individual empowerment, portability (access and re-use), transparency and accountability, and interoperability of personal data – and the accessibility of these principles – admittedly need to be considered as part of data administration as well. For instance, in TuVJ (2018) it has been noted that GDPR hampers the organization of individual level safety but, on the other hand, protects individual's information. Like said, the focus group participants envisioned that maintaining the overall safety of the cadastral information could materialize by increasing international co-operation and coordination by creating a continent-level backing up mechanism. Here the backing up mechanism denotes a system that includes the base registers of European countries.

Creating a cross-national system naturally introduces new international actors. In addition, new safety producing actors enter the regime to secure safety. It is also possible that due to high safety requirements the number authorities decreases. In addition, professionals that increase knowledge and models of human-centred personal data management are needed. For operations and infrastructure this pathway suggests the introduction of decentralized solutions as a means to accomplish for instance the goal of transparency. Decentralized solutions provided for example by blockchain technology also reduce the risk of human errors, and hence provide a potential solution to the requirement of information stability mentioned in Section 5.2.1. Maintenance costs are expected to increase due to the new back-up mechanism.

In recent years one of the most dominant forces in land administration has been the opening of data archives and sharing data. The key challenge is how to balance the controversy of calls for increasing openness and data sharing and increasing sensitivity of personal data management. Risk management should be considered as a challenge as well since if to be realized, the consequences of a (global) cyberattack could be large-scale. Further, lack of expert knowledge regarding safety and cyberthreats is a likely challenge. More attention should be paid to communication during crisis to manage avoiding reputation harms that could lead to decreasing 'trustworthiness'. A final challenge is to control the spreading of the effects of cybersecurity attacks if they materialize – in an increasingly networked environment the chain of consequences can become considerable.

6. Discussion

Next, mainly the following two questions are discussed: How well did the MLP framework structure our forward-looking analysis, and, what are the differences and similarities of the outlined pathways in comparison to previous cadastral literature? The limitations of the study are addressed in Section 6.2.

6.1. Insights on the findings

Cadastral visions and scenarios often focus on certain technologies and their impacts on a narrow aspect such as cadastral survey proceedings, data models and database structures, or legislation. Although these kinds of images of the future are valuable as they help us clearly picture what the future might hold, our findings indicate that very few niche innovations might have the potential to change the rules of several or all regime dimensions, which would denote that relying on a limited number of innovations or technologies as a source of transformative change is not a very fruitful starting point.

Hence, in this paper we argue that more nuanced ways of understanding and analysing potential changes of cadastral systems are needed. Through interpreting the pathways in terms of the MLP approach we identified a variety of societal dynamics and challenges that are usually excluded from publications concerning the future of cadastral systems. First, even though many studies stress how continuing urbanization intensifies land use in urban areas and therefore creates more demand for creation and registration of 3D RRR's (see e.g. Atazadeh et al., 2017; Paulsson and Paasch, 2013), few – if none – studies have speculated on the wider effects of demographic changes on cadastral systems up to the degree this study does. In particular, the suggestion of differentiating urban and rural cadastral systems have been rarely brought up. In Finland in recent history the direction has been in fact the opposite, as the regulation regarding the keeping of a cadastre in urban and rural areas was harmonized in 1985 (Lappalainen, 2002). Second, to best of our knowledge, none of the previous studies has brought up the question of how cyberattacks and new directions in personal data management challenge the functioning of cadastral systems. Also related to the third pathway, the (very broad and general) solutions presented here are new to the discussion: In Europe continent-level collaboration has thus far focused on the exchange of knowledge and practices between the actors, and the common back-up system proposed would take the co-operation to a completely new level. Third, one distinct dissimilarity is the lack of emphasis given on volunteered geographic information in the pathways. Perhaps this relates to the fact that the cadastre covers the whole country in Finland, even though some known inaccuracies for instance

in the location information exists. Therefore, improving the quality of register data with the current available technology is not seen as a priority in the coming decades since the focus lies in the complexity of possible emerging use right solutions. Further, it could be argued that the automation development described in the first pathway extends also to the collection of cadastral information, making the volunteered data collection less indispensable in the long run.

Many similarities with previous studies can also be detected. Calls for more networked register authorities and reasonably organized spatial data infrastructures (SDI)[5] with shared values have been raised many times before (e.g. Macharis and Crompvoets, 2014; Crompvoets et al., 2004; Enemark et al., 2005). The platform management concept in case of spatial data is, however, a less examined topic (Jabbour et al., 2019). We discuss the concept of a land administration service ecosystem in a vague manner here but note that the business logic and the roles in the system are difficult determine up front. We do, still, essentially talk about a transition to a sustainable funding mechanism as do Jabbour et al. (2019) in their work. In addition, several authors have brought up the need to find new tools to manage the growing number of increasingly complex RRR's. Continuing with data management, also the requirement of interoperability across different sectors and increasing quality requirements have been regularly mentioned in the literature. (Williamson et al., 2010, p.443; Kalantari et al., 2008.)

Considering the theoretical grounds and the concept of socio-technical change, an important question arises: What is the suitable transition pattern in the case of cadastral system? Optimizing the existing regime and respecting the long-standing traditions and practices seem to have been the strategy in most countries with developed cadastral systems. But whether this is enough for the future is probably the relevant question to be asked next. Ho et al. (2013) have also underlined the inertia stemming especially from the cultural-cognitive elements in case of 3D property registration. The same inertia of cultural-cognitive elements holds – equally strong if not stronger, we believe – when the whole cadastral system is considered instead of just the property registration function, which makes the speculation about future transitions challenging.

6.2. Limitations of study

We recognize that there are limitations to our approach. First, the focus group contained only a small number of experts. Hence, lack of diversity in views brought up during the discussions must be brought up as one potential limitation. We note, however, that the aim of this study was not to conduct quantitative scenarios, but to exploit expert knowledge to illustrate the applicability of the MLP framework in the context of land administration. Therefore, a focus group method that aims to produce unexpected insights through group interaction was selected as a research method. Another limitation relates to the limited number of landscape and niche level factors considered in this study. Had we used different sources or criteria for conducting the lists used in focus group working, the outcome could have been different. In particular, the identified niche-innovations could be argued to be technology-oriented, and higher versatility in that regard would be desirable. Limiting the complexity of analysis by sticking with a non-exhaustive list of factors is necessary, though.

There are some limitations regarding the theoretical framework, too. The question of spatial scale, or rather an implicit treatment of spatial dimensions in MLP applications, is often brought up in sustainable transition literature. Some recent studies emphasize that territorial embeddedness has a larger impact on shaping the co-evolution of technologies, actors, and institutions than the original MLP framework suggests (e.g. Coenen et al., 2012). We discuss the alternative pathways on the national scale, and the scalability of our findings to other countries and further to the continental (European) and global scale should be weighted carefully. Transferability of the findings is always a debatable matter in qualitative approaches, but here we argue that the findings transfer best to contexts where some similarities in cultural and judicial background and in land registration tradition can be found. In other words, the findings should be best transferable to country contexts where mature, multipurpose cadastral systems exist.

Another often mentioned criticism towards the MLP framework is the homogenous description of regime, and following that, the too linear depiction of transitions that are mainly based on alternative technological innovations (Fuenfschilling and Truffer, 2014). This paper intentionally focuses on the regime concept to avoid such small-scale portrayal of the potential transitions and emphasizes the importance to focus on wider developments rather than single technologies that were seen more as enablers than system disrupters. Nevertheless, providing a realistic enough picture of the regime, its dynamics and dimensions, which are particularly prone to change of rules, is a challenge.

7. Conclusions

In this study concepts that are more familiar from studies on sustainability transitions have been exploited to build alternative transition pathways for cadastral systems. The empirical part presents an illustrative case study of the Finnish cadastral system. The process of drafting the pathways did not start with a fixed normative goal like most studies on socio-technical transitions do. Instead, they were formed based on a review of topical niche and landscape level factors, followed by a description of the current cadastral system regime and its dynamics. Then, a limited set of interactions between the three levels were anticipated and speculated to form plausible transitions for the Finnish cadastral system. Considering the similarity of central values, technologies, actors and organizational forms in land administration throughout the world, the findings of our study should be interesting outside Finland as well.

This study contributes the land administration literature on several fronts. First, it advances the conceptual understanding of the cadastral system as a sociotechnical system and as a subject of sociotechnical change. We emphasize the description of the resistant and path-dependent regime level in our analysis, which is backed up also by the historical development of cadastral systems (e.g. Lin et al., 2015; Divithure and Tang, 2013). Second, we illustrate with an MLP based approach how to build pathway variants in a systematic manner. The current discourse is marked by plethora of new technologies, innovations, and megatrends that potentially shape the whole industry. However, a systematic approach for anticipating the impacts of these developments from a cadastral system point of view has been missing so far, and this study addresses this gap. Last, the study provides new and fresh insights about the future of cadastral systems for both academia and practitioners. We believe that at a time of constant change, new openings and debates are more than welcome also within the land administration domain.

We also detect many interesting future research avenues. First, this study completely neglects the feasibility and probability assessment of the pathway variants. The selection of a preferred future state, a common practice in scenario studies, is left aside here too. Moreover, moving to operational level scenarios, i.e. concentrating on the design and policy implications of the variants, should be interesting. Such results could provide some concrete support to policy and strategy development for different land administration actors.

CRediT authorship contribution statement

Pauliina Krigsholm: Conceptualization, Data curation, Formal

[5] SDIs refer to infrastructures that "facilitate the sharing and integration of multisource datasets with data specifically related to land administration" (Williamson et al., 2010, p.229).

analysis, Investigation, Methodology, Validation, Writing - original draft, Writing - review & editing. **Kirsikka Riekkinen:** Conceptualization, Funding acquisition, Project administration, Supervision, Validation. **Pirjo Ståhle:** Conceptualization, Supervision.

Acknowledgements

This work was supported by National Land Survey of Finland (NLS), Aalto University School of Engineering and the Finnish Ministry of Forestry and Agriculture.

Appendix A

Table A1

Table A1
Full list of the niche innovations presented to the focus group participants.

Innovation	
1. Neural networks and deep learning	11. Real time 3D detection of environment
2. P2P -trust solutions, blockchain	12. Quantum computing and communication
3. Cloud computing and storage services	13. Quadcopters and other drones
4. Conveyance of commercial platforms	14. Encrypted and anonymous communications
5. Automated vehicles in passenger and commodity transport	15. Gamification of collaboration and society
6. MyData and GDPR	16. Reverse learning and demonstration of know-how
7. Ubiquitous environment and IoT	17. VR-glasses and virtual reality
8. Rapid development of computing power	18. Intelligent glasses, AR-glasses and augmented reality
9. Verbot/chatbot – dialogic and literary robots	19. Imaging and positioning through sensor technologies
10. AR&VR -platforms and standards	

References

Anand, A., McKibbin, M., Pichel, F., 2016. Colored coins: bitcoin, blockchain, and land administration. In: Annual World Bank Conference on Land and Poverty. March 14—18 (2016).

Atazadeh, B., Kalantari, M., Rajabifard, A., Ho, S., Champion, T., 2017. Extending a BIM-based data model to support 3D digital management of complex ownership spaces. Int. J. Geogr. Inf. Sci. 31 (3), 499–522.

Banister, D., Hickman, R., 2013. Transport futures: thinking the unthinkable. Transp. Policy (Oxf) 29, 283–293.

BoF, 2018. Bank of Finland Bulletin: the Finnish Real Estate Investment Market. 23.5.2018 Bank of Finland. Helsinki [referred 6.12.2019]. Available at:. https://www.bofbulletin.fi/en/2018/2/the-finnish-real-estate-investment-market/.

Börjeson, L., Höjer, M., Dreborg, K.-H., Ekvall, T., Finnveden, G., 2006. Scenario types and techniques: towards a user's guide. Futures. 38 (7), 723–739.

Coenen, L., Benneworth, P., Truffer, B., 2012. Toward a spatial perspective on sustainability transitions. Res. Policy 41 (6), 968–979.

Crompvoets, J., Bregt, A., Rajabifard, A., Williamson, I., 2004. Assessing the worldwide developments of national spatial data clearinghouses. Int. J. Geogr. Inform. 18 (7), 665–689.

Dale, P., McLaughlin, J., 1999. Land Administration. Oxford University Press, New York, NY, USA 1999.

Divithure, H., Tang, C., 2013. Evolution of land registration and cadastral survey systems in Sri Lanka. Surv. Rev. 45 (329), 126–135.

EEA, 2015. European Environment – State and Outlook 2015: Assessment of Global Megatrends [e-publication]. March 2015. European Environment Agency, Copenhagen. [referred: 2.10.2019]. Access method:. https://www.eea.europa.eu/soer-2015/global/action-download-pdf.

Elzen, B., Geels, F.W., Hofman, P.S., Green, K., 2004. Socio-technical scenarios as a tool for transition policy: an example from the traffic and transport domain. Syst. Innov. Transit. to Sustain. Theory, Evid. policy 251–281.

Enemark, S., Williamson, I., Wallace, J., 2005. Building modern land administration systems in developed economies. J. Spat. Sci. 50 (2), 51–68.

EY, 2018. What's After What's Next? The Upside of Disruption – Megatrends Shaping 2018 and Beyond [e-publication]. Ernst and Young Global, London. [referred: 2.10.2019]. Access method:. . https://staging-area.info/EY/ey_report_v14_v04E_INTERACTIVE.pdf.

Foxon, T.J., Hammond, G.P., Pearson, P.J.G., 2010. Developing transition pathways for a low carbon electricity system in the UK. Technol. Forecast. Soc. Change 77, 1203–1213.

Fuenfschilling, L., Truffer, B., 2014. The structuration of socio-technical regimes - Conceptual foundations from institutional theory. Res. Policy 43, 772–791.

Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study. Res. Policy 31, 1257–1274.

Geels, F.W., 2004. From sectoral systems of innovations to socio-technical systems: insights about dynamics and change from sociology and institutional theory. Res. Policy 33, 897–920.

Geels, F.W., 2011. The multi-level perspective on sustainability transitions: responses to seven criticisms. Environ. Innov. Soc. Transit. 24–40.

Geels, F.W., 2018. Disruption and low-carbon system transformation: progress and new challenges in socio-technical transitions research and the Multi-Level Perspective. Energy Res. Soc. Sci. 37, 224–231.

Genus, A., Coles, A.-M., 2008. Rethinking the multi-level perspective of technological transitions. Res. Policy 37, 1436–1445.

Ghosh, B., Schot, J., 2019. Towards a novel regime change framework: studying mobility transitions in public transport regimes in an Indian megacity. Energy Res. Soc. Sci. 51, 82–95.

Ho, S., Rajabifard, A., Stoter, J., Kalantari, M., 2013. Legal barriers to 3D cadastre implementation: What is the issue? Land Use Policy 35, 379–387.

Ho, S., Rajabifard, A., Kalantari, M., 2015. 'Invisible' constraints on 3D innovation in land administration: a case study on the city of Melbourne. Land Use Policy 42, 412–425.

Hofman, P., Elzen, B., Geels, F., 2004. Sociotechnical scenarios as a new tool to explore system innovations: co-evolution of technology and society in the Netherlands' energy system. Innov. Manag. Policy Pract. 6 (2), 344–360.

ISO 19152, 2012. Geographic Information - Land Administration Domain Model (LADM). the International Organization for Standardization, Geneva, Switzerland.

Jabbour, C., Rey-Valette, H., Maurel, P., Salles, J.-M., 2019. Spatial data infrastructure management: a two-sided market approach for strategic reflections. Int. J. Inf. Manage. 45, 69–82.

Kalantari, M., Rajabifard, A., Wallace, J., Williamson, I., 2008. Spatially referenced legal property objects. Land Use Policy 25, 173–181.

Konrad, K., Truffer, B., Vos, J.-P., 2008. Multi-regime dynamics in the analysis of sectoral transformation potentials: evidence from German utility sectors. J. Clean. Prod. 16, 1190–1202.

KPMG, 2014. Future State 2030: the Global Megatrends Shaping Governments [e-publication]. February 2014. KPMG International and Mowat Centre for Policy Innovation, Toronto, Canada. [referred 2.10.2019]. Access method:. https://assets.kpmg/content/dam/kpmg/pdf/2014/02/future-state-2030-v3.pdf.

Krigsholm, P., Zavialova, S., Riekkinen, K., Ståhle, P., Viitanen, K., 2017. Understanding the future of the Finnish cadastral system: a Delphi Study. Land Use Policy 68, 133–140.

Krigsholm, P., Riekkinen, K., Ståhle, P., 2018. The changing uses of cadastral information: a user-driven case study. Land 7, 83. https://doi.org/10.3390/land7030083.

KTI, 2019. The Finnish Property Market [e-publication]. March 2019. Helsinki: KTI Finland. [referred 2.10.2019]. Access method:. https://kti.fi/wp-content/uploads/The-Finnish-Property-Market-2019.pdf.

Lappalainen, P., 2002. Kuntien Kiinteistörekisterinpidosta Uuden Kiinteistötietojärjestelmän Käyttöönoton Näkökulmasta. Kiinteistöopin Ja Talousoikeuden Julkaisuja A27. Otamedia Oy, Espoo 2002. ISBN 951-22-6260-6.

Lin, Q., Kalantari, M., Rajabifard, A., Li, J., 2015. A path dependence perspective on the Chinese cadastral system. Land Use Policy 45, 8–17.

LVM, 2018. MyData – A Nordic Model for Human-Centered Personal Data Management and Processing [E-Publication]. 2018. Helsinki: Ministry of Transport and Communications. [referred: 2.10.2019]. Access method:. https://www.lvm.fi/documents/20181/859937/MyData-nordic-model/2e9b4eb0-68d7-463b-9460-821493449a63?version=1.0.

Macharis, C., Crompvoets, J., 2014. A stakeholder-based assessment framework applied to evaluate development scenarios for the spatial data infrastructure for Flanders. Comput. Environ. Urban Syst. 46, 45–56.

Markard, J., Stadelmann, M., Truffer, B., 2009. Prospective analysis of technological innovation systems: identifying technological and organizational development options for biogas in Switzerland. Res. Policy 38 (4), 655–667.

Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of

research and its prospects. Res. Policy 41 (6), 955–967.
Mittelstaedt, J.D., Shultz, C.J., Kilbourne, W.E., Peterson, M., 2014. Sustainability as megatrend – two schools of macromarketing thought. J. Macromarket. 34 (3), 253–264.
MMM, 2018. Paikkatietopoliittinen Selonteko [e-publication]. Maa- Ja Metsätalousministeriön Julkaisuja 4a/2018. Helsinki: Ministry of Agriculture and Forestry of Finland. [referred: 2.10.2019]. Access method:. http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/160909/MMM%204a%202018%20Paikkatietopoliittinen%20selonteko%20FINAALI.pdf?sequence=1&isAllowed=y.
Moradi, A., Vagnoni, E., 2018. A multi-level perspective analysis of urban mobility system dynamics: What are the future pathways? Technol. Forecast. Soc. Change 126, 231–243.
Morgan, D.L., 1996. Focus groups. Annu. Rev. Sociol. 22, 129–152. https://doi.org/10.1146/annurev.soc.22.1.129.
Niukkanen, K., 2014. On the Property Rights in Finland – the Point of View of Legal Cadastral Domain Model. Dissertation. Aalto University. Department of Real Estate. Planning and Geoinformatics, Espoo, Finland.
NLS, 2018. Annual Statistics of National Land Survey of Finland [e-publication]. December 2018. Access method:. National Land Survey of Finland, Helsinki. https://www.maanmittauslaitos.fi/sites/maanmittauslaitos.fi/files/attachments/2019/02/MML_vuositilasto_2018.pdf.
North, D.C., 1990. Institutions, Institutional Change and Economic Performance. Cambridge University Press, Cambridge.
North, D.C., 1994. Economic performance through time. Am. Econ. Rev. 84, 359–368.
OSF, 2019a. Official Statistics Finland: Population Projection 2015 According to Vital Statistics and Sex by Area in 2015 to 2040. Access method:. http://pxnet2.stat.fi/PXWeb/pxweb/en/StatFin/StatFin_vrm_vaenn/statfin_vaenn_pxt_004.px/?rxid=fc10ee81-a02c-4392-80ee-3a626bab31ab.
OSF, 2019b. Official Statistics Finland: Prices of Dwellings in Housing Companies [e-publication]. ISSN=2323-8801. July 2019. Helsinki: Statistics Finland [referred: 20.9.2019]. Access method:. http://www.stat.fi/til/ashi/2019/07/ashi_2019_07_2019-08-28_tie_001_en.html.
Ottens, M., Stubkjaer, E., et al., 2008. A socio-technical analysis of cadastral systems. In: Zevenbergen, J. (Ed.), Real Property Transactions: Procedures, Transaction Costs and Models. IOS Press, 2008. ProQuest Ebook Central.
Paasch, J., 2012. Standardization of Real Property Rights and Public Regulations - the Legal Cadastral Domain Model. Dissertation, Royal Institute of Technology (KTH). Real Estate Planning, Stockholm, Sweden.
Pathways project, 2016. In: Geels, F.W. (Ed.), Exploring Transition Pathways to Sustainable, Low Carbon Societies. Deliverable D2.5: 'Forward-Looking Analysis of Transition Pathways With Socio-Technical Scenarios', [e-publication]. [referred 6.9.2019] Access method: https://www.pathways-project.eu/sites/default/files/MAIN%20REPORT%20Deliverable%202.5_final_web.pdf.
Paulsson, J., Paasch, J., 2013. 3D property research from a legal perspective. Comput. Environ. Urban Syst. 40, 7–13.
PwC, 2016. Five Megatrends and Their Implications for Global Defense & Security [e-publication]. November 2016. [referred 2.10.2019]. Access method:. PricewaterhouseCoopers, United Kingdom. https://www.pwc.com/gx/en/government-public-services/assets/five-megatrends-implications.pdf.
Rahmatizadeh, S., Rajabifard, A., Kalantari, M., 2016. A conceptual framework for utilizing VGI in land administration. Land Use Policy 56, 81–89.
Raven, R., Sengers, F., Spaeth, P., Xie, L., Cheshmehzangi, A., de Jong, M., 2019. Urban experimentation and institutional arrangements. Eur. Plan. Stud. 27 (2), 258–2281. https://doi.org/10.1080/09654313.2017.1393047.
Riekkinen, K., Toivonen, S., Krigsholm, P., Hiironen, J., Kolis, K., 2016. Future themes in the operational environment of the Finnish cadastral system. Land Use Policy 57, 702–708.
Rosenbloom, D., 2017. Pathways: an emerging concept for the theory and governance of low-carbon transitions. Glob. Environ. Chang. Part A 43, 37–50.
Scott, W.R., 1995. Institutions and Organizations. Foundations for Organizational Science. Sage Publications, London.
Sitra, 2016. Megatrendit 2016 – Tulevaisuus Tapahtuu Nyt [e-publication]. January 2016. Sitra, Helsinki [referred: 2.10.2019]. Access method:. https://media.sitra.fi/2017/02/23211717/Megatrendit_2016.pdf.
Smith, A., Voss, J.-P., Grin, J., 2010. Innovation studies and sustainability transitions: the allure of multi-level perspective and its challenges. Res. Policy 39, 435–448.
Stewart, D.W., Shamdasani, P.N., Rook, D.W., 2007. Focus Groups – Theory and Practice, 2nd edition. ISBN: 9781412991841.
Sutherland, L.-A., Peter, S., Zagata, L., 2015. Conceptualising multi-regime interactions: the role of the agriculture sector in renewable energy transitions. Res. Policy 44, 1543–1554.
TuVJ, 2014. 100 Opportunities for Finland and the World. Publication of the Committee for the Future 11/2014 [e-publication]. Parliament of Finland, Helsinki. [referred: 2.10.2019]. Access method:. https://www.eduskunta.fi/FI/tietoaeduskunnasta/julkaisut/Documents/tuvj_11+2014.pdf.
TuVJ, 2016. Technological Change 2013-2016: Preliminary Investigation of the Development of Radical Technologies After the 2013 Review. Publication of the Committee for the Future 2/2016 [e-publication]. Parliament of Finland, Helsinki. [referred 2.10.2019]. Access method:. https://www.eduskunta.fi/FI/tietoaeduskunnasta/julkaisut/Documents/tuvj_2+2016.pdf.
TuVJ, 2018. Suomen Sata Uutta Mahdollisuutta 2018—2037. Publication of the Committee for the Future /2018 [e-publication]. Parliament of Finland, Helsinki. [referred 2.10.2019]. Access method:. https://www.eduskunta.fi/FI/tietoaeduskunnasta/julkaisut/Documents/tuvj_1%2B2018.pdf.
van Bree, B., Verbong, G.P.J., Kramer, G.J., 2010. A multi-level perspective on the introduction of hydrogen and battery-electric vehicles. Technol. Forecast. Soc. Change 77, 529–540.
van Welie, M.J., Cherunya, P.C., Truffer, B., Murphy, J.T., 2018. Analysing transition pathways in developing cities: the case of Nairobi's splintered sanitation regime. Technol. Forecast. Soc. Change 137, 259–271.
Verbong, G., Geels, F.W., 2007. The ongoing energy transition: lessons from a socio-technical, multi-level analysis of the Dutch electricity system (1960-2004). Energy Policy 35 (2), 1025–1037.
WB, 2019. Ease of Doing Business Ranking & Ease of Doing Business Score: Quality of Land Administration Index. World Bank Group [referred 26.9.2019] Access method: https://www.doingbusiness.org/en/data/doing-business-score?topic=registering-property.
Williamson, I.P., Enemark, S., Wallace, J., 2010. Land Administration for Sustainable Development, 1st ed. ESRI Press, Redlands, CA, USA ISBN 978-1-58948-041-4.
Zetterqvist, F., 2019. Transforming Land Administration – a Scenario Study on Future Land Administration. FIG Working Week 2019: Geospatial Information for a Smarter Life and Environmental Resilience. Hanoi, Vietnam, April 22-26, 2019. .
Zevenbergen, J., 2004. A systems approach to land registration and cadastre. Nordic J. Surv. Real Estate Res. 1, 11–24.