



Licentiate Thesis in Real Estate and Construction Management

# Modern Cadastral Systems: Structure and Resilience with Reference to Ukraine

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# Abstract

This dissertation examines the structure, functionality, and resilience of cadastral systems (CS) as a core component of land administration systems (LAS), with a particular focus on Ukraine under conditions of institutional stress and armed conflict. Efficient and secure land administration is essential for ensuring property rights, supporting economic development, and maintaining social stability. However, the relationship between the structural organization of cadastral systems and their performance under crisis conditions remains insufficiently understood.

The study adopts a qualitative research design combining legal analysis, literature review, and systems theory. It conceptualizes cadastral systems as socio-technical structures composed of juridical, technical, organizational, and financial aspects. The research is structured around two main objectives: (1) to analyze and compare cadastral systems in selected European countries (England and Wales, France, and Sweden) in order to identify features of a resilient model suitable for Ukraine, and (2) to assess how the Ukrainian land administration system has adapted to the challenges of martial law since 2022.

The first part of the thesis applies a comparative law and systems-based approach to examine how different legal traditions and institutional arrangements shape cadastral design and performance. The findings demonstrate that system resilience depends not on legal tradition alone but on the degree of integration and coherence among legal frameworks, technical solutions, institutional coordination, and financial mechanisms. Fragmentation between cadastral and land registration systems is identified as a key limitation in Ukraine.

The second part analyzes Ukraine as a case of land administration under active conflict, using a resilience framework that emphasizes institutional adaptability and risk management. The study identifies several operational responses, including emergency legal measures, increased reliance on digital and remote tools, and adjustments to administrative procedures to maintain core functions despite war-related disruptions. These measures illustrate the system's capacity to absorb shocks and adapt, while also revealing vulnerabilities related to data security, legal fragmentation, and institutional coordination.

The thesis contributes to the field by integrating systems approach with resilience analysis, offering a comprehensive framework for evaluating cadastral systems under both stable and crisis conditions. It provides practical recommendations for strengthening the Ukrainian cadastral system, including improved interoperability, legal harmonization, and development of secure, resilient digital infrastructures. More broadly, the study highlights the importance of designing land administration systems that can maintain functionality, protect property rights, and support recovery in times of crisis.

## **Keywords**

Cadastral system, Ukraine, land administration, land governance, resilience, real property rights, martial law, systems approach, comparative law.

# Sammanfattning

Denna avhandling undersöker struktur, funktionalitet och resiliens hos fastighetsinformationssystem (kadastersystem, CS) som en central del av markförvaltningssystem (land administration systems, LAS), med särskilt fokus på Ukraina under förhållanden präglade av institutionell stress och väpnad konflikt. Effektiv och säker markförvaltning är avgörande för att säkerställa äganderätt, stödja ekonomisk utveckling och upprätthålla social stabilitet. Sambandet mellan kadastersystemens strukturella utformning och deras funktion, särskilt under krisförhållanden, är dock fortfarande otillräckligt utforskat.

Studien baseras på en kvalitativ forskningsdesign som kombinerar rättslig analys, litteraturstudie och systemteori. Kadastersystemet conceptualiseras som en socio-teknisk struktur bestående av juridiska, tekniska, organisatoriska och finansiella aspekter. Forskningen har två huvudsakliga syften: (1) att analysera och jämföra kadastersystem i utvalda europeiska länder (England och Wales, Frankrike och Sverige) för att identifiera egenskaper hos en resilient modell som kan tillämpas i Ukraina, samt (2) att undersöka hur det ukrainska markförvaltningssystemet har anpassat sig till de utmaningar som uppstått under krigstillståndet sedan 2022.

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resilient modell som kan tillämpas i Ukraina, samt (2) att undersöka hur det ukrainska markförvaltningssystemet har anpassat sig till de utmaningar som uppstått under krigstillståndet sedan 2022.

Den andra delen analyserar Ukraina som ett fall av markförvaltning under pågående konflikt, med hjälp av ett resiliensperspektiv som betonar institutionell anpassningsförmåga och riskhantering. Studien identifierar flera operativa åtgärder, såsom tillfällig lagstiftning, ökad användning av digitala och fjärrbaserade verktyg samt anpassning av administrativa rutiner för att upprätthålla systemets grundläggande funktioner trots krigets konsekvenser. Dessa åtgärder visar på systemets förmåga att absorbera störningar och anpassa sig, men synliggör även sårbarheter kopplade till datasäkerhet, rättslig fragmentering och institutionell samordning.

Avhandlingen bidrar till forskningsfältet genom att integrera systemteori med resiliensanalys och därigenom erbjuda ett övergripande ramverk för att analysera kadastersystem både under normala förhållanden och i krissituationer. Den ger även praktiska rekommendationer för att stärka det ukrainska kadastersystemet, inklusive förbättrad interoperabilitet, rättslig harmonisering och utveckling av säkra och resilienta digitala infrastrukturer. Mer generellt understryker studien vikten av att utforma markförvaltningssystem som kan upprätthålla funktionalitet, skydda äganderätt och stödja återuppbyggnad i tider av kris.

### **Nyckelord**

Kadastersystem, Ukraina, markförvaltning, markstyrning, resiliens, fastighetsrätt, krigstillstånd, systemteori, komparativ rätt.

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*Andrii Kozikov,*

*Stockholm, April 2026*

# List of publications and declaration of contributions

Paper A: Kozikov, A. (2026). Comparative Study of Cadastral Systems. A manuscript.

The paper was written by Andrii Kozikov (AK).

Paper B: Kozikov, A. & Kuznetsova, D. (2026). Published in the Nordic Journal of Surveying and Real Estate Research, 19(1), on 13th February 2026.

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The paper was written by Andrii Kozikov (AK) jointly with Daria Kuznetsova (DK).

AK is a primary author of the paper who designed the study, conducted overview of Ukrainian land administration system and analysis of Ukrainian legislation after introduction of the martial law in Ukraine. DK drafted section about theoretical framework and fulfilled the analysis of Ukrainian legislation before introduction of the martial law. Introduction, methodology, discussion of findings and conclusions were joint efforts of both authors.



## List of abbreviations

CDM	Cadastral domain model
CS	Cadastral system
CTI	Cyber Threat Intelligence (CTI)
DGFIP	French agency at the Ministry of Economy, Finance and Industrial and Digital Sovereignty responsible for the maintenance of the cadastre and land register (in French: Direction générale des finances publiques)
DLT	Distributed ledger technology
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FIG	International Federation of Surveyors (in French: Fédération Internationale des Géomètres)
GIS	Geographical Information System
ICSM	Intergovernmental Committee on Surveying and Mapping (Australia)
INSPIRE	Infrastructure for Spatial Information in the European Community
IT	Information technology

LAS	Land administration system
Lantmäteriet	The Swedish Mapping, Cadastral and Land Registration Authority
LGAF	Land Governance Assessment Framework of the World Bank
RRRs	Rights, restrictions and responsibilities
SDI	Spatial data infrastructure
SSM	Soft systems methodology
StateGeoCadastre	State Service of Ukraine for Geodesy, Cartography and Cadastre
ULAS	Ukrainian land administration system
UML	Unified Modelling Language
UN	United Nations
UNDP	United Nations Development Program
UNECE	United Nations Economic Commission for Europe
UN-Habitat	United Nations Human Settlements Programme
UNMIK	United Nations Mission in Kosovo
USAID	The United States Agency for International Development

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# 1 Introduction

This section includes a brief background to the study and introduces the research problem. The following section is aimed at setting up a general purpose of the thesis and research questions. Finally, a thesis outset is provided.

## 1.1 Background

An efficient and equitable land administration system<sup>1</sup> (hereinafter referred to as LAS) is vital for promoting fair access to land, secure tenure, and sustainable resource management, all of which are fundamental to social stability and economic growth (UN-Habitat, 2008, FAO, 2021). By ensuring transparent and trustworthy land ownership records, LAS enhances land rights security, minimizes conflicts, and encourages investments in both urban and rural areas (UN-Habitat, 2008). Effective land administration also aids in regulating land use, addressing challenges such as informal settlements, environmental damage, and resource overuse—issues often prevalent in areas with weak governance (FAO, 2021). Additionally, a strong LAS contributes to poverty reduction by formalizing land tenure for marginalized groups,

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<sup>1</sup> In this thesis, an *efficient* land administration system refers to a system that ensures timely, accurate, and cost-effective registration and updating of land rights, reduces transaction costs, and provides reliable and accessible land information (Williamson et al., 2010; UNECE, 1996). An *equitable* land administration system denotes a system that guarantees non-discriminatory access to land services, protects legally recognized rights, supports tenure security for vulnerable groups, and operates in a transparent and legally predictable manner (UN-Habitat, 2008; FAO, 2012).

enabling them to use land assets as leverage for credit and economic opportunities (UN-Habitat, 2020).

Comprehensive system of land records is essential part of land administration (Simpson, 1976). For the convenience of this study, such a system is named a cadastral system (hereinafter referred to as CS) in this thesis. It unifies the concept of classical cadastre (originally established to record land parcels and their value for taxation purposes) and legal land registration system.

Robust and well-functioning structure of CS which means that it has ability to maintain its functions under stress or disturbance (e.g., institutional, technical, or legal changes) (Williamson et al., 2010), forms a basis for an efficient maintenance of land records<sup>2</sup> and protection of property rights. Better understanding of such structure would support the improvement of registration procedures and implementation of more efficient land administration. The structure of CS can be examined purely from a technical perspective, focusing on database content, data structures, and other IT approaches. However, such a perspective captures only one dimension of how the system operates. In this thesis, the CS is examined from its juridical, technical, organizational, and financial aspects, and particular attention is paid to how these aspects are defined and implemented in the system. This approach makes it possible to assess how the overall design of the CS influences its functionality, security, and capacity to operate under conditions of stress.

Security concerns in land administration are crucial for societies, as they prioritize robust property rights (legally enforceable, socially recognized, and institutionally protected even under conditions of stress or instability (UN-Habitat, 2008; Deininger et al., 2012)) and reliable CS. The structure of the cadastral system comprising its legal, organizational, technical, and financial aspects serves as the foundation for maintaining accurate and secure land records, since coherent institutional arrangements and interoperable databases (sharing and synchronizing information without manual duplication or inconsistencies) enable consistent updating and protection of information. While most societies maintain some form of land administration, the degree of

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<sup>2</sup> *Efficient maintenance of land records* denotes the timely, accurate, and continuous updating of spatial and legal information, supported by standardized procedures, secure data management, and institutional coordination that minimizes inconsistencies and transaction delays (UNECE, 1996; Enemark et al., 2014).

robustness varies widely: developed and rule-of-law-based countries tend to uphold secure, transparent cadastral systems, whereas states affected by conflict or institutional fragility often face fragmented systems, weak legal enforcement, and higher risks to property rights (FAO, 2012; World Bank, 2021). At the same time, gaining a comprehensive understanding of security challenges in land administration has proven challenging due to difficulties in obtaining the necessary background data such as information on system vulnerabilities, cyber incidents, or institutional preparedness. This may be attributed to the fact that, until recently, military conflicts were relatively limited in scope and occurred in regions with less developed land tenure systems. The large-scale hostilities that began in 2022 in the heart of Europe, impacting the lives of over 40 million people in Ukraine, have introduced new challenges to security across various sectors, including land administration.

Thus, closer investigation of the structure of modern CS in combination with proper analysis of the security issues of land administration could facilitate the development of more resilient and sustainable models of land recording, which are especially on demand in Ukraine and other developing countries.

Despite the growing recognition of these needs, the relationship between the structural organization of cadastral systems and their security performance remains insufficiently understood. In many countries, including Ukraine, modernization has focused mainly on technical solutions such as digitalization and online access, while challenges of institutional coordination, legal coherence (consistency of the legal framework), and data protection have often been addressed through isolated or short-term measures rather than as part of a comprehensive national reform strategy. These gaps become particularly visible in situations of crisis (like war) or rapid transformation, when the effectiveness of cadastral systems depends on how well their legal, technical, organizational, and financial aspects function together. This study addresses this problem by examining how the structure of the Ukrainian cadastral system influences its security, functionality, and resilience, and how insights from this case can support further improvements in Ukraine.

## **1.2 Purpose and research questions**

Previous section emphasized the importance of developing of more resilient model of CS that could be ready to respond to existing military and other emergency threats. The aim of this thesis is two-fold: (1) to analyze cadastral system key elements in selected developed countries and propose an optimal

solution for Ukraine in line with European best practices; (2) to examine how the Ukrainian land administration system has responded to challenges during the martial law period, taking into account its historical development, existing structure, and pre-war weaknesses. The thesis builds upon the principles of real estate<sup>3</sup>, cadastral legislation in Ukraine and other selected European countries (England & Wales, France and Sweden). The thesis also builds on martial law regulations in Ukraine, incorporating method of systems approach. The use of this approach in cadastral research is explained in section 3.1.

Research questions:

RQ 1: What should be the key elements of Ukrainian CS in comparison with other countries like England & Wales, France and Sweden to achieve and demonstrate its resilience?

RQ 2: What measures have been taken by the Ukrainian government or other relevant institutions to maintain the land administration system during martial law in Ukraine?

RQ 3: In what ways have historical developments and the existing land administration landscape in Ukraine influenced the current responses and adaptations to the martial law period?

Paper 1 discusses research question 1 and paper 2 discusses research questions 2 and 3.

### **1.3 Disposition of the thesis**

Chapter 1 has outlined the background of the research, defined the problem, and presented the overall purpose of the thesis along with its research questions. The second chapter introduces the theoretical framework that serves as the basis for the thesis. First, the concept of cadastral system is considered. Secondly, the resilience framework is introduced as a conceptual approach for analyzing how land administration systems maintain functionality, adapt, and recover during crises such as war. This section also outlines several wartime models of land administration that illustrate different

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<sup>3</sup> Principles of real estate are fundamental legal and economic principles that underpin land tenure and property systems (De Soto, 2000; Williamson et al., 2010; Larsson, 1991), such as: right to own and dispose land and property; security and publicity of property rights (transparency of ownership and registration); indefeasibility and legal certainty of title (registered ownership is protected and enforceable); equity and access to land markets (ensuring fairness and efficiency in transactions).

institutional responses under conflict conditions. The third chapter reviews previous studies in the field of cadastral systems that are directly relevant to the aims of this thesis, particularly those addressing the structure, modernization, and security of cadastral and land administration systems. The fourth chapter deals with methodological aspects such as research design, data selection, methods used, ethical considerations and limitations. Fifth chapter includes the summary of paper 1 and paper 2, and discussion of the results in light of their connection with previous studies and theoretical framework. In the final chapter, conclusions and contributions of the thesis are presented, and potential research questions for future studies are outlined.



## 2 Theoretical framework

In the current chapter, theoretical framework used in the study is described. First, the concept of the cadastral system is examined. That is the theoretical understanding of how a cadastral system functions as part of the broader land administration and land governance framework. Then, resilience framework theory is described to understand the principles of secure and resilient land administration during martial law period.

### 2.1 Concept of cadastral system

Explanation of the concept of cadastral system is given in this section. It is important because this term is central in this thesis, but as it was mentioned earlier, it is a part of wider concept called land governance that also needs to be explained in detail.

**Land governance** could be determined as the set of processes, institutions and actors through which decisions about use of land resources are made and implemented (Mattsson & Mansberger, 2017). It encompasses three interrelated pillars:

- Land (use) management, which addresses the planning, regulation and oversight of how land is allocated and used on the ground, ensuring that development, conservation and social objectives are balanced (UNECE, 1996).
- Land policy, the strategic framework of laws, regulations and incentives that guide long-term land distribution, tenure security and land-use planning (FAO, 2012).

- Land administration, the operational component that establishes and enforces legal rights, restrictions and responsibilities relating to land, supported by the systematic collection, maintenance and dissemination of land-related information (Mattsson & Mansberger, 2017).

Within this triad, land administration serves as the backbone of good land governance by providing the legal infrastructure (e.g., statutes, regulations), technical tools (e.g., surveying, mapping) and information systems (e.g., registries, cadastral databases) necessary to document and uphold land rights and values.

The CS is an essential sub-system of land administration (Simpson, 1976), providing the geospatial and legal framework for defining, recording and managing land parcels. For example, one group of land administration experts from Australia defines it as “the system of land parcels and land boundaries including a geometric description of land and real property boundaries linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements” (ICSM, 2014). Larsson in its book “*Land Registration and Cadastral Systems: Tools of Land Information and Management*” (2002) defined it as a “parcel-based land information infrastructures supporting legal, fiscal, planning and management functions.”

Crucially, a cadastral system integrates spatial data (maps, boundary coordinates) with legal and fiscal information (rights, restrictions, valuations), enabling transparent land transactions, secure tenure and efficient land-use planning (Williamson et al., 2010).

The CS typically comprises two tightly linked sub-systems: cadastre and land registration system.

**Cadastre**, according to the definition of the International Federation of Surveyors (FIG, 1995) is “a parcel-based, and up-to-date land information system containing a record of interests in land (e.g., rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements (e.g. the house or any other structures built on the parcel). It may be established for fiscal purposes, legal purposes, to assist in the

management of land and land use and enables sustainable development and environmental protection.”<sup>4</sup>

While this definition remains influential, later conceptual frameworks have significantly broadened the understanding of the cadastre beyond a static register of parcels and ownership. A major milestone in this evolution is the FIG vision of Cadastre 2014 (Kaufmann & Steudler, 1998), which reconceptualized the cadastre as an integrated digital land information infrastructure. In this vision, the cadastre is expected to provide a complete and continuously maintained record of rights, restrictions, and responsibilities (RRRs) related to land and real property, tightly linked to land registration and other public registers. Cadastre 2014 emphasizes full digital management, institutional integration, and the reduction of fragmentation between mapping and legal registration functions.

More recent strategic agendas, often referred to as Cadastre 2034, further extend this perspective by framing the cadastre as a user-oriented and interoperable component of a broader spatial or “location” information ecosystem (Lemmens, 2010). In this view, cadastral systems are expected not only to ensure legal security and fiscal reliability but also to communicate complex land-related information in a way that is accessible and understandable to a wide range of users. Cadastre 2034 highlights the importance of improved visualization, clearer representation of spatial extents of RRRs, and the capacity to support increasingly complex property arrangements.

These conceptual developments reflect several widely recognized modern trends in cadastral development. First, contemporary cadastres are increasingly digital-first and interoperable, integrated with land registries, valuation systems, and national spatial data infrastructures to allow automated data exchange and reduce inconsistencies (Enemark et al., 2016). Second, there is a growing move toward 3D (and, increasingly, time-aware or 4D) cadastres, which are necessary to represent multi-level ownership situations such as underground infrastructure, apartment complexes, and overlapping land uses (Uşak et al., 2024). Third, modern cadastral systems increasingly

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<sup>4</sup> Cadastre supports sustainable development and environmental protection by providing reliable spatial and legal information that underpins land-use planning, natural resource management, and monitoring of sustainability indicators (Williamson et al., 2010; UN-Habitat, 2016)

adopt a citizen-centric orientation, aiming to provide transparent access, intuitive visualization, and clear information for non-expert users (Bennett et.al., 2011). Finally, many countries pursue incremental and adaptable reform approaches, often discussed under the “fit-for-purpose” paradigm, which emphasizes flexibility, cost-effectiveness, and resilience, which are particularly relevant in contexts of institutional transition or crisis (Bennett et.al., 2011).

Key functions of the modern cadastre could be identified as follows:

- Fiscal (providing a basis for equitable property taxation through accurate parcel valuation (UNECE, 1996)).
- Legal (definitive identification of parcel boundaries and associated interests, reducing boundary disputes and underpinning conveyancing (Enemark & Williamson, 2004)).
- Planning & Management (supplying planners and administrators with current land-use data to inform zoning, infrastructure development and environmental stewardship (FIG, 1995)).
- Sustainability (monitoring land-cover changes and supporting natural resource management (FAO, 2012)).

Thus, cadastre is nowadays increasingly considered as a multipurpose land information system, when originally it was launched in civil law countries for the needs of land taxation (Simpson, 1976).

A **land registration system** is defined in publications (e.g. Larsson, 1991 and Zevenbergen, 2002) as a system that serves for legal purposes. It is a national registry maintained by governmental authorities (usually within justice sphere) to record and guarantee real property rights and ownership. De Soto (2000) defines land registration system also as a searchable database of title deeds or registration entries that prevent fraudulent transfers, resolves disputes and streamlines transactions.

Land registration system is usually classified for different countries by two models (UNECE 2004):

- Deeds registration that records the history of transactions (documents, deeds), but does not itself guarantee title; the evidence of ownership depends on the completeness of the documented chain of deeds.
- Title registration (Torrens system) that conveys conclusive proof of ownership in a central registry. The state guarantees the accuracy of the registered title (Larsson, 1991).

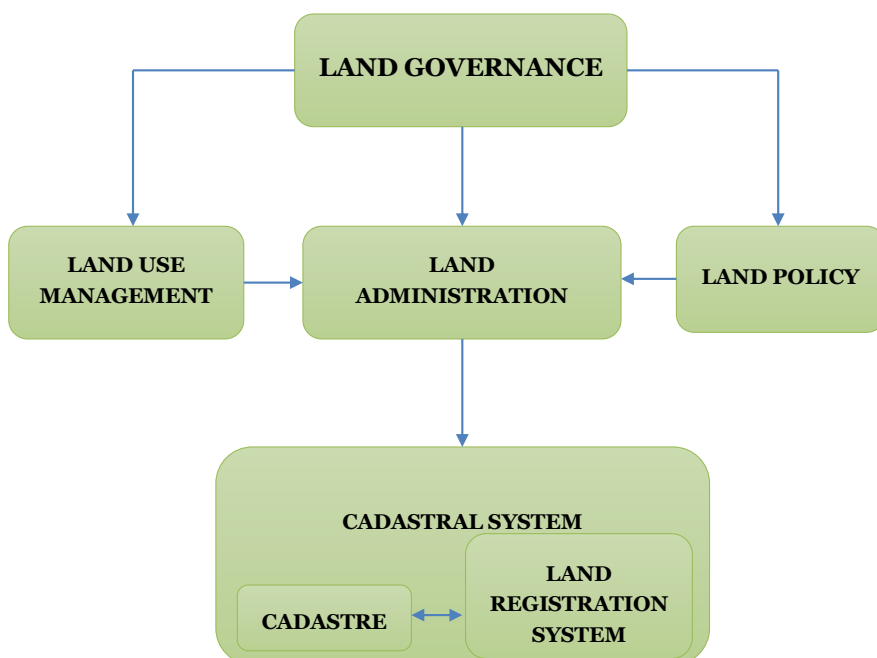


Figure 1: Conceptual framework of cadastral system within land governance (based on Mattsson & Mansberger, 2017, Simpson, 1976)

The cadastral system (CS) plays an integrative role in land governance and constitutes the operational core of land administration. It enhances tenure security by enabling individuals and communities to assert and protect their land rights. It promotes transparency, as parcel and ownership data are publicly accessible in many jurisdictions. The CS also supports policy implementation by providing the empirical foundation for land use planning, property taxation, and monitoring progress toward sustainable development goals (UN-Habitat, 2016). Furthermore, it facilitates environmental management by supplying up-to-date spatial information that underpins conservation zoning and land monitoring.

To sum up the information described in this section let us look at figure 1 that shows the place of cadastral system within land governance hierarchy (Mattsson & Mansberger, 2017). It highlights the relationships between land governance, land administration, and the cadastral system. Land (use) management and land policy are integral components of land governance and influence the operation and design of land administration. Cadastral system is a subsystem of land administration as it was mentioned earlier and consists of

two parts: the cadastre and the land registration system, which could be closely interconnected.

## **2.2 Resilience framework**

In the times of military, social, political instability, protection of governmental databases and other improvements of various systems of administration is becoming a critical issue. Land administration is one of such systems. However, there is a question what approach could be used to analyse its security aspects?

Tengblad and Oudhuis in their book “The Resilience Framework: Organizing for Sustained Viability” (2018) described the concept of so-called resilience framework, an approach that examines the ability of systems or institutions to maintain functionality, adapt, and recover after crisis, disasters, or conflicts such as war. The resilience framework provides a useful analytical tool for examining the security aspects of land administration systems and cadastral systems as their integral part. It enables an assessment of how these systems respond to challenges caused by military actions and how they adapt to new circumstances.

Originally rooted in ecology, the concept of resilience has evolved into a multidisciplinary framework for understanding how systems cope with disruption. Holling (1973) introduced resilience as the ability of ecological systems to absorb disturbances while retaining essential structure and function. Later, resilience theory was expanded to include the adaptive and transformative capacities of social and institutional systems (Folke et al., 2005). In the context of governance and public administration, resilience refers to the capacity of institutions to absorb shocks, adapt to changing conditions, and, when necessary, undergo structural transformation to maintain or recover core functions (Comfort et al., 2010; Scott, 2014).

Applied to land administration, resilience captures both the institutional adaptability of LAS and their capacity for risk management. These two dimensions are central to understanding how LAS can continue functioning in environments marked by legal uncertainty, infrastructure destruction, population displacement, and governance breakdowns.

Institutional adaptability refers to the ability of land administration organizations and frameworks to adjust to socio-political, legal, environmental, or technological changes without losing their functional integrity (Scott, 2014). In conflict-affected contexts, this includes rapid adjustments to legal

frameworks, organizational structures, and operational procedures to accommodate urgent needs—such as securing property rights for displaced populations or reallocating land for emergency use.

Adaptive land administration systems show flexibility during crises by introducing temporary procedures, adjusting legal rules to fit emergency conditions, and cooperating with non-state actors such as local communities or NGOs to ensure continuity of land management.

In the context of resilient land administration systems, risk management refers to the systematic process of identifying, assessing, and responding to threats that may endanger land tenure security, data integrity, administrative capacity, or public trust. This interpretation builds upon the general definition of risk management in the ISO 31000:2018 framework and its adaptation to the LAS context in studies by Williamson et al. (2010), Lemmen et al. (2020), and Todorovski et al. (2016). In fragile or conflict-affected environments, risks range from the physical destruction of cadastral offices to the political manipulation of land claims or the erosion of legal certainty due to displaced populations and competing authorities (Hopkin, 2018; UN-Habitat, 2018).

A risk-informed theoretical perspective rooted in resilience and risk management theory (Hollnagel et al., 2011; Enemark et al., 2016) enables the evaluation of how land administration systems anticipate threats, design redundancies such as backup databases or alternative workflows, and sustain critical functions during and after crises. Effective risk management involves preparedness planning, the use of both digital and analog backup systems, and the incorporation of multiple dispute-resolution mechanisms.

Building on the resilience framework outlined in Section 2.2, which applies the principles of adaptability, redundancy, and recovery from resilience theory (Holling, 1973; Folke, 2005) to land administration systems, five conceptual models of LAS operation under conflict conditions can be identified (Sections 2.2.2–2.2.5). They serve as analytical constructs rather than categories derived from observed cases, providing a framework for comparing how various land administration systems adapt under crisis conditions.

### **2.2.1 Emergency land administration**

This model prioritizes immediate response measures in active conflict zones, often with a focus on protecting land rights of displaced populations and

preventing opportunistic land grabbing<sup>5</sup>. Emergency LAS rely on temporary legal provisions, mobile data collection units, and simplified procedures for documenting claims (Lund, 2009). GIS mapping and remote assessments may be used to document destruction, track displacement, and allocate land provisionally.

Emergency land administration model emphasizes institutional flexibility and speed, often bypassing conventional bureaucratic processes in favor of expediency and humanitarian protection. It reflects resilience through adaptive decision-making under legal uncertainty (van der Molen & Lemmen, 2004; Unruh & Williams, 2013).

### **2.2.2 Decentralized, community-based models**

Where state capacity is compromised, customary or community-based land administration systems often become more viable alternatives. These systems operate through locally accepted norms and institutions, such as traditional authorities or village councils, rather than through formal statutory frameworks. In some countries, they are legally recognized and integrated into the national tenure system. In countries the systems function informally but continue to provide tenure security and land dispute resolution when state institutions are weak (FAO, 2012; Deininger et al., 2012).

Such systems often enjoy greater legitimacy among affected populations and can operate independently of national bureaucracies. They demonstrate resilience because they are socially embedded (rooted in local norms and community authority structures that people trust) and therefore retain legitimacy even when state institutions weaken. They also display redundancy, operating as parallel structures that can continue recording and mediating land rights when formal mechanisms are disrupted. Through these qualities, they help maintain tenure security and prevent land-related conflict during periods of crisis or institutional breakdown (FAO, 2012; Unruh & Williams, 2013).

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<sup>5</sup> The phenomenon of **opportunistic land grabbing** (previously described in Paper 2) refers to the unlawful or exploitative appropriation of land that occurs when governance structures weaken or collapse, such as during armed conflict or post-disaster recovery. In such contexts, individuals or groups exploit institutional vacuums, gaps in registration, or the absence of enforcement to acquire or occupy land outside legal procedures (Alden Wily, 2013; Unruh, 2016).

### **2.2.3 Interim land management via digital and remote tools**

Advances in digital technologies have allowed LAS to operate remotely, even in regions with limited or no physical access. Tools such as satellite imagery, remote sensing, mobile GIS, and blockchain are used to monitor land use, document tenure claims, and secure digital records (Deiningner et al., 2012).

Emerging technologies, such as blockchain-based land registries, illustrate how digital innovation can enhance the resilience of land administration systems. A blockchain land registry is a system for managing property ownership using blockchain technology that is a distributed ledger that maintains a historical record of all transactions across a peer-to-peer network. This creates a secure, transparent, and immutable record of land ownership and transactions, thereby reducing the risks of fraud, disputes, and document tampering, as well as lowering administrative costs compared with conventional registries (Krishnapriya & Greeshma, 2020). Because data is decentralized and stored across multiple nodes rather than in a single government database, such systems help maintain continuity of services and data integrity even when local administrative structures are disrupted. In this way, blockchain technology contributes to the resilience of land administration by ensuring reliability, transparency, and accessibility of records during crises (Graglia & Mellon, 2018; World Bank, 2020).

### **2.2.4 Post-conflict land restitution programs**

Land restitution is a critical component of transitional justice and post-conflict recovery. Transitional justice refers to the judicial and non-judicial measures used by societies to address the consequences of conflict and systematic human rights violations during a transition toward peace and democracy (Teitel, 2000; UN, 2010). It typically includes truth-seeking, criminal accountability, reparations, institutional reform, and reconciliation. Within this framework, land restitution constitutes a key reparative mechanism aimed at restoring property rights and supporting sustainable post-conflict recovery (De Greiff, 2012; UN-Habitat, 2007). Frameworks such as the Pinheiro Principles (UN-Habitat, 2007) articulate international norms for the restitution of housing, land, and property to refugees and internally displaced persons. They emphasize that restitution should be pursued as soon as conditions allow (usually during the early stages of post-conflict recovery) to facilitate return, reconciliation, and the restoration of property rights.

Restitution programs in post-conflict contexts often rely on specialized commissions, legal reconstruction efforts, and international oversight to address disputes arising from destroyed records, overlapping claims, and institutional collapse. Such mechanisms have been established, for instance, in Bosnia, Rwanda, and Kosovo to adjudicate property claims and rebuild confidence in the rule of law. Their resilience function lies in restoring legal order, rebuilding public trust, and re-establishing land administration systems essential for recovery and reconciliation (Leckie, 2007; UN-Habitat, 2007; De Greiff, 2012; Unruh & Williams, 2013).

### **2.2.5 International transitional administration**

In some high-conflict settings, international organisations assume responsibility for LAS until stable governance structures can be restored. For example, the UN Interim Administration Mission in Kosovo (UNMIK) established temporary legal frameworks and property registration systems after the 1999 conflict (Leckie, 2007). These administrations often blend international legal standards with locally adapted mechanisms.

Such arrangements represent resilience through external support, legal innovation, and capacity substitution, creating foundational structures for long-term governance while national institutions recover.

Summing up, the resilience framework provides a valuable theoretical basis for analyzing land administration under stress. It emphasizes institutional flexibility, redundancy, and adaptive capacity as key features enabling LAS to function during disruption. The five models outlined above provide conceptual typologies of how LAS can respond to crises. Each model highlights different configurations of actors (state institutions, local governments, community authorities, private actors, and international organizations) as well as varying tools and governance strategies.

These models will serve as analytical instruments in this study, guiding the evaluation of how Ukraine's LAS responded to wartime challenges. In doing so, the resilience framework not only helps explain system behavior under crisis but also supports discussions on how LAS can be designed to withstand future shocks and enable sustainable recovery.

## 3 Previous research of cadastral systems

This section includes the overview of previous research with the focus on application of systems approach in cadastral domain, issues of reforming/ updating cadastral systems, and security aspects of land administration from international and Ukrainian perspectives.

### 3.1 International research

Over the past two decades, the evolution of cadastral systems has been characterized by an increasing complexity of legal, institutional, and technological arrangements. Academic literature and international institutional reports consistently emphasize that cadastral systems are no longer simple mechanisms of land registration but are instead multifunctional infrastructures underpinning land governance, economic development, and legal certainty. A significant body of research has approached cadastral systems not just as technical artifacts but as dynamic socio-technical systems that are deeply embedded in national governance and property rights regimes (Williamson et al., 2010; Enemark et al., 2005; Dale & McLaughlin, 2000).

One of the seminal contributions to systems-based thinking in this field comes from Jaap Zevenbergen, who in his doctoral thesis *Systems of Land Registration: Aspects and Effects* (2002), conceptualized land registration as an open system. Zevenbergen used a black-box model where the input is the

actual land tenure situation, the throughput represents legal and administrative processes, and the output is legal security. He does not consider registration as merely information processing, instead emphasizing that land registration system should deliver tangible legal certainty and protection of ownership rights. Legal security, he asserts, must be seen as a structural output that ensures enforceability of claims, immunity from unlawful dispossession, and access to land markets.

Canadian scholar Susan Nichols (1993) proposed a different yet complementary perspective, modeling land registration as a four-sided pyramid of interconnected perspectives: cadastral, land policy, conveyancing, and technology. Her information-theoretic approach warned against single-discipline dominance in system development and called for a holistic apex view that integrates data, rights, institutional logic, and service delivery. Similarly, Ian Williamson (2001) emphasized that cadastral systems must be viewed globally, particularly in federated states like Australia. He framed the cadastre as part of a broader land administration paradigm, encompassing surveying, mapping, registration, and land market dynamics.

Barry (1999), drawing on Checkland's soft systems methodology<sup>6</sup>, explored how cadastral systems behave under uncertain or transitional conditions, such as urbanization or political change. He viewed land administration as a set of interacting sub-systems where legal, technical, and social frameworks collide or converge.

Jesper Paasch (2004) advanced the technical modeling of cadastral systems through the development of a Cadastral Domain Model (CDM), advocating standardized UML-based representations that enable data exchange between systems and reduce dependence on specific software providers.

In parallel to these theoretical models, several studies have addressed the institutional reform of cadastral systems in post-socialist and transitional economies. The work of Dale and McLaughlin (2000) and Palmer et al. (2009) for the World Bank documented how cadastres in Central and Eastern Europe were reengineered to shift from centralized, state-dominated records to

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<sup>6</sup> Soft Systems Methodology (SSM) is a structured approach developed by Peter Checkland to address complex, ill-defined problem situations, particularly those involving human and social factors. It emphasizes understanding different perspectives and facilitating learning and action within a group, rather than solely focusing on finding a single "right" solution (Reynolds, Holwell, 2010)

decentralized, customer-oriented systems. The FAO and FIG have promoted models of “fit-for-purpose” cadastre (Enemark et al., 2016), which emphasize adaptability, cost-effectiveness, and incremental improvement in countries where land tenure is undocumented or informal.

As the cadastre transitions into a fully digital ecosystem, scholars argue that it must be governed by principles of digital sovereignty, legal robustness, and technical resilience. Lemmen et. al (2020) call for land administration systems to be “interoperable, secure, and citizen-centric,” emphasizing the importance of public trust. This requires not only legal reform and technological innovation but also a deeper understanding of the system as a multi-actor, multi-layered socio-technical infrastructure. That corresponds to something that systems theorists like Zevenbergen, Barry, and Nichols have long emphasized.

The modernization of cadastral systems in fragile or post-conflict settings has emerged as a distinct subfield in recent years. A notable contribution comes from socio-legal scholarship on property, which conceptualizes land governance as a plural and dynamic system in which formal legal frameworks coexist with customary and informal tenure arrangements (e.g. von Benda-Beckmann et al., 2006). It means that formal laws do not operate alone, but coexist and interact with customary rules, informal practices, and practical decisions made by public authorities. In such settings, land rights are not shaped only by written legislation, but also by ongoing adjustments between state institutions, local communities, and other actors. This perspective shows that land governance in transitional contexts often develops through practical accommodation and gradual institutional adaptation rather than through strict and uniform application of statutory law.

Another emerging area of scholarship concerns blockchain and distributed ledger technology (DLT)<sup>7</sup> in land registration, reflecting the broader push for transparency, tamper-resistance, and trustless verification in institutional data systems. Blockchain, as a decentralized and cryptographically secure ledger, is

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<sup>7</sup> DLT refers to a **decentralized database** that is **maintained and updated independently by multiple participants (nodes)** across different locations. Unlike a traditional centralized database, there’s no single point of control and **all nodes in the network hold an identical copy of the ledger**, and changes are recorded only when a consensus is reached among participants. **Blockchain** is the most well-known form of DLT. It organizes data into blocks that are cryptographically linked. **DLT** is the broader concept; not all DLTs use the chain-of-blocks structure that defines blockchain. (Tapscott et. al, 2016)

particularly attractive for environments plagued by corruption, insecure land tenure, or weak institutional oversight. Its application in land administration allows for immutable records of property transactions, real-time auditability, and increased citizen trust, particularly in countries with a history of document forgery or overlapping claims (Lemmen et al., 2020; Mueller & Seifert, 2019).

Scholars such as Kaczorowska (2019) have emphasized that blockchain's decentralized nature can help disintermediate authorities and reduce transaction costs, while also highlighting key challenges, including scalability (the ability of the system to handle a large number of transactions efficiently as usage increases), legal admissibility (the extent to which blockchain records are formally recognized as valid evidence under national law), and interoperability (the capacity of the digital systems to exchange and function seamlessly with existing cadastral and land registration databases) with existing cadastral infrastructure. In transitional or post-conflict settings like Georgia and Ukraine, international pilot projects have explored blockchain's feasibility (Mueller & Seifert, 2019), though most remain at the experimental or feasibility-assessment stage. Researchers continue to debate whether blockchain serves merely as a supplementary layer for data verification or whether it can structurally redefine how rights and land relationships are encoded and as data become more protected, they could be enforced in law and practice.

Land administration systems worldwide and CS as their integral part are increasingly seen as critical infrastructure requiring security and resilience. Many scholars are concerned about rapid digitization that has expanded LAS vulnerability: cadastral databases now store sensitive personal and tenure data, integrate with financial and government systems, and often run on outdated software with many access points (Lengoiboni, et al., 2019). This creates new attack surfaces for cybercrime. Recent studies emphasize that cybersecurity risk management is crucial for LAS: without it, data integrity (and thus property rights) can be compromised (Blin et al., 2025). For example, Blin et al. (2023) note that manual workflows and lack of controls in land transactions yield high risks to cadastral data and call for structured frameworks to identify and mitigate threats. Similarly, Blin et al. (2025) find that legacy technologies, multiple user profiles, and integration with other databases make LAS "highly valuable targets" for cyberattack. They advocate

integrating Cyber Threat Intelligence (CTI)<sup>8</sup> approach into LAS operations to anticipate and counter threats.

Van der Molen (2016) and Lemmen et al. (2020) pointed out that growing reliance on digital platforms such as e-conveyancing systems, cloud-hosted spatial data, and blockchain applications has exposed cadastral systems to new vulnerabilities. Land registry hacking incidents in countries like Greece in 2024 have highlighted the need for encrypted transactions, digital identity verification, and disaster recovery protocols (Protothema 2024).

Besides the cyber issues, experts also link land insecurity with conflict. Studies show that unaddressed land disputes and insecure tenure can fuel violence and undermine peace (Prettitore, 2021; FAO, 2005). Cadastres are dynamic: conflict destroys records and property, and post-conflict rebuilding of land administration is essential for stability (Kuryltsiv, Kryshenyk, 2022; Blin et al., 2023). For instance, Todorovski et al. and Manirakiza (cited in Kuryltsiv & Kryshenyk, 2022) argue that any post-conflict recovery must restore cadastre legitimacy and functionality, since unresolved land claims tend to rekindle disputes.

In sum, majority of international reports and publications stress that secure, transparent land administration, which is enabled by robust digital systems in combination with legal safeguards, is fundamental to tenure security, economic development, and social stability.

### **3.2 Ukrainian research**

Ukraine constitutes a particularly relevant case for contemporary cadastral research because it combines three features that are rarely present simultaneously: a nationwide cadastral system developed through extensive reform efforts, ongoing alignment with European land governance standards, and the need to maintain land administration functionality under conditions of prolonged armed conflict. This combination makes Ukraine an informative case for examining how cadastral systems evolve structurally and respond to extreme institutional, legal, and security stress.

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<sup>8</sup> Cyber Threat Intelligence (CTI) is a proactive approach to cybersecurity that involves collecting, analyzing, and interpreting data about potential and ongoing cyber threats (<https://www.picussecurity.com>).

Within the Ukrainian context, scholarly attention to cadastral reform intensified after independence in 1991, with growing urgency following land privatization efforts in the late 1990s and early 2000s. Ukrainian academics such as Bordyuzha (2012) and Popov (2019) examined institutional fragmentation between the State Land Cadastre and land registry systems (legal definitions of these systems are stated in paper 1), pointing out inconsistencies in data, legal standards, and interoperability. Ukraine's reform efforts were initially hampered by bureaucratic inertia and overlapping mandates between land administration institutions, particularly due to fragmented responsibilities and parallel registries (Popov, 2019). However, since the launch of the nationwide digital system of State Land Cadastre in 2013, supported by the World Bank and USAID, the country has moved toward greater transparency, public access to data, and digital coordination.

Yet, despite visible progress, significant structural challenges persist. The war that began in 2014 and escalated in 2022 has further strained land governance. According to the UN FAO (2022), wartime destruction of land records, displacement of populations, and contested land boundaries pose grave risks to cadastral integrity and legal security. Recent publications by Ukrainian scholars (e.g., Malashevskiy et. al., 2025) have begun exploring the functioning of the state land cadastre under martial law. Such system needs to be designed to retain functionality during and after crisis, with data redundancy, cloud-based storage, and decentralized access.

Security considerations have become a central theme in the research field. Discussions about the cybersecurity of land information systems became especially urgent after a series of cyberattacks on government infrastructure in 2017. Although the StateGeoCadastre (Ukrainian national agency responsible for maintenance of the state land cadastre; described in detail in paper 1) has since adopted backup protocols and upgraded its server infrastructure, critics (e.g., Popov, 2019) note that legal frameworks for cyber-resilience in the land sector remain underdeveloped. The World Bank's Land Governance Assessment Framework (LGAF) noted in 2020 that Ukraine still lacked adequate policy integration between digital infrastructure and legal standards in land administration.

The drive for modernization in Ukraine has also been influenced by cross-national policy diffusion. The EU's INSPIRE Directive<sup>9</sup> and the implementation of spatial data infrastructure (SDI)<sup>10</sup> have had normative and technical impact. Popov (2019) suggests that integration with European standards has contributed to the gradual alignment of Ukraine's data interoperability and open-access frameworks with EU norms. However, this alignment has often remained more aspirational than consistently implemented in practice (Popov, 2019, Malashevskiy et. al., 2025).

More recently, Ukrainian academic discourse has begun to explore the potential role of decentralized digital technologies in cadastral and land registration reform. While no full-scale blockchain-based cadastral systems have been implemented, studies by Bida and Petrova (2019) examine how distributed ledger technologies could enhance transparency, traceability, and protection against unauthorized data manipulation. The central argument is that a distributed system, where transaction records are validated by consensus and stored redundantly across nodes, could reduce opportunities for tampering, document forgery, and unauthorized changes. Such issues have historically plagued Ukraine's land administration. Furthermore, researchers are examining the legal and infrastructural constraints that may hinder such innovation, including the rigidity of legacy systems, unclear regulatory frameworks, and the need for digital identity verification protocols (e.g., Shapenko et al., 2026). These emerging publications reflect a growing interest in adopting secure-by-design digital infrastructures to rebuild institutional trust and reinforce tenure security, particularly in post-conflict and high-corruption contexts in Ukraine.

Summing up, contemporary cadastral research increasingly integrates systematic, interdisciplinary perspectives with applied digital and governance frameworks. This means that current studies no longer treat the cadastral system solely as a mapping or registration tool but as a dynamic component of

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<sup>9</sup> The INSPIRE Directive (Infrastructure for Spatial Information in the European Community) was created to build a shared EU system for spatial data (Directive 2007/2/EC). This system supports environmental policies and any activities that may affect the environment. The Directive requires public authorities that work with spatial data, such as creating, receiving, managing, or updating it, to make sure their information about land and sea areas is part of this EU-wide system.

<sup>10</sup> A Spatial Data Infrastructure (SDI) is a system made up of policies, organizations, technologies, data, and people that makes it easier to share and use geographic information. It does this by setting common standards and formats so that different systems and users can access and work with the data seamlessly (Tochovska et. al. 2012).

land administration that interacts with technology, law, and policy. The Ukrainian case adds complexity to this picture, which is marked by both impressive strides in openness and modernization, and persistent challenges of legal fragmentation, wartime disruption, and digital vulnerability. Continued scholarly engagement, particularly from Ukrainian researchers, will be critical to shaping a resilient, legally secure CS.

## 4 Research design and methods

This chapter describes the research design applied in this study as well as selection of material / data for the two papers. It then discusses the methods used in those papers as well as reflections on ethical considerations and limitations of the study.

### 4.1 Research design

The research design of a study refers to the plan for its implementation. It typically encompasses, for example, the formulation of research questions, the selection of an appropriate theoretical framework, and the choice of research methods (Flick, 2009). The research design of this thesis is presented in the following paragraphs, focusing on the research questions, the theoretical framework that informs the study, and the methodological approach adopted.

The major focus of this thesis is the structural key elements of the cadastral system in Ukraine, examined in relation to its capacity to ensure functionality, security, and resilience under conditions of institutional stress. This focus is reflected in both the formulation of the research questions and the design of the two constituent papers. Paper 1 examined and compared the structure of cadastral systems in Ukraine and three other European countries that belong to different legal traditions with assistance of systems theory concepts and comparative law method. The idea behind this approach was to explore how various legal traditions affect cadastral design and functionality and what need to be improved in order to get more resilient and sustainable model of land recording for Ukraine. Paper 2 is focused on the analysis of the resilience of Ukrainian land administration system and cadastral system as its integral part

in a wartime through the lens of different LAS models. It examined the institutional and legal framework for land administration before the conflict and the changes introduced in Ukraine since February 2022. Together, the two papers allow the thesis to address the Ukrainian cadastral system from different angles and to link structural design with practical performance. By combining comparative analysis with the examination of wartime operation, the study moves beyond description of institutional arrangements and evaluates how the existing design influences the system's ability to function under conditions of stress. Thereby two papers support the development conclusions regarding future model of resilient CS in Ukraine.

Three research questions (see section 1.2) were formulated based on the aim of this thesis. Firstly, the aim was to “analyze the existing key elements of CS in some developed countries and propose the optimal solution for Ukraine as an example of a developing country striving to reform its land relations in accordance with the best practices that exist in Europe. Secondly the aim was to examine how the Ukrainian LAS has responded to the ongoing challenges posed by martial law period, taking into account the historical background, the existing land administration landscape, the weaknesses present prior to the full-scale military conflict”. Cadastral system theory as well as the theory of resilience framework were selected as theoretical framework. As it was mentioned in section 2, analysis of cadastral system theory is important because “this term is central in this thesis”, while resilience framework is important “to understand the principles of secure and resilient land administration during martial law period”. Previous studies described in section 3 demonstrated wide use of these concepts in various research fields.

This thesis adopts a qualitative research approach, focusing on the interpretation of legal sources, policy documents, and academic literature. Such an approach seeks to develop a conceptual understanding of how land administration systems operate and adapt under specific legal, institutional, and geopolitical conditions such as martial law. Accordingly, the analysis of laws, reports from international and governmental organizations, and scholarly publications serve as the research strategy for both papers. The study employs qualitative techniques such as document analysis and comparative case examination, which enable the identification of key themes, institutional patterns, and governance mechanisms relevant to the resilience of land administration systems.

## 4.2 Selection of material/ data for paper 1

The comparative nature of Paper 1 required the selection of material that would allow for both cross-national comparison and theoretical interpretation. Two principal categories of material were employed: (1) legal and institutional documents and (2) academic and policy literature.

First, the jurisdictional selection was guided by methodological principles of comparative law which are based on the functionalist approach and the inclusion of countries representing different legal traditions (Kischel, 2019; Eberle, 2011). Four countries were chosen such as England and Wales, France, Sweden, and Ukraine. The reason for such selection is that they represent distinct legal traditions and development trajectories of cadastral systems. England and Wales embody the common law tradition with a title registration model; France, the civil law tradition with its dual system of cadastre and deeds registry; Sweden, the Nordic civil tradition with a technologically advanced, integrated system; and Ukraine, the civil law tradition in a transitional post-Soviet context seeking alignment with European standards. The functionalist approach applied for this selection of countries assumes that, although legal systems differ in structure, they are designed to solve similar social problems, such as ensuring secure land ownership. At the same time, the analysis is grounded in a close examination of national legal texts, statutory frameworks, and institutional regulations, allowing comparison not only of functional outcomes but also of the formal legal structures through which these functions are implemented. By prioritizing variation in institutional design, this approach enables comparison of how distinct cadastral, or land administration systems fulfill equivalent functions such as ensuring tenure security, managing land information, or supporting governance. The purpose is to reveal both convergence (shared solutions or principles) and divergence (context-specific adaptations) in how comparable challenges are addressed (Van Hoecke, 2011).

Second, the data sources included legislative texts, policy frameworks, and official reports of the respective cadastral authorities. These comprised foundational laws such as the Law of Property Act 1925 and Land Registration Act 2002 in England; the Code Général des Impôts and Décret n° 55-22 (1955) in France; the Real Property Formation Act (SFS 1970:988) and Land Code (SFS 1970:994) in Sweden; and the Land Code of Ukraine (2001), Law on State Registration of Rights (2004), and Law on the State Land Cadastre (2012) in

Ukraine. By analyzing these texts, the study was able to trace the juridical, technical, organizational, and financial dimensions of CS.

Third, the study drew on academic literature and international standards to provide a theoretical and comparative framework. Influential works included Zevenbergen (2002) on systems of land registration, Larsson (1991) on cadastral systems, and Williamson (2001) on cadastral reform. International guidelines from organizations such as FAO (2019), UNECE (1996), and UN-Habitat (2008) provided comparative benchmarks and highlighted principles of good land governance. Systems theory sources (von Bertalanffy, 1968; Checkland, 1999) informed the conceptualization of cadastral systems as open, interacting entities composed of legal, technical, organizational, and financial “aspect systems.”

To summarize, the rationale for this material selection was threefold. First, it ensured comparability by focusing on countries representing distinct legal families (like common law, civil law and post-soviet law), a common technique in comparative law research (Eberle, 2011; Kischel, 2019). Second, it allowed the analysis to go beyond legal texts and examine how the system is organized, funded, and supported by digital technologies. Third, it offered practical relevance: the inclusion of Ukraine as a transitional case provided an applied dimension to the study, highlighting pathways for reform in contexts of systematic modernization.

### **4.3 Selection of material/ data for paper 2**

The empirical basis of Paper 2 was derived from two complementary types of material: documentary sources (legal and other regulatory texts) and scholarly literature. This choice was deliberate, reflecting both the aim of the paper and the constraints of conducting research during martial law period in Ukraine.

First, legal and other regulatory documents constituted the primary data for tracing institutional and legislative responses of the Ukrainian land administration system (ULAS) under martial law. These included the Constitution of Ukraine (1996), the Land Code (2001), the Law on the State Land Cadastre (2011), presidential decrees, and Cabinet of Ministers’ resolutions issued between February 2022 and December 2024. By analyzing these sources, it was possible to examine the mechanisms through which the state sought to safeguard land rights, regulate transfers, and maintain cadastral functions during wartime. The reliance on documentary analysis follows the jurisprudential tradition in legal studies of systematic

interpretation of statutory texts (Moncrieff, 2020; Sunstein & Vermeule, 2003), which in turn makes it possible to identify the strengths and limitations of land administration institutions in terms of their functions, resources, and performance.

Second, reports and studies published by international organizations such as UN-Habitat, the World Bank, FAO, and FIG were analyzed to contextualize Ukraine's case within broader theoretical and empirical debates on land administration, resilience, and conflict. The analysis encompassed academic studies, international policy reports, and methodological frameworks published by organizations such as FAO (2021), UN-Habitat (2008, 2020), and the World Bank (2003, 2021). Comparative materials, including case studies of land administration in post-conflict settings (Todorovski et al., 2016; Unruh & Williams, 2013), were included to highlight similarities and differences with the Ukrainian experience. The use of publications (literature) study aligns with recommendations in qualitative research methodology, where scholar sources are employed to establish theoretical grounding and identify analytical gaps (Creswell & Creswell, 2018; Williamson et al., 2010).

The selection of these materials was guided by both relevance and availability. Given the security situation in Ukraine, it was not feasible to collect primary empirical data (such as interviews with land administrators or displaced persons). Documentary sources were therefore prioritized as they offer reliable, verifiable, and contemporaneous evidence of institutional responses. At the same time, drawing on global literature made it possible to compare the Ukrainian case across several theoretical perspectives on land administration and resilience, ensuring that the analysis was not conducted in isolation but aligned with broader conceptual models.

This two-pronged selection strategy ensured that the study could meet its primary objective: to assess the adaptability and resilience of the ULAS during martial law by interpreting its legal responses considering international knowledge on crisis land administration.

#### **4.4 Methods used**

This thesis adopts a qualitative approach because it seeks to interpret legal norms, institutional arrangements, and governance practices rather than to measure statistical relationships. Given that the research questions concern institutional structure, legal development, and resilience under crisis

conditions, qualitative analysis of legislation, policy documents, and academic literature provides an appropriate methodological foundation for that.

The use of a qualitative research approach allows the study to examine how meanings, interpretations, and relationships emerge between institutional, legal, and technical elements of land administration systems, rather than seeking to quantify or generalize findings statistically (Flick, 2014). This approach emphasizes understanding the *context* and *interdependence* of these elements, focusing on depth and explanation instead of measurement. The combination of academic literature study, textual analysis of legal sources, and systems theory created a complementary framework that strengthened the study's reliability by enabling different perspectives to inform and support one another (Creswell & Creswell, 2018; Williamson et al., 2010).

This approach reflects Flick's (2014) view that qualitative inquiry is particularly suited to examining complex social and institutional arrangements where multiple dimensions interact. In this sense, cadastral systems were studied not as isolated technical registers, but as dynamic socio-legal systems shaped by historical trajectories and contemporary challenges.

#### **4.4.1 Literature study**

Literature study was undertaken to establish theoretical foundation and situate the study within existing debates on land administration, cadastral systems, and resilience. Sources included peer-reviewed scientific journal articles, monographs, papers published in conference proceedings, and international policy reports. To ensure breadth and rigor, materials were collected through academic databases such as Scopus, Web of Science, and Google Scholar, alongside the literature from international organizations (FAO, UN-Habitat, World Bank).

Works published between 1990 and 2024 were included to ensure both coverage of foundational contributions that established key concepts in cadastral and land administration research (e.g., systems perspectives, land registration models, and institutional reform trajectories) and coverage of the most recent debates on digitalization, institutional design, cybersecurity, resilience, and crisis land administration. However, the study was conducted with the emphasis on the recent literature, particularly publications from approximately 2014–2024, as these best reflect the current state of research and the rapid evolution of digital land administration, ability of different digital systems to exchange, interpret, and use data effectively

(interoperability), and security challenges. Older sources were used selectively and primarily to clarify enduring conceptual frameworks or to trace the origins of widely adopted models that remain influential in contemporary literature. In addition, to capture up-to-date knowledge on Ukraine and wartime land administration, the review intentionally included recent policy reports and peer-reviewed studies published after 2022 where available, since this field is developing rapidly and is sensitive to new legal and institutional developments. Especially, priority was given to peer-reviewed academic studies, international policy reports (e.g., FAO, UN-Habitat, World Bank), and comparative case studies addressing land administration in transitional or conflict-affected settings. Publications were selected for their discussion of institutional frameworks, governance mechanisms, or systemic reforms relevant to cadastral systems.

Conversely, sources that were purely technical or engineering-oriented have been excluded from the study since these lacked an institutional or governance perspective. Examples of such sources are papers limited to surveying methodologies, geospatial data processing, or software design. In this study, I also exclude non-academic commentaries, short policy briefs without methodological transparency (documents presenting conclusions or recommendations without explaining their data sources or analytical methods), and materials unrelated to land administration or property rights.

Following best practice in qualitative synthesis (Booth, Sutton & Papaioannou, 2016), sources were coded thematically around three domains: (1) models of cadastral systems, (2) resilience and crisis land administration, and (3) post-conflict reconstruction. This study enabled contextualization of Ukrainian developments within the global debates while also identifying analytical gaps addressed by the thesis.

#### **4.4.2 Legal method**

Legal analysis formed the methodological foundation of both papers.

Paper 1 employed the comparative law method with functionalist approach (Kischel, 2019; Eberle, 2011). Functionalism in comparative law rests on the premise that different legal systems can be compared meaningfully by examining how they fulfill similar societal functions or address comparable problems, rather than merely placing their legal doctrines side by side without regard to context or purpose. As Zweigert and Kötz (1998) famously articulated, the central idea of the functionalist method is that “the legal rule is

a response to a social need.” Thus, the comparison focuses on how various jurisdictions achieve objectives such as tenure security, cadastral integration, or fiscal balance within their own institutional and cultural settings.

The functionalist approach also implies a degree of methodological neutrality. It avoids normative ranking of legal systems and instead seeks to uncover patterns of equivalence or divergence that may inspire reform or policy learning (Kischel, 2019). In this thesis, the approach allowed comparison across distinct legal traditions such as common law (England and Wales), civil law (France), Nordic mixed systems (Sweden), and post-Soviet transitional law (Ukraine), by situating each system’s solutions within its historical and institutional context.

The comparative analysis also drew on international guidelines and soft-law<sup>11</sup> documents from organizations such as FAO, UNECE, and UN-Habitat. These materials offered common international standards for good governance, transparency, and sustainable practices in land administration.

Paper 2, by contrast, applied dogmatic legal method, which is grounded in the systematic examination, interpretation, and synthesis of legal sources (Nääv & Zamboni, 2018; Peczenik, 2008; Van Hoecke, 2011). In legal scholarship, the dogmatic method focuses on identifying, organizing, and critically analyzing the existing body of law within a given jurisdiction (Nääv & Zamboni, 2018; Peczenik, 2008). It seeks internal coherence and logical consistency of legal norms, emphasizing what the law is rather than what it ought to be.

From a theoretical point of view, dogmatic legal method follows a normative approach that treats laws, court decisions, and administrative regulations as authoritative legal texts that should be carefully interpreted using recognized methods of legal reasoning (Peczenik, 2008). As explained by Nääv & Zamboni (2018), this approach aims to reconstruct the system of legal norms that govern a specific domain by clarifying terminology, resolving ambiguities, and systematizing principles. In the context of this thesis, such an approach is particularly relevant to the martial law framework, since emergency legislation often modifies or suspends ordinary legal procedures.

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<sup>11</sup> The term *soft law* generally refers to non-binding international instruments such as guidelines, declarations, or principles that, while not legally enforceable, influence state behavior and policy development (Shelton, 2008; Abbott & Snidal, 2000).

To ensure that the dogmatic method in Paper 2 remained connected to practical realities, it was complemented by a contextual perspective. In this method, the emergency decrees were examined not only for their formal legal content but also trying their practical function as instruments of crisis management. This broader view linked the close study of legal norms with an understanding of how those norms were applied and operated within the wider institutional and wartime context.

#### **4.4.3 Systems Approach**

The systems approach is used in this study to understand cadastral systems as interconnected structures in which legal, technical, organizational, and financial aspects interact. In Paper 1, this approach is combined with the comparative method to analyze and compare how these aspects are organized in different countries.

A system can be described as a set of elements that work together to achieve a common goal (Checkland, 1999). According to general systems theory, developed by Ludwig von Bertalanffy (1968), every system interacts with its environment through inputs, internal processes, and outputs. Applied to land administration, this means that cadastral systems are influenced by external factors such as law, policy, economy, and technology, and in turn produce outcomes such as tenure security, fair taxation, and transparent governance (Williamson et al., 2010).

The systems approach emphasizes relationships and interdependence between the parts of one system. Each part of cadastral system such as land registration, surveying, or data management has its own function, but none can operate effectively in isolation. Studying these connections helps identify where weaknesses occur, for example when institutions fail to coordinate or when legal frameworks are inconsistent (Dale & McLaughlin, 2000).

A key distinction within systems thinking is between subsystems and aspect systems. Subsystems are parts of the whole that perform specific functions (von Bertalanffy, 1968) The examples of such subsystems could be found in the land registration authority or mapping agency. Aspect systems, on the other hand, represent analytical perspectives (e.g. juridical, technical, organizational, and financial) that run through all subsystems and help explain how the overall system operates (Zevenbergen, 2002). Viewing cadastral systems through these aspect systems makes it possible to understand how different dimensions interact and where reforms should be targeted.

The “black box” model is another concept in systems approach that was applied in Paper 1. It describes a system as a structure that transforms inputs into outputs, while the internal processes remain partially or fully unobserved. Inputs include legal norms, institutional arrangements, technical infrastructure, and financial resources, while outputs represent the results produced by the system, such as legal certainty and reliable land information. The internal processes that transform inputs into outputs (e.g., registration procedures and data management) are treated as a “black box” and are not analyzed in detail. Instead, the system is evaluated by examining how it converts inputs into desired outputs. If the outputs are weak or inconsistent, this indicates shortcomings in the design or interaction of the system’s components (Heylighen, 1998).

In this thesis, the black box model is used to compare how different cadastral systems transform their legal and institutional design (inputs) into practical outcomes (outputs), such as tenure security (legal security) and administrative efficiency (fair real property taxation). Rather than analyzing all detailed administrative procedures in CS, the study evaluates whether the overall structure of each CS enables it to deliver stable, transparent, and reliable land administration services. This approach allows for functional comparison across jurisdictions with different legal traditions and institutional arrangements.

#### **4.4.4 Justification of the methods used**

This study combines qualitative methods, specifically literature study, legal (dogmatic) method, and comparative law method, supported by a systems approach to examine cadastral systems from different perspectives. Using more than one method made it possible to look at the topic in a fuller and more balanced way, as each method offered its own strengths and helped to reduce the limitations of the others. The legal analysis examined both the laws governing land administration and their application. The literature study placed these findings in a wider theoretical and international context, showing how similar challenges have been addressed in different countries. The systems approach provided a broader perspective for understanding CS as integrated wholes, where its legal, technical, financial, and organizational aspects interact continuously. The legal aspect defines rights and procedures that guide technical data collection and management; the technical aspect translates those rules into spatial and digital records; financial aspect ensures maintenance and development of CS; and organizational aspect coordinates the functions of defining legal rules, managing technical systems, and ensuring

financial support. Viewed together, these interactions explain how well the system can maintain stability during normal operation and how it can recover or adapt (its resilience) under conditions of war or crisis.

#### **4.4.5 Ethical considerations**

Although the study relied primarily on secondary sources rather than human participants, ethical reflection is central. Following the European Code of Conduct for Research Integrity (ALLEA, 2017), materials were selected, cited, and interpreted with transparency and accuracy. Sensitive legal and policy documents produced during wartime were handled with careful attention to their context, ensuring that their content and purpose were accurately represented and not interpreted outside their exceptional legal circumstances.

The study aligns with ethical standards in qualitative and legal research, where the key issues are integrity of interpretation, proper attribution, and contextual sensitivity rather than informed consent (Resnik, 2018; SFS 2003:460, Act on ethical review of research involving humans). The use of international reports and national legislation also requires consideration of open access and copyright compliance.

#### **4.4.6 Limitations**

Every research project is shaped not only by its design but also by the constraints and trade-offs that accompany it. In qualitative and legal research, acknowledging limitations is particularly important because findings are often context-dependent and rely on interpretation of texts and secondary materials (Maxwell, 2012; Yin, 2018). This thesis, conducted taking into account highly dynamic martial law environment in Ukraine and with a focus on comparative institutional analysis, faced methodological constraints that inevitably influenced the scope and generalizability of its results. These limitations differ between Paper 1 and Paper 2, reflecting their respective designs and objectives, yet they also share common features: both relied primarily on documentary analysis and secondary data. Paper 1 relied mainly on publicly available international reports and studies. While access to such sources was not significantly restricted, the study did not include primary empirical data (such as interviews or field observations). This limitation was accepted to keep the analysis consistent across countries and to allow comparison using similar sources. In case of Paper 2 access to primary materials in Ukraine was constrained by wartime conditions and data-security restrictions.

Paper 1 adopted a comparative approach to analyzing cadastral systems in four countries. This enabled theoretical richness but also presents methodological challenges such as:

- No *court cases* as well as no preparatory works for introducing the new legislation were considered in the paper.
- *Restricted case selection*. Only four jurisdictions were included, chosen purposively to represent different legal traditions. While this enhances theoretical comparability, it limits generalizability to other systems (Kischel, 2019).
- *Comparability across legal cultures*. The functionalist approach in comparative law assumes that similar societal needs can be addressed through different institutional solutions. However, this risks oversimplifying unique socio-legal contexts (Eberle, 2011).
- *Reliance on secondary sources and translations*. Some national materials (especially in France and Sweden) were accessed in English translation or through secondary commentaries (academic analyses or institutional reports interpreting the original legal texts), which raises the risk of nuance being lost or misinterpreted.
- *Exclusion of user perspectives*. The analysis focused on legal and institutional design but did not capture how cadastral systems are perceived by users, professionals, or administrators. Issues such as accessibility, trust, or efficiency from a stakeholder perspective thus remain outside the scope of the thesis.

Paper 2 relied primarily on the analysis of legislative sources (laws, decrees, and regulations) and documentary sources (policy reports and institutional publications) to trace the resilience of the Ukrainian LAS under martial law. While this provided authoritative insight into state responses, several limitations remain such as:

- *Absence of primary field data*. Security risks and ethical constraints made it impossible to conduct interviews with land administrators, displaced persons, or policymakers. This limited the ability to capture lived experiences or implementation challenges at the local level (Maxwell, 2012).
- *Rapidly evolving legal environment*. Martial law in Ukraine generated frequent legislative amendments. The study analyzed materials up to December 2024, but subsequent changes may alter institutional dynamics, highlighting the temporal limitation of the findings.

- *Potential state bias.* Many of the main sources were official government decrees and communications, which primarily reflect the state's formal perspective. Such documents may underrepresent informal land practices, downplay corruption risks, or overlook implementation gaps between legal prescriptions and administrative reality, since their purpose is often to document compliance rather than expose deficiencies. Without field validation, findings must be interpreted with caution.
- *Contextual sensitivity.* Laws and policies issued during war were intended as emergency measures. Evaluating them against peacetime standards risks overlooking their temporary and adaptive nature (Unruh & Williams, 2013).

Both papers illustrate different types of methodological trade-offs. In Paper 1, the comparative design across several countries required a balance between breadth and depth, limiting the level of detail that could be achieved for each case. In Paper 2, the research was conducted under external constraints related to the wartime situation in Ukraine, which restricted access to primary data and necessitated reliance on documentary and legislative sources.

These limitations do not diminish the value of the findings. Instead, they define the boundaries of their applicability. The conclusions are context-specific and most relevant to the legal and institutional environments studied.

Future research could extend this work through empirical field studies once conditions permit. It could also include longitudinal analyses of Ukraine's post-war land administration reforms. In addition, broader comparative studies of cadastral modernization and resilience across different governance settings would be valuable.

#### **4.4.7 Declaration of generative AI and AI-assisted technologies**

During the preparation of this thesis, the author used ChatGPT, a language model developed by OpenAI, to improve readability, language, and grammar. The author reviewed and edited the content, taking full responsibility for the final publication.



## 5 Summary of papers and discussion on findings

In this chapter major highlights of paper 1 and paper 2 are summarized. Findings of both papers are then discussed.

### 5.1 Summary of paper 1: Comparative Study of Cadastral Systems

**Purpose.** The paper aims to compare the cadastral systems (CS) of four European countries such as England (including Wales), France, Sweden, and Ukraine in order to explore how different legal traditions, administrative models, and technical solutions shape cadastral structure and performance. The goal is to identify common patterns and context-specific challenges, and to outline lessons useful for Ukraine’s ongoing cadastral and land-administration reforms. By combining systems theory with comparative method, the study develops an analytical model that links juridical, technical, organizational, and financial “aspect systems” to the overall resilience and functionality of cadastral institutions.

**Method.** The research applies a systems approach (von Bertalanffy 1968; Checkland 1999) together with the functionalist method of comparative law (Kischel 2019; Eberle 2011).

Using systems approach, the cadastral system is conceptualized as an integrated socio-technical entity that is a structure in which legal norms, institutional actors, and technical infrastructures are interdependent. The juridical, technical, organizational, and financial subsystems interact continuously: laws define data requirements and responsibilities, technology

implements them, organizations coordinate their application, and financial mechanisms ensure sustainability. This perspective follows the framework proposed by Williamson, Enemark, Wallace, and Rajabifard (2010). In their view, land administration systems function as socio-technical infrastructures that integrate technology with legal and institutional arrangements to support tenure security, land valuation, and spatial management.

The comparative law method allows for cross-jurisdictional analysis of how different legal systems address similar societal needs or functions, such as ownership protection and fiscal land administration, even when their legal frameworks and institutional arrangements differ (Zweigert & Kötz 1998; Van Hoecke 2011).

**Data and case study.** The analysis is based on national legal acts, official regulations, and institutional data from all four countries, complemented by academic sources (e.g. Larsson 1991; Zevenbergen 2002; Williamson et al. 2010) and publications of international organisations (e.g. FAO 2012). In total, over fifty statutes and policy documents were reviewed.

Data on organizational structure and digitalization were drawn from institutional reports such as those of HM Land Registry<sup>12</sup>, DGFIP<sup>13</sup>, Lantmäteriet<sup>14</sup>, and StateGeoCadastre<sup>15</sup>.

Each case was selected based on its distinct legal and institutional model, reflecting different legal families in Europe. England and Wales represent the common law tradition (Zweigert & Kötz, 1998), characterized by the central role of judicial precedent and a title-registration system providing state-backed guarantees of ownership. France exemplifies the civil law tradition (Zweigert & Kötz, 1998), grounded in comprehensive codification and operating a dual system consisting of a fiscal cadastre and a deeds registry. Sweden is also a civil

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<sup>12</sup> HM Land Registry - non-ministerial government department in England and Wales responsible for maintaining the Land Register, which records ownership of land and property, along with certain rights and interests affecting it (HM Land Registry 2025. Practice Guide 63).

<sup>13</sup> DGFIP (Direction générale des finances publiques) – an agency of the Ministry of Economy, Finance and Industrial and Digital Sovereignty responsible for the maintenance of the cadastre and land register in France (DGFIP. (n.d.). Nos services – Direction générale des finances publiques).

<sup>14</sup> Lantmäteriet (The Swedish Mapping, Cadastral and Land Registration Authority) – governmental authority responsible for the maintenance of the Real Property Register and Cadastral Index Map in Sweden (Andersson & Ersbo 2023).

<sup>15</sup> StateGeoCadastre (State Service of Ukraine for Geodesy, Cartography and Cadastre) – Ukrainian governmental agency responsible for the maintenance of the state land cadastre (Statement on State Service of Ukraine for Geodesy, Cartography and Cadastre, # 1302, 09.12.2021, par. 1)

law country, but it belongs to the Nordic branch of civil law systems (Zweigert & Kötz, 1998), which is characterized by relatively limited codification, more influenced by precedent than is typical of "civil law" in other countries, strong administrative practice, and pragmatic legislative development. Ukraine reflects a post-Soviet legal system with civil law foundations, shaped by codified legislation but undergoing significant institutional reform, including the development of dual registers for land parcels and ownership rights.

**Results.** The comparative analysis reveals several key distinctions among the four examined systems:

(1) Legal foundations: The title registration system of England and Wales is based on the principle of state-guaranteed title, where registration has constitutive effect and the register itself provides conclusive proof of ownership. This model prioritizes legal certainty and transactional security, supported by indemnity mechanisms in case of registry error.

In France, the system is based on deeds registration combined with a separate fiscal cadastre. Registration records transactions rather than guaranteeing title, and legal validity depends on the underlying contract. The cadastre primarily serves taxation and parcel identification purposes, resulting in a system that emphasizes fiscal completeness and documentary traceability rather than absolute title security.

Sweden operates an integrated real property registration system within a unified institutional framework, where cadastral surveying, property formation, and land registration are closely coordinated. Registration has strong legal effect, and the system combines high legal certainty with comprehensive spatial and administrative integration.

Ukraine maintains a dual structure consisting of the State Land Cadastre (parcel-based spatial information) and the Register of Property Rights (registration of rights to real property). Although reforms have strengthened digitalization and interoperability, the separation between these registers and ongoing institutional development contribute to a hybrid and evolving legal framework.

(2) Institutional integration: In Sweden, cadastral surveying, property formation, and land registration are carried out within a single public authority, Lantmäteriet. This organizational unity allows legal and spatial decisions to be closely coordinated and reduces duplication between institutions.

In England and Wales, land registration is centralized under HM Land Registry, but cadastral mapping functions are institutionally separate. Although coordination mechanisms exist, the division of responsibilities means that legal registration and spatial data management are not fully unified within one authority.

In France, the fiscal cadastre and the deeds registry operate under different administrative structures, reflecting a historical separation between taxation and legal registration functions.

Ukraine also maintains separate institutions for the State Land Cadastre and the Register of Property Rights. While digital links between the registers have been strengthened, the continued institutional separation may create coordination challenges and limit full data integration.

(3) Technological maturity: All examined systems are formally digitalized; however, the degree of technological integration differs significantly. Sweden and France operate advanced GIS-based platforms with high levels of spatial precision and publicly accessible digital services, supporting transparency and data interoperability. England and Wales have a highly developed digital title registration system, but its historical reliance on document-based conveyancing means that spatial data integration is less central to the system's operation. Ukraine has made substantial progress in digitalizing the State Land Cadastre and enabling online access. Nevertheless, incomplete spatial coverage and inconsistencies between parcel data and rights registration remain structural limitations.

(4) Financing model: The systems also differ in how cadastral and registration activities are funded. England and Sweden largely rely on self-financing mechanisms based on user fees, which create incentives for efficiency and service orientation. France operates within a tax-based administrative model, where cadastral functions are closely linked to fiscal administration. Ukraine's system is primarily financed through the state budget, supplemented by service fees, which may constrain long-term technological investment and institutional development in periods of fiscal pressure.

(5) Outputs ("black box" model): From a functional perspective, the systems demonstrate different primary outputs. In England and Wales, the title registration system is designed primarily to ensure legal certainty and secure land transactions. In France, the dual structure emphasizes fiscal completeness and taxation accuracy, with legal protection relying more heavily on registered

ownership documents. Sweden combines strong title protection with comprehensive spatial and administrative integration, thereby delivering both legal security and fiscal reliability. Ukraine's system currently exhibits elements of both approaches but continues to evolve toward greater integration, aiming to achieve a similar balance between legal certainty and administrative coherence.

**Findings.** The comparative synthesis shows that cadastral resilience depends on the balance among four aspect systems. Analysis of juridical aspect system revealed that clear, enforceable property rights legislation ensures trust and predictability. The technical aspect revealed that digital interoperability (the capacity of different land-related information systems to exchange and use data seamlessly) and spatial completeness determine efficiency and accessibility. The organizational aspect showed that integration and transparency strengthen coordination between national, regional, and local authorities responsible for cadastral and land administration functions. And the financial aspect showed that stable funding models underpin continuity and innovation.

For Ukraine, the findings underscore that fragmentation between the State Land Cadastre and the Register of Property Rights remains a critical bottleneck. The study highlights the need for unified data platforms, stronger legal harmonization, and expansion of spatial coverage.

**Conclusions.** This study shows that cadastral systems reflect each country's legal traditions and institutional choices but can still evolve toward shared standards of efficiency and transparency. The comparison demonstrates that strong performance depends less on the legal family itself and more on how well the legal, technical, organizational, and financial parts of the system work together. In other words, resilience comes from integration and adaptability rather than from any single model. For Ukraine, the findings point to the need for deeper institutional coordination, clearer laws, and better digital connections between cadastral and land registration data. More generally, the study highlights that improving cadastral systems is not only a technical task—it is also about good governance, building public trust, and ensuring that land information supports both secure ownership and fair taxation.

**Contributions.** The paper contributes to cadastral research by applying a systems approach that examines cadastral systems through four key aspects: juridical, technical, organizational, and financial. These aspects serve as a way to organize the comparison, not as a formal model, enabling systematic

analysis of how different national systems are designed and how they function in practice according to available sources. The approach offers a clear basis for identifying reform priorities for the Ukrainian cadastral system.

**Implications.** For Ukrainian policymakers, the study provides practical guidance on merging cadastre and land-rights registers, expanding interoperability, and aligning national legislation with EU and UNECE standards. For land-administration practitioners, it demonstrates the value of unified governance, open geodata access, and sustainable fee-based financing. For researchers, it illustrates how combining systems thinking with comparative analysis deepens understanding of cadastral evolution and resilience.

**Limitations.** The paper relies on academic and documentary sources without empirical fieldwork or stakeholder interviews, limiting assessment of implementation realities. The comparison is restricted to four countries, so findings may not generalize to all legal traditions. Translation of legal texts and uneven data availability may have introduced interpretive bias.

## **5.2 Summary of paper 2: Resilience of the Ukrainian Land Administration System under Martial Law**

**Purpose.** The paper investigates how the Ukrainian Land Administration System (ULAS) has functioned and adapted under the extraordinary circumstances of martial law introduced after Russia's full-scale invasion in 2022. It aims to analyze the institutional and legal resilience of ULAS during wartime. The study explores how the system maintains its core functions while responding to the destruction of administrative and digital infrastructure, the displacement of staff and landholders, and governance disruptions caused by the 2022 Russian invasion and the ensuing state of martial law. The research addresses a gap in existing literature, which has largely concentrated on post-conflict land administration and reconstruction (e.g., Unruh, 2016; UN-Habitat, 2007; FAO, 2012), while offering limited insight into how land administration systems function and adapt during an ongoing-armed conflict. It applies a resilience framework to assess Ukraine's institutional adaptability and risk-management capacity.

**Method.** The study employs a qualitative approach integrating two complementary methods:

A literature study in order to analyze international models of land administration in crises. (including emergency, community-based, and digital systems). The purpose of the literature study is to identify theoretical and comparative foundations.

A legal study to examine Ukrainian legislative acts, presidential decrees, and ministerial regulations adopted before and after the introduction of martial law. Analysis of court cases was not included in the study, as Ukraine's civil law system is primarily based on statutory sources, and relevant wartime jurisprudence was limited.

This combined legal and literature-based approach enables a comprehensive assessment of both the formal regulatory framework and its practical implementation. Legal analysis allows for tracing institutional responses through legislative amendments and regulatory adjustments, while the review of scholarly and policy sources helps to evaluate how these changes functioned in practice. Together, this methodology facilitates the identification of institutional resilience mechanisms that sustained core system functions under wartime conditions. The analysis is structured in three steps: (1) describing ULAS before martial law; (2) identifying legal and institutional adjustments after introduction of martial law in February 2022; and (3) interpreting them through the lens of resilience framework.

**Data and case study.** The empirical basis consists of documentary sources such as Ukrainian laws, Cabinet resolutions, and decrees between 2022 and 2024. These sources are complemented by reports of international organizations and academic publications (e.g., FAO 2022; UN-Habitat 2007; Williamson et al. 2010). Ukraine serves as a single-case study, selected for its unique position as a large European country maintaining a nationwide land administration system amid an ongoing full-scale war. The case provides insight into how a digitized and partially decentralized LAS can remain operational despite security threats and institutional disruption.

**Results.** Three operational models through which the ULAS continues to function were identified in the paper: (1) emergency land administration, including temporary legislation for land use, forced alienation of property for defense, and simplified procedures for agricultural leases and damage assessment; (2) decentralized, community-based administration, where local and regional authorities manage urban reconstruction, temporary housing, and recovery programs under the Law on Priority Measures for Urban Planning Reform (2022); (3) interim digital and remote management, using e-

government, the State Land Cadastre, and cooperation with UNDP to maintain and protect spatial data despite restricted access. Additionally, Ukraine has begun developing post-conflict restitution frameworks aimed at quantifying and compensating land losses. It is also working on methodologies for environmental rehabilitation, addressing soil contamination, damaged ecosystems, and other war-related impacts on land.

**Findings.** The study shows that resilience in ULAS manifests in two intertwined capacities:

(1) Resilience in ULAS manifests in institutional adaptability in which the system preserved its multi-level structure while reallocating authority.

Furthermore, it was possible to establish the Agency for Restoration and Infrastructure Development (2023), and introduce flexible legal instruments for emergency land use.

(2) Resilience in ULAS manifests in risk management where the safeguarding of digital cadastral and property records, limitation of public access to sensitive data, and coordination with international partners illustrate proactive protection of land-related information and assets. These findings demonstrate that ULAS not only sustains essential operations but also lays the groundwork for post-war reconstruction through legislative foresight and inter-agency collaboration.

**Conclusions.** The Ukrainian case study demonstrates that the resilience of a land administration system during armed conflict depends on the ability to balance continuity, flexibility, and legitimacy. The integration of emergency legal measures, decentralized governance, and digital infrastructures has allowed Ukraine to preserve institutional functionality. However, full restoration and restitution of property rights will require long-term coordination between national authorities, local governments, and international partners.

**Contributions.** This article extends land administration studies by shifting attention from post-conflict reconstruction to the functioning of land administration systems during an ongoing-armed conflict. It applies the resilience framework to the analysis of land administration systems during armed conflict, offering a structured approach to assessing wartime adaptability. The idea of resilience is considered here by focusing on two main aspects such as institutional adaptability and risk management, and by identifying key operational models (see Results) through which land

administration continues to function during the war. Applied to the Ukrainian case, this model provides a structured and replicable approach for analyzing how land administration systems maintain core functions, adjust legal and institutional arrangements, and protect land-related data under crisis conditions, with relevance for both academic research and practical policy assessment.

**Implications.** For policymakers and practitioners, the study offers insights into: the need for legal frameworks that can be rapidly adapted to emergency conditions; the importance of data security and digital continuity of cadastral information; the role of local administrations and community-based governance in recovery; the potential of international cooperation for post-war restitution and environmental remediation. These implications are relevant for countries strengthening resilience of their land administration systems against crises.

**Limitations.** The research relies exclusively on documentary analysis without primary data such as interviews or field observations. Consequently, it cannot evaluate the practical effectiveness of wartime measures or the experiences of landowners and administrators in implementation. Some legislative changes are ongoing, so their outcomes remain uncertain. Finally, the focus on a single-country case limits generalization, though it provides valuable lessons for comparative studies.

### 5.3 Discussion and analysis of findings

This section addresses the research questions of the thesis by synthesizing the findings from Paper 1 and Paper 2. It further explores how the insights interconnect to inform a future resilient model of the Ukrainian cadastral system.

*RQ1: What should be the key elements of the Ukrainian cadastral system in comparison with England and Wales, France, and Sweden to achieve resilience?*

The comparative analysis presented in Paper 1 demonstrates that no single cadastral model can be directly transferred to Ukraine. However, several key elements of resilient systems can be identified. As shown in Paper 1, strong legal clarity and protection of property rights, particularly in England and Wales and Sweden, are essential for ensuring legal certainty. Furthermore, institutional integration or effective coordination between cadastral and land

registration functions (most clearly exemplified by Sweden) enhances system efficiency and reduces inconsistencies.

Paper 1 also highlights the importance of advanced digitalization and interoperable databases, which improve accessibility, transparency, and reliability of land information. In contrast, the Ukrainian cadastral system remains characterized by institutional fragmentation, particularly the separation between the State Land Cadastre and the Register of Property Rights, as well as incomplete data integration.

Based on the findings of Paper 1, a resilient CS in Ukraine should therefore focus on strengthening legal coherence, improving institutional coordination, and achieving full digital interoperability, while adapting these elements to national legal and institutional conditions.

*RQ2: What measures have been taken by the Ukrainian government or relevant institutions to maintain the land administration system during martial law?*

The findings of Paper 2 show that Ukraine has implemented a range of emergency legal and institutional measures to ensure the continuity of land administration under wartime conditions. As analyzed in Paper 2, these measures include temporary restrictions on certain land transactions, simplified procedures for essential land use, and legal provisions enabling the use of land for defense and reconstruction purposes. In addition, access to cadastral data has been partially restricted to protect sensitive information and reduce security risks.

Paper 2 further demonstrates that digital infrastructure has played a critical role in maintaining system functionality. The continued operation of the State Land Cadastre and the Register of Property Rights enabled ongoing registration processes and access to land information despite disruptions to physical offices. These findings illustrate how legal adaptability and digital capacity have been combined to preserve core land administration functions during the martial law period.

*RQ3: In what ways have historical developments and the existing land administration landscape influenced Ukraine's response to martial law?*

As discussed in Paper 2, Ukraine's response to wartime challenges has been strongly shaped by its historical and institutional development. The existence of a nationwide digital cadastral system prior to the full-scale invasion provided an important foundation for maintaining system functionality under

crisis conditions. At the same time, Paper 2 identifies long-standing structural challenges such as institutional fragmentation, incomplete territorial coverage, and limited interoperability between registers that have constrained the system's resilience.

These findings indicate that Ukraine's ability to sustain land administration during the war reflects both the progress achieved through earlier reforms and the persistence of structural weaknesses. The wartime experience therefore highlights the need for further institutional integration and technological development in order to enhance long-term resilience.

The findings further suggest that resilience was not only institutional but also community based. Professional networks of notaries, surveyors, and municipal administrations ensured continuity of services at the grassroots level, functioning as buffers when central institutions were under strain. This confirms the broader resilience literature, which holds that redundancy and diversity of actors strengthen systemic survival (Boin & Van Eeten, 2013). At the same time, the martial law period underscored a new dimension of the LAS: its role as a matter of national security. Protection of cadastral databases from cyberattacks and safeguarding of physical servers and archives emerged as critical priorities (Todorovsky et. al, 2016). Consequently, Paper 2 portrays the Ukrainian LAS as adaptive and partially resilient, but constrained by incomplete digitization, institutional fragmentation, and insufficient security safeguards.

Figure 2 illustrates how the two studies complement one another by addressing the Ukrainian cadastral system from two interconnected but distinct analytical perspectives. Paper 1 analyses the structural design of cadastral systems through a comparative and systems-based lens, identifying how juridical, technical, organizational, and financial aspects influence system performance and resilience. Paper 2, by contrast, examines how the existing land administration and cadastral system functioned under wartime conditions, focusing on institutional adaptability, emergency governance, and risk management in practice. Taken together, the papers link underlying structural characteristics and design choices of CS (Paper 1) with its observed wartime behavior (Paper 2), allowing the discussion to move from empirical response to crisis toward normative insights about the future model of a resilient Ukrainian cadastral system.

At the same time, the findings clarify the core characteristics that a resilient Ukrainian cadastral system must possess. Paper 1 underscores the importance

of structural coherence across juridical, technical, organisational, and financial aspects, while Paper 2 highlights the role of adaptability, redundancy, community involvement, and data protection under crisis conditions.

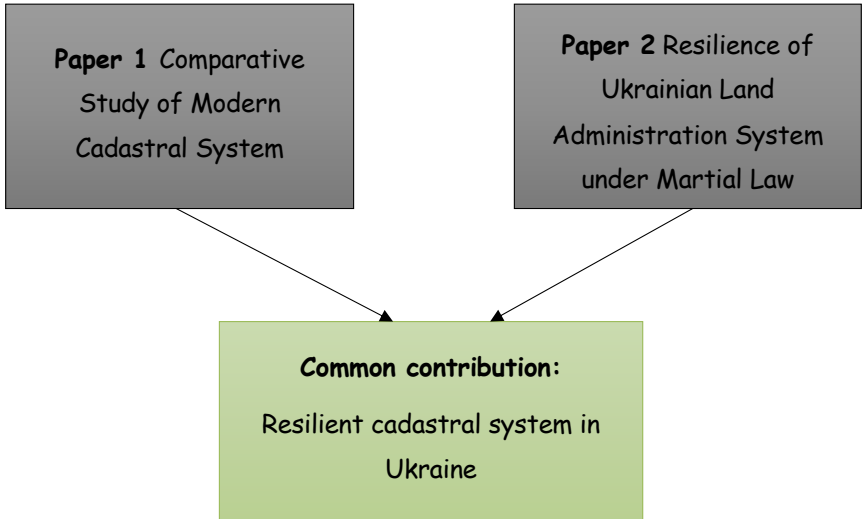
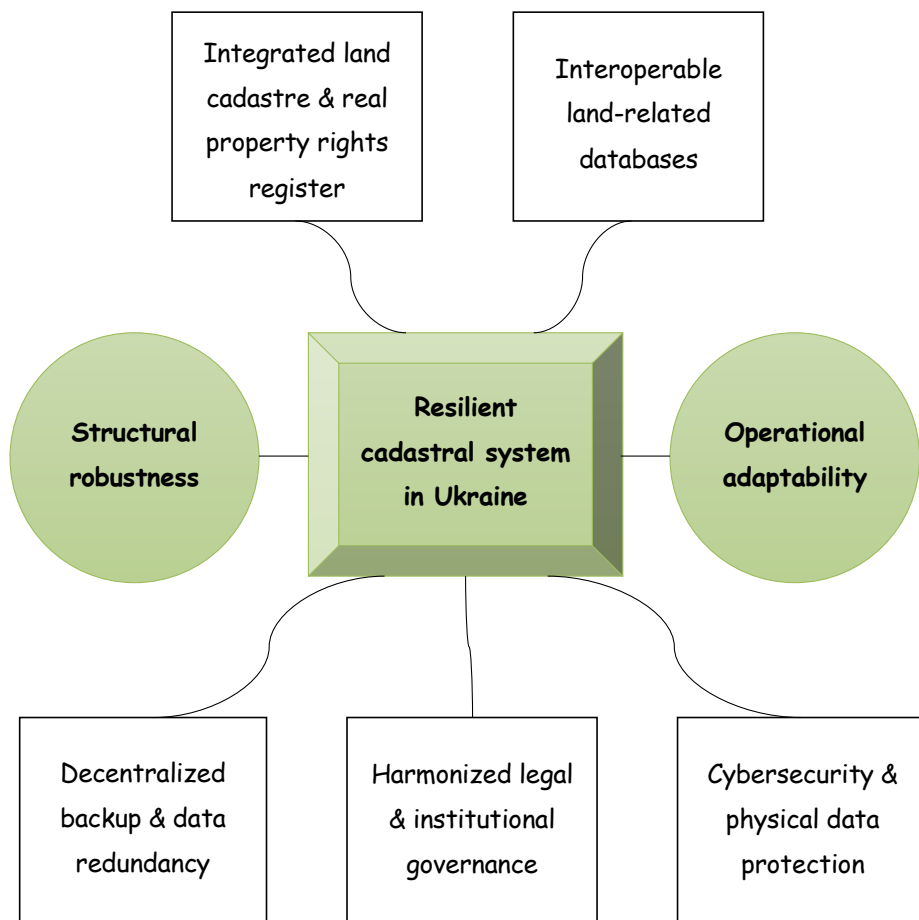


Figure 2. Connection between Papers 1 and 2 within the thesis framework

Drawing together the findings from Paper 1 and Paper 2, this thesis proposes a resilient cadastral system for Ukraine (see figure 3) that integrates both structural robustness (legal and institutional stability) and operational adaptability (continuity under crisis conditions). The model is based on five interrelated elements. First, it emphasizes the unification or close functional integration of the cadastre and the register of property rights, reducing institutional fragmentation and legal inconsistencies. Second, it requires fully interoperable land-related databases, enabling automated data exchange and synchronization between cadastral, property rights, tax, planning, and environmental registers through unified technical standards and common data definitions. Third, to address security risks exposed during wartime, the model incorporates decentralized backup and data-redundancy mechanisms, reducing reliance on centralized infrastructure and enhancing continuity under crisis conditions. Fourth, it calls for harmonized legal frameworks and coherent institutional governance, ensuring that responsibilities, procedures, and data stewardship are aligned across land administration institutions. Finally, the model embeds cybersecurity and physical data protection as core design principles rather than auxiliary technical measures. Together, these

elements describe a cadastral system capable of maintaining legal certainty and data integrity in normal conditions while remaining adaptable and secure during periods of crisis, thereby operationalizing resilience in the Ukrainian land administration context.



*Figure 3. Proposed key elements of a resilient cadastral system for Ukraine.*

In light of the objectives of this thesis, the analysis confirms that cadastral systems should be understood as complex socio-technical arrangements whose resilience emerges from the interaction between structural soundness (the coherence and stability of legal, institutional, technical, and financial components) and the capacity to adapt to changing and disruptive conditions (Mattsson & Mansberger, 2017; Paasch, 2004). The Ukrainian case

demonstrates that resilience is not an add-on feature, but an emergent property shaped by historical legacies, institutional design, and the availability of digital and professional capacities. Strengthening resilience therefore requires coordinated reform that reinforces internal system coherence while enabling redundancy, secure digital operation, and the involvement of professional and community-based actors who sustain land administration during the periods of crisis.

## 6 Conclusions

The major goal of this thesis was to examine security and structural aspects of modern cadastral systems in order to facilitate improvement of existing model of Ukrainian cadastral system. In this final section, the contributions from this thesis and suggestions for the future research are pointed out. The analysis has brought together both a comparative investigation of structural aspects of cadastral systems in four European countries and a resilience-oriented case study of the Ukrainian land administration system under martial law. Together, these studies contribute to a deeper understanding of cadastral systems as socio-technical arrangements in which resilience, security, and institutional coherence are closely interlinked.

Building on the answers to the research questions discussed in Section 5.3, this section also outlines forward-looking implications for the future development of the Ukrainian cadastral system. While the analysis has demonstrated how the system currently operates and responds to crisis conditions, it also highlights the need for structural reforms aimed at strengthening institutional integration, improving digital interoperability, and enhancing data security. Future reforms should focus on reducing fragmentation between cadastral and land registration systems, ensuring resilience through decentralized data management, and embedding strengthened data security as a core component of land administration infrastructure. These forward-looking considerations extend the empirical findings of the study and contribute to ongoing policy discussions on the modernization of land administration systems in Ukraine.

## **6.1 Theoretical contributions**

From a theoretical perspective, the thesis contributes to land administration research by integrating resilience theory with systems theory. Previous studies have often addressed cadastral system structure and institutional resilience separately, particularly in earlier strands of land administration research and in literature published before resilience became a central analytical concept in the field. Systems-oriented studies traditionally focused on juridical, technical, organisational, and financial arrangements of cadastral systems (Dale, 1995; Larsson, 1991; Zevenbergen, 2002; Williamson et al., 2010), while resilience-oriented research initially emphasized institutional adaptability and system response under crisis conditions without detailed engagement with cadastral system design (Holling, 1973; Folke et al., 2010; Boin & Van Eeten, 2013). More recent research has increasingly begun to connect these perspectives (e.g. Uşak et al., 2024), but their integration in cadastral system analysis remains uneven. This thesis demonstrates that resilience in cadastral systems emerges from the coherent interaction of these structural aspects rather than from isolated institutional or technical measures.

By linking systems thinking with resilience concepts, the study advances a perspective in which resilience is understood as an emergent property of system design, shaped by legal traditions, organisational arrangements, and technological infrastructures. This theoretical synthesis moves the debate beyond descriptive accounts of either structural diversity or emergency response, and toward an integrated understanding of how cadastral systems are designed to withstand and adapt to disruption.

## **6.2 Practical contributions**

From a practical standpoint, the thesis offers analytically grounded insights relevant to policymakers, cadastral authorities, and international development organizations by identifying structural and institutional conditions that support or constrain cadastral system resilience. These insights are derived from comparative system analysis and documentary evidence rather than from primary stakeholder interviews. The Ukrainian case illustrates both the benefits and limitations of digital land administration infrastructures under extreme conditions, highlighting the importance of system-wide coherence, secure digital operation, and institutional coordination for maintaining continuity and legal certainty.

The comparative analysis further demonstrates that effective cadastral systems reflect long-term legal traditions and reform trajectories, balancing legal security, fiscal functionality, and administrative efficiency. While the specific reform challenges identified are context-dependent, the findings provide guidance for ongoing cadastral modernisation efforts in Ukraine and other countries undergoing institutional transition. More broadly, the thesis supports the view that cadastral systems should be assessed not only in terms of efficiency or completeness, but also in terms of their robustness, security, and capacity to adapt as elements of national infrastructure.

Based on the findings of this thesis, improvement of the existing Ukrainian cadastral system should focus on system-level integration rather than incremental technical fixes. In particular, reform should aim to reduce institutional fragmentation by strengthening functional integration between the cadastre and the register of property rights. It should also ensure complete nationwide digital coverage and reliable interoperability among land-related registers through unified technical standards and common data definitions.

At the same time, the system should be redesigned to better withstand crisis conditions. Redundancy, decentralized data storage, robust cybersecurity, and strong physical data-protection measures should be embedded as core design principles.

These improvements would allow the cadastral system to maintain legal certainty and operational continuity not only under normal conditions, but also during periods of disruption, thereby strengthening its role as critical national infrastructure.

### **6.3 Future research**

While this thesis establishes a theoretical and empirical foundation for analyzing the structural and security dimensions of cadastral systems, it also points to several directions for future research. Further studies could focus both on the Ukrainian context and on comparative international cases, in order to deepen understanding of cadastral system resilience across different legal, institutional, and risk environments. The following issues could be explored:

- The development of indicators and metrics for assessing cadastral resilience under both normal and crisis conditions.

- The interaction between land administration systems and broader digital government infrastructures, particularly with respect to cybersecurity.
- Comparative research examining how historical cadastral reform paths influence both system structure and adaptive capacity over time.
- The role of local actors, professional networks, and communities in sustaining cadastral services during periods of institutional stress.
- The applicability of the integrated structural–resilience perspective to other contexts of real estate management, including post-conflict, climate-affected, or rapidly urbanizing regions.

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