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A PRACTICAL PROPOSAL: DESIGNING A ROOT DATABASE FOR EXPROPRIATION TRACKING IN NORTH MACEDONIA

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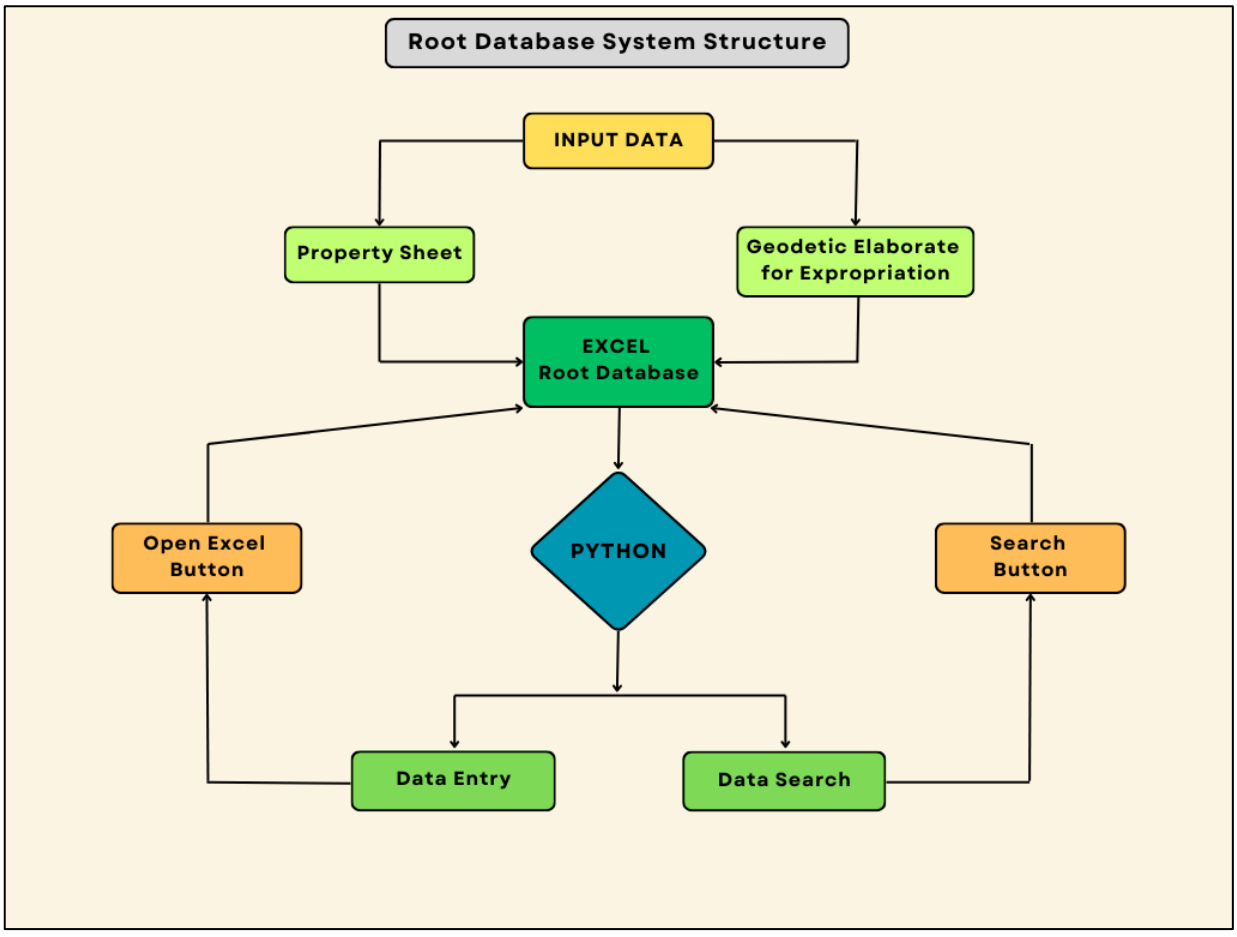
Highlights

- Innovative Database Framework for Expropriation Management
- Data-Driven Decision Support
- Scalable and Adaptable Solution

Graphical Abstract



Database system structure

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ABSTRACT: Land expropriation is a critical and vital process underpinning infrastructure development and urban planning. However, less developed and developing countries, as well as those in transitional phases, often face challenges due to inadequate practices, including the lack of essential systems and standardized procedures. North Macedonia exemplifies this issue, as it currently lacks an official digital database for systematically tracking and managing expropriation–related data. This study proposes a basic and practical framework for establishing a centralized land expropriation database. Potentially, herewith is marking the onset of a new era in the development of a robust and consolidated database, with North Macedonia as a case study. The database design is anchored in the Property Sheet, regarded as the foundational document for the land expropriation process and procedures. It is complemented by the geodetic elaborate for expropriation, which initiates the land expropriation process. Contributions from relevant state institutions involved in land expropriation processes further enrich the structured database. Initially developed in Excel, the system integrates Python–based applications to enhance functionality for data entry and data search, providing a cost–effective solution aimed at improving transparency, accuracy, and institutional coordination. This study offers a replicable model for monitoring land expropriation processes and highlights the critical importance of digital transformation in modernizing land management systems. It establishes a foundation for the development of a comprehensive, real–time, and multi–institutional system to establish a unified database and control mechanism for land expropriation in the Republic of North Macedonia.

Keywords: *Cadastre, Databas, Land Expropriation, North Macedonia, Property Sheet*

1. INTRODUCTION

Land expropriation is an inescapable phenomenon in the process of rapid urbanization [1–3]. It is recognized as a difficult topic [4], and at the same time multifaceted and highly sensitive process. Essential for facilitating a country's development, the land expropriation process has been experiencing a notable increase in developing countries [5–9], and it continues to surge [10]. It constitutes the lawful process by which a state or government hand over privately owned properties into public or state–owned property [11]. In most instances the process involves and requires land [12] represented as cadastral parcels. In certain cases depending on the specific circumstances and characteristics of the terrain or the project itself, it may also encompass buildings as part of the land. Land expropriation is defined as the act of seizing or altering property or land rights from their owner for purposes of public use or in the public interest, typically executed under the authority of eminent domain or through state–led nationalization [13, 14]. Land expropriation serves as a mechanism for transferring ownership of land from private–owned to state–owned or public ownership, facilitating the development of urban land for purposes aligned with national interests [15]. The land expropriation procedure is governed by legislation that continually evolves and improves [5], as well as by authorities prescribed by law to serve the public interest [11]. It is legally established that expropriation, in the public interest, enables the state or local governments to acquire privately owned real property [16]. The initial step in the land expropriation process involves the acquisition of suitable land or other types of real estate [17]. Land

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expropriation arises from the necessity to fulfill public services intended to address societal needs in all systems that recognize private ownership [18]. It is a land management execution [19], and constitutes a limitation on property rights, serving as a mechanism for the acquisition of immovable property from private or legal entities to facilitate the provision of public services [20, 21]. Land expropriation often results in the creation of irregularly shaped and typically small land parcels that are unsuitable for optimal utilization [22]. In North Macedonia, a cadastral parcel is defined by the Law on Real Estate Cadastre [23] as a land area with a minimum size of 1 m². Each parcel is assigned a unique identification number, its boundaries are delineated by coordinates, and it is associated with a specific land area [24]. In the past, when technological methods were not utilized, the land expropriation process was significantly more challenging than it is today [25], but still nowadays the land expropriation process is typically prolonged [16], and this occurs due to various factors. One of the primary reasons property rights holders oppose the land expropriation process is the inadequate valuation of the property subject to expropriation, even though the value of properties is determined by expert committee. The primary issue encountered in determining land expropriation prices is whether the prices established by the expert committees accurately reflect the true market value [26]. Land expropriation is also recognized as a form of "state action" or "governmental activity" [1], and it is not a simple matter [27] and a straightforward process. The approach to land expropriation as a process varies across countries and is influenced by differing land expropriation laws and practices. Different countries employ various modern methods and technologies and exhibit varying formulations and approaches in managing the land expropriation processes. The application of open–source software in resolving geodetic issues, particularly even in the context of the land expropriation process, offers unlimited possibilities [28]. In developing countries, land expropriation serves as a significant source of conflicts between the government and landowners, since land expropriation inevitably impacts the lives of owners (mostly farmers), particularly altering the livelihoods of individuals engaged in agricultural activities [29]. However, it must be acknowledged that land expropriation is inherently a forceful process, affecting all parties involved without exception. Moreover, the progression of the process, from initiation to the final land expropriation of the property, differs across countries. Some developed countries adopt more advanced and streamlined approaches compared to developing ones. For developing countries, the effective utilization of land acquisition powers to secure land resources for urbanization, while fostering economic growth and enhancing human settlements, represents one of the most significant challenges in the realm of land management [30]. The relationship between individuals and land is a fundamental principle [31], and the inclusion of real property in the land expropriation process adversely impacts their livelihoods [32]. However, diverse compensation options are made available to property owners. Land expropriation includes compensation for the acquired properties, which may be provided in monetary form or through other means, as agreed upon by the expropriating authority and the property owners [33]. Yet usually, inadequate compensation and dissatisfaction with the compensation process have led to various conflicts between expropriating authorities and property owners [32, 34]. The government or the entity responsible for executing land expropriation is legally obligated to ensure fair and adequate compensation for the affected property owners [35] and this is influenced by the legal frameworks established within the state. Furthermore, the development and implementation of information systems related to land expropriation are essential. These systems, supported by diverse practices and accumulated experiences, must evolve and advance continuously to meet emerging needs. Even compensation associated with land expropriation varies significantly between developed and developing countries [4]. In North Macedonia, compensation for expropriated immovable property shall not be less than its market value, as determined in accordance with the Law on Expropriation [36] and the provisions of the Law on Appraisal. The expropriation process seeks to balance the public interest with the rights of former property owners by guaranteeing compensation that is no less than the market value of the expropriated property. Legal provisions and procedural safeguards are implemented to prevent arbitrary actions by state authorities, thereby ensuring the protection of the rights and interests of affected individuals [37]. According to the Law on Expropriation, the right to claim compensation

shall not be subject to a statute of limitations. The party initiating the expropriation process shall be responsible for covering the compensation and procedural expenses related to the expropriated property. Additionally, for projects involving linear infrastructure or the relocation of energy facilities, the associated costs for easement rights, land ownership restrictions, and related procedures shall be borne by the project investor. The Law on Expropriation [36] in North Macedonia governs the removal or restriction of ownership and property rights over immovable property to facilitate the realization of public interest as defined by law. It establishes provisions for the construction of buildings, the execution of other works, the determination of public interest, the expropriation process, and the procedures for establishing market–based compensation. In North Macedonia, the absence of large–scale projects and national investments focused on public interests has led to the underdevelopment of an adequate system for managing expropriation process. Despite the existence of well–defined laws and regulations, which have also undergone interventions, leading to continuous improvements and further enhancement, the implementation of these provisions faces significant challenges and limitations in practice. One of the primary shortcomings and challenges faced by North Macedonia is the approach to tracking the land expropriation process, from the initiation of land expropriation procedures to their conclusion with the finalization of the expropriation process or the expropriated land. This is a result of the absence of a fundamental requirement, even such as a digital database, which would facilitate and expedite the process, fostering its development in a positive direction. A digital database, would facilitate the acceleration of the process, reduce costs, and promote the positive development of the land expropriation procedure. In this context, a digital database could serve as a catalyst for the creation of a more comprehensive, robust and refined database, representing a crucial step toward establishing a robust information system specifically designed for expropriation. The establishment, advancement, and maintenance of robust systems significantly influence societal development and progress, while also contributing to the growth and advancement of individual professionals and various professional fields [38].

2.1. A comparative study in land expropriation practices

Slovenia – According to the study conducted by Šumrada et al., (2013) [39], the expropriation process in Slovenia is designed to prioritize voluntary acquisition over compulsory measures. The procedure begins with efforts by state or municipal authorities to acquire the necessary real property through mutual agreement with the owner, ensuring that compensation reflects prevailing market values. Expropriation is employed strictly as a measure of last resort, invoked only when negotiations are unsuccessful and the project is confirmed to serve the public interest. In such instances, property may be acquired without the owner's consent; however, compensation is generally calculated based on the actual economic loss incurred as a result of the acquisition. This framework highlights Slovenia's commitment to balancing the protection of private property rights with the pursuit of public benefit, ensuring that expropriation practices are both legally justified and equitably compensated. According to Kovač (2018) [40], the expropriation process in Slovenia is regulated by the Spatial Planning Act, which stipulates that land acquisition for infrastructure development must demonstrably serve the public interest and be accompanied by fair and adequate compensation. The process prioritizes voluntary agreements with landowners; however, in cases where consensus cannot be reached, compulsory acquisition is initiated. Compensation is generally determined based on the market value of the property, taking into account factors such as land use designation, geographic location, and potential income loss. Notable challenges in the implementation of this process include delays arising from disputes over compensation and the complexity of valuation methodologies, both of which can impede the timely execution of infrastructure projects. The overarching legal framework seeks to strike a balance between the imperatives of public infrastructure development and the safeguarding of private property rights, thereby promoting fairness, legal certainty, and transparency throughout expropriation proceedings.

Croatia – According to Uzelac and Šarin (2025) [41], the expropriation process in Croatia is governed

by constitutional principles that prioritize the inviolability of private property. Expropriation is permissible only when it serves a legitimate public interest and must be accompanied by fair compensation, typically reflecting the market value of the property. The Croatian Constitution, underscores the protection of ownership rights, allowing for property deprivation or restriction solely to protect constitutional values or goods. The Constitutional Court of the Republic of Croatia plays a pivotal role in interpreting these provisions, ensuring that any expropriation measures align with constitutional guarantees. This framework aims to balance the state's developmental needs with the protection of individual property rights, maintaining legal certainty and public trust in expropriation proceedings. As noted by Uzelac and Javorović (2015) [42], the expropriation process in Croatia is regulated by the Expropriation Act, which permits the compulsory acquisition of property strictly under the condition that it serves a clearly defined public interest and that the affected owner receives fair compensation. The procedure entails a formal declaration of public interest, followed by negotiations aimed at achieving a consensual agreement with the property owner regarding compensation. In instances where an agreement cannot be reached, the process advances to administrative and, if necessary, judicial proceedings. The authors identify key challenges within the current legal framework, including procedural inefficiencies and ambiguities surrounding the definition of "public interest," both of which contribute to delays in the implementation of infrastructure projects. They advocate for legal and institutional reforms to enhance the efficiency of the expropriation process while upholding fundamental property rights and legal certainty. According to Vasilj et al., (2007) [43], the expropriation process in Croatia constitutes a critical legal mechanism for facilitating the development of road transportation infrastructure. The authors note that the procedure is regulated by the Expropriation Act, which stipulates that compulsory acquisition of property is permissible exclusively for projects classified as serving the public interest, particularly those related to the construction of highways and other essential infrastructure. A key principle of the process is the provision of fair compensation, typically determined by the prevailing market value of the affected property, thereby ensuring the protection of private property rights. Nevertheless, the authors identify procedural inefficiencies and delays as significant obstacles that hinder the timely implementation of infrastructure projects. The study advocates for a balanced legal and administrative framework that simultaneously promotes infrastructure advancement and upholds the rights of individual property owners.

Serbia – According to Prica (2020) [44], the expropriation process in Serbia encompasses both formal and material dimensions. Formal expropriation pertains to the legally sanctioned transfer of private property into public ownership for purposes explicitly justified by public interest. In contrast, material expropriation refers to situations in which property rights are substantially restricted or nullified without undergoing established legal procedures, often through legislative or administrative measures. Prica underscores that material expropriation, occurring outside the conventional legal framework, poses significant risks to the protection of property rights. He advocates for the establishment of clearer legal definitions and robust procedural safeguards to ensure that all forms of expropriation, whether formal or material, comply with constitutional protections and uphold the fundamental rights of property owners. Based on Stojanović (2012) [45], the expropriation process in Serbia has undergone substantial transformation, evolving from the practices embedded within the former Yugoslav legal system to the contemporary framework governed by the Law on Expropriation. Under the socialist legal model, expropriation primarily served centralized planning objectives, often at the expense of individual property rights. In contrast, the current legal regime stipulates that expropriation may only be executed in cases where a clearly articulated public interest exists, and it must be accompanied by just compensation to the affected property owner. The procedure involves a formal declaration of public interest, followed by administrative proceedings to establish the amount of compensation, which is generally determined based on the property's market value. Despite the presence of these legal safeguards, the expropriation process continues to face challenges, including procedural inefficiencies and frequent disputes over compensation, which can hinder the timely implementation of infrastructure projects and raise critical concerns regarding the adequate protection of property rights. Jerinić (2021)

[46] asserts that in Serbia, the expropriation process is governed by the Law on Expropriation, which mandates that the state provide a justification based on "public interest" for the appropriation of private property. The procedure involves an administrative decision made by the relevant authority, which may then be subject to judicial review to assess the legality and proportionality of the expropriation. Serbian courts are empowered to examine whether the declared public interest is appropriately substantiated; however, their review is typically confined to procedural compliance rather than an assessment of the substantive merits of the case. Affected property owners retain the right to challenge the expropriation in court, especially if there are violations of due process or fair compensation standards. Nonetheless, judicial oversight remains limited, as courts often defer to the state's determination of public interest.

2. MATERIAL AND METHODS

North Macedonia currently lacks a structured and centralized digital database for tracking and managing land expropriation processes. This study proposes the design of such a database, grounded in key documents and workflows integral to the land expropriation process, including the Property Sheet and the geodetic elaborate for expropriation, both as the main documents related to expropriation process. According to Law on Real Estate Cadastre, Property Sheet represents an official document that identifies the legal owner of a property and serves as a prerequisite for initiating legal procedures, such as sale or purchase transactions. Meanwhile, a "Geodetic Elaborate" refers to the technical geodetic documentation prepared for the execution of fundamental geodetic tasks, including the measurement of real estate for the purposes of the Real Estate Cadastre, the maintenance of the state borders of the Republic of Macedonia, and geodetic activities for special purposes that influence the Real Estate Cadastre [23].

2.1. Proposed database

The designed database was initially developed in Excel, chosen for its accessibility and familiarity among institutional users. The design incorporates fields derived from the Property Sheet (Figure 1 and 2), and the geodetic elaborate for expropriation. Additional input sourced from institutions was involved in land expropriation oversight, essential and critical for determining eligibility as required by the respective institutions.

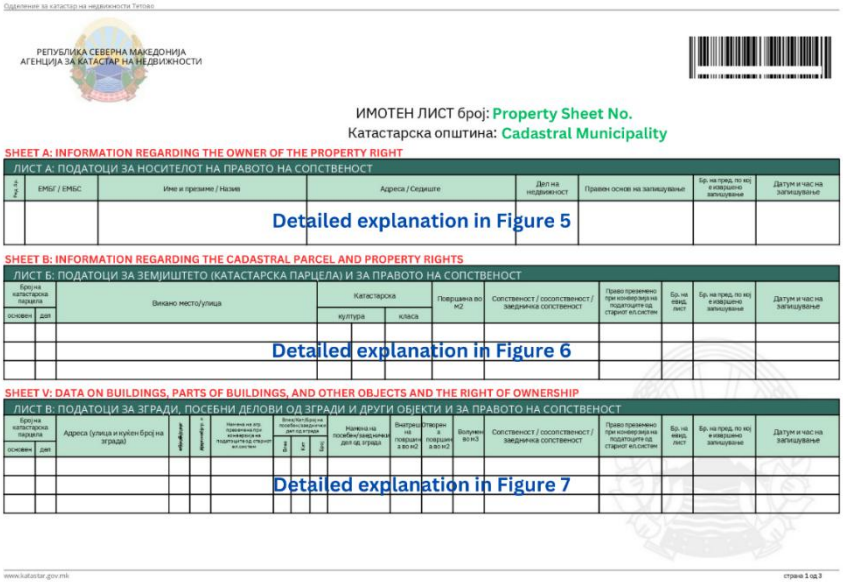
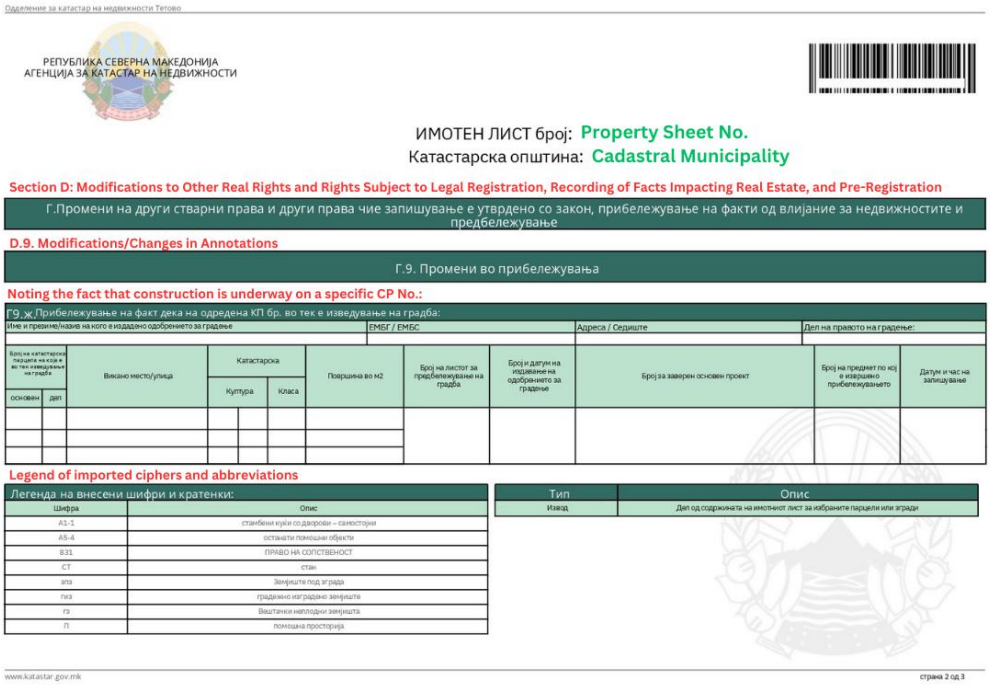


Figure 1. Property Sheet – Example of the first page (provided by private office for cadastral–surveying services and engineering)


Одделение за катастар на недвижности Тетово

РЕПУБЛИКА СЕВЕРНА МАКЕДОНИЈА
АГЕНЦИЈА ЗА КАТАСТАР НА НЕДВИЖНОСТИ

ИМОТЕН ЛИСТ број: Property Sheet No.
Катастарска општина: Cadastral Municipality

Section D: Modifications to Other Real Rights and Rights Subject to Legal Registration, Recording of Facts Impacting Real Estate, and Pre-Registration

Г.Промени на други стварни права и други права чие запишување е утврдено со закон, прибележување на факти од влијание за недвижностите и предбележување

D.9. Modifications/Changes in Annotations

Г.9. Промени во прибележувања

Noting the fact that construction is underway on a specific CP No.:

Г9_ж Прибележување на факт дека на одредена КП бр. во тек е изведување на градба:

Име и презиме/назив на кого е издадено одобрението за градење	ЕМБГ / ЕМБС	Адреса / Седиште	Дел на правото на градење:

Број на катастарска парцела на која е во тек изведувањето на градбата: основен	дел	Внесено место/улица	Катастарска: Култура	Класа	Површина во м2	Број на листот за предбележување на градба	Број и датум на издавање на одобрението за градење	Број за заверен основен проект	Број на предмет по кој е извршено прибележувањето	Датум и час на запишување

Legend of imported ciphers and abbreviations

Легенда на внесени шифри и кратенки:

Шифра	Опис
A1-1	станбени куќи со дворови – самостојни
A5-4	останати помошни објекти
B31	ПРАВО НА СОПСТВЕНОСТ
СТ	стан
зпз	Земјиште под зграда
пиз	градежно изградено земјиште
гз	Вештачки неплодни земјишта
П	помошна просторија

Тип	Опис
Извод	Дел од содржината на имотниот лист за избраните парцели или згради

www.katastar.gov.mk

страна 2 од 3

Figure 2. Property Sheet – Example of the second page (provided by private office for cadastral–surveying services and engineering)

The examples provided are abstract and do not reflect the actual data within the document. All representative data and other details contained in the document have been removed to safeguard the privacy of the document's rightful owner. Furthermore, to enhance functionality, various software tools were utilized. Microsoft Excel was employed for database structuring, designing and initial data entry. Python codes were developed to create custom interfaces for efficient data entry and data search application. These applications streamline database interaction and improve usability, thus facilitating faster access and more flexible utilization.

Based on the substantial information provided for the development and design of the proposed database, a workflow has been compiled. The workflow (Figure 3) illustrates the sequential stages involved in designing and implementing the land expropriation database system. It begins with the collection of core cadastral documentation and concludes with the development of functional data interfaces using Python. Each step is designed to ensure accurate, verifiable, and collaborative data management across institutional stakeholders:

Step 1: Document Collection – Collect essential base documents.

Step 2: Database Architecture Design – Define the database schema, including entities and attributes based on cadastral and legal requirements.

Step 3: Data Validation and Entry – Perform quality control, cross–reference parcel data with official records, and manually or semi–automatically enter verified information into the database.

Step 4: Inter–Institutional Data Amalgamation – Collaborate with relevant government bodies to collect additional spatial or legal data layers.

Step 5: User Interface Development – Develop interactive forms using Python for data entry and advanced search functionality, allowing authorized users to access and manage expropriation–related data.

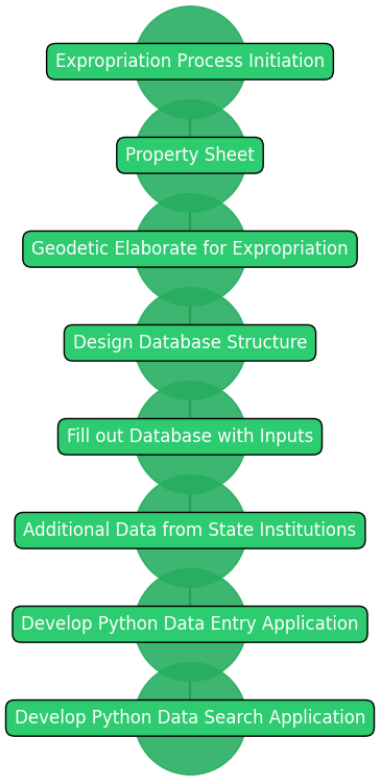


Figure 3. Workflow of Land Expropriation Database Design.

The figure 4 below presents the core system architecture developed for managing land expropriation data. The structure is grounded in official cadastral documentation, namely the Property Sheet and the Geodetic Elaborate for Expropriation. These documents provide the base data, which is organized into an MS Excel database. The database is linked to a user interface developed in Python, comprising two main components: (1) a Data Entry Form and (2) a Data Search Form. Both interfaces are designed for seamless interaction with the backend database via programmed control buttons, such as "Open Excel" for data entry and "Search" for query execution. This integrated structure ensures real–time data handling, institutional usability, and operational efficiency.

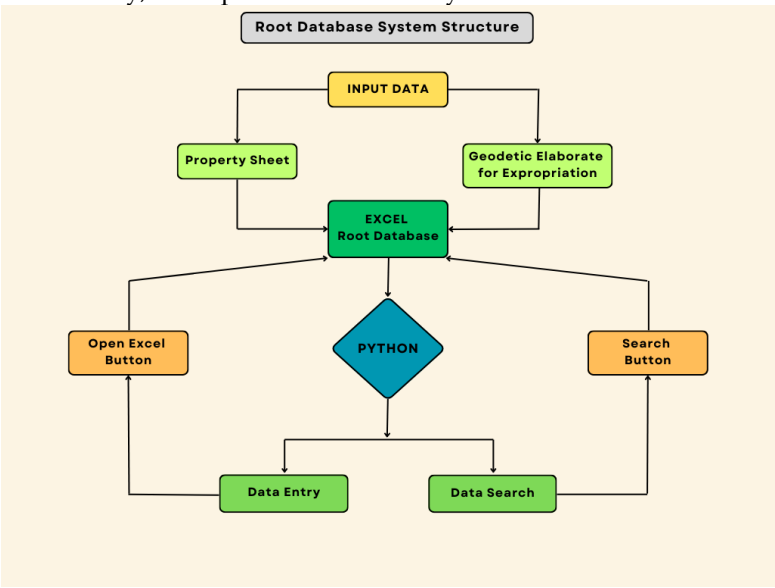


Figure 4. Database system structure.

3. RESULTS AND DISCUSSION

The principle of land expropriation establishes that any right may be subject to expropriation; however, in practice, it predominantly involves rights related to land [12]. According to the Expropriation Law [36] in North Macedonia, property rights encompass easements, long–term leases of construction land as stipulated by the Law on Construction Land, the right to use construction land under state ownership, and the right to a long–term lease of construction land under state ownership in accordance with the Law on Privatization and Lease of Construction Land in State Ownership. The Expropriation Law defines immovable property as land (including agricultural land, construction land, forests), along with buildings and installations constructed on or beneath it and permanently affixed thereto, unless otherwise specified by law. A comprehensive overview of the Law on Expropriation, including the Law on amending and supplementing the Law on Expropriation enacted during specific periods, governing the jurisdiction of this process, is presented in the following Table 1:

Table 1. A summary of the Law on Expropriation and Law on amending and supplementing the Law on Expropriation list in Republic of North Macedonia

Laws	Year	Publication on Official Gazette (number of gazette and year of publication)
Law on Expropriation	1995	33/1995 [48]
Law on amending and supplementing the Law on Expropriation	1998	20/1998 [49]
Law on Amending and supplementing the Law on Expropriation	1999	40/1999 [50]
Law on Expropriation	2012	95/2012[51]
Law on amending and supplementing the Law on Expropriation	2012	131/2012 [52]
	2013	24/2013 [53]
	2014	27/2014 [54]
	2015	104/2015 [55]
	2015	192/2015 [56]
	2016	23/2016 [57]
	2016	178/2016 [58]
	2021	122/2021 [59]
	2023	111/2023 [36]

Referring to the Law on Real Estate Cadastre a "Right Holder" refers to a natural person, legal entity, the Republic of North Macedonia, or a local self–government unit, including the City of Skopje, in whose name the ownership or other rights to real estate are registered in the Real Estate Cadastre [23]. The right of ownership is unequivocally acknowledged as a fundamental property right that significantly influences the social and economic well–being of individuals [47]. The entity responsible for expropriating rights over land or structures associated with the land is determined by the purpose, significance, or public interest of the project [5]. The expropriator is the authority or institution seeking to acquire these rights [12]. For projects of national significance, the expropriator is typically the state, represented by the government, relevant ministries, or general directorates operating under government authority. In other instances, depending on the project's importance, interest, and objectives, cities or municipalities may also serve as expropriators.

The process of expropriation necessarily is intrinsically connected to the Agency for Real Estate Cadastre. Land expropriation procedures commence with the initiation of the process by the expropriator, who submits a request for the preparation of a study, serving as the foundational document for the procedure called geodetic elaborate. Geodetic elaborate for expropriation requires and

utilizes informational data provided by the cadastre institution. The geodetic elaborate for expropriation, once completed, is submitted to the Cadastre institution (it is also submitted to other institutions that carry on land expropriation process) to initiate the land expropriation process. Additionally, upon the conclusion of the land expropriation process, any changes in property rights resulting from the land expropriation must be officially registered within the Real Estate Cadastre [12].

The concept of "property" is not easily defined with precision [60]. The right to property and the right to inheritance are guaranteed by the Constitution of the Republic of North Macedonia [61]. As outlined in the constitution, property ownership entails both rights and obligations and must serve the welfare of the individual and the community. Furthermore, according to the constitution of the republic, no individual may be deprived of or restricted in their property or related rights, except in cases of public interest defined by law. The constitution also ensures that expropriation can only occur with compensation that is not less than the market value of the property. Ownership is a legal right granting the owner full and exclusive authority over the object of ownership. Consequently, the owner is entitled to utilize and manage the property in any manner deemed appropriate, provided such actions comply with the limitations established by law [47]. The Property Sheet includes information regarding the holder of ownership rights, identifying the legal owner of the real estate, specifically the cadastral parcel and any buildings associated with it, provided these structures are constructed and registered as part of the parcel in the cadastre. Information about the property rights holder or owner is recorded in the first section, referred to as "Sheet A". This section includes details such as the holder's identification number, full name, address, ownership share, and other relevant information (Figure 5).

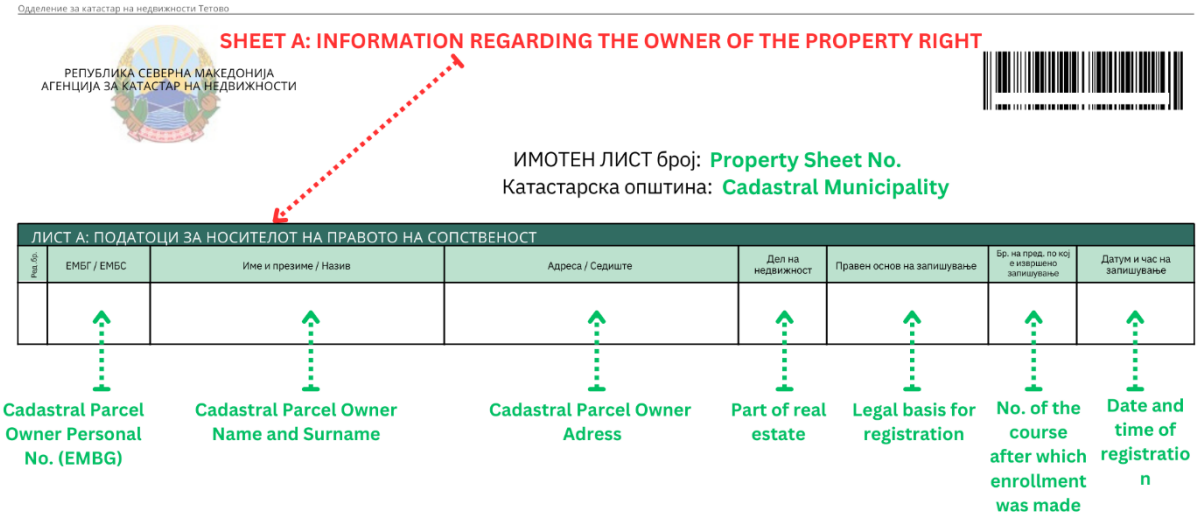


Figure 5. Sheet A – Information regarding the owner of the property right or cadastral parcel (Property Sheet – provided by private office for cadastral–surveying services and engineering).

According to the Law on Real Estate Cadastre [23], a "Cadastral Parcel" is the fundamental unit of the cadastre, delineated by boundaries, classified by cadastral culture and class, situated within a cadastral municipality, and associated with designated ownership rights holders. Also, "Descriptive data" refers to information utilized to detail the attributes and characteristics of real estate, such as cadastral land use and classification, location, building number, or specific/shared parts of a structure or other objects, entrance details, floor level, surface area, volume, identifier and type of infrastructure elements, dimensions (length/height), value, among others. This data also encompasses details regarding real estate rights and the holders of these rights, recorded in numerical or textual formats [23]. This document also contains information pertaining to the parcel, which is detailed in the section referred to as "Sheet B". The "Sheet B" section provides detailed information about the parcel, including its parcel

number, location (i.e., address), culture, class, surface area, and other descriptive attributes (Figure 6).

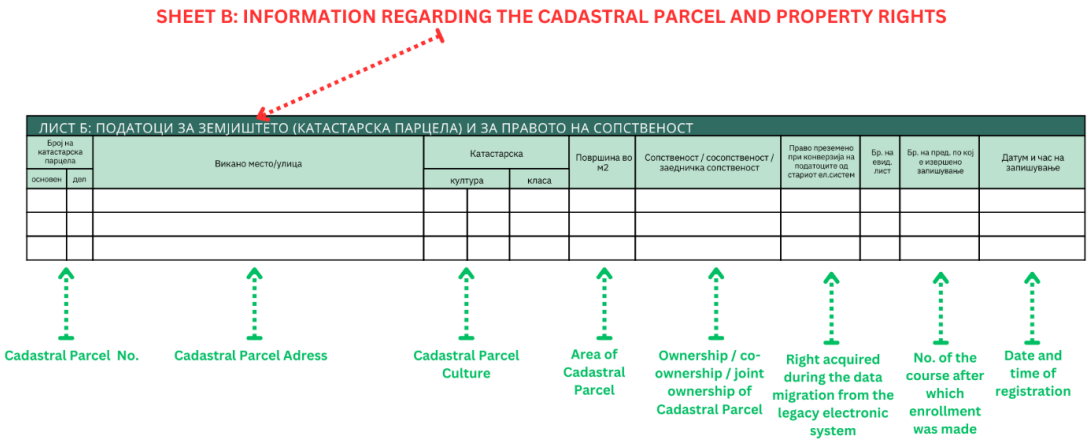


Figure 6. Sheet B – Information regarding the cadastral parcel and property rights (Property Sheet – provided by private office for cadastral–surveying services and engineering).

The "Sheet V" contains information about the object, including the rights registered. In "Sheet V" information about the object is detailed. This includes the parcel number where the object is located, the object's address, its identification number (if multiple objects exist), its designated purpose, entrance number, floor number(s), apartment number(s), internal surface area, and other descriptive data pertaining to the object (Figure 7).

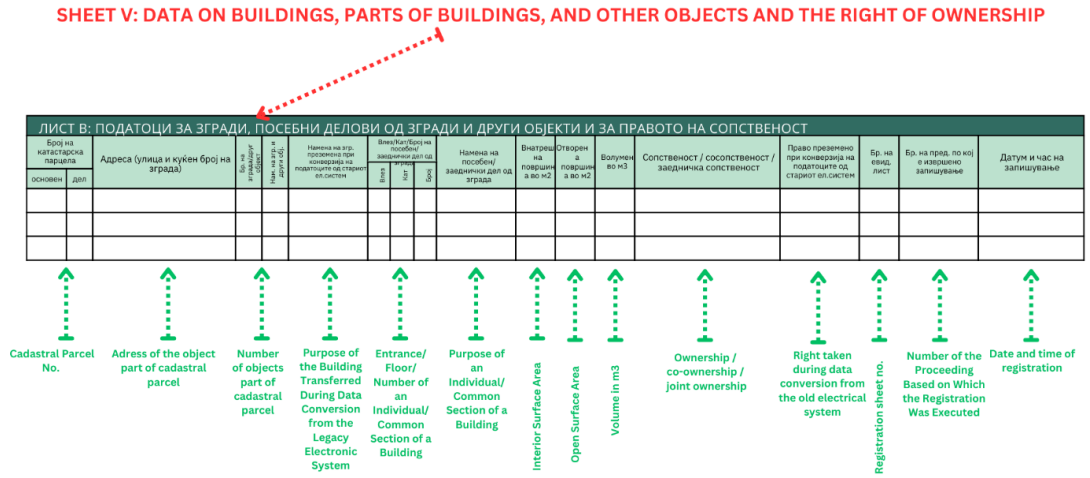


Figure 7. Sheet V – Information regarding the data on buildings, part of buildings, and other objects and the right of ownership (Property Sheet – provided by private office for cadastral–surveying services and engineering).

The list of indications for cadastral parcel is an integral component of the geodetic elaborate for expropriation, typically prepared by private offices specializing in geodetic, cadastral, and engineering services. The list of indications includes detailed information from the Property Sheet. It provides data about the owner, including the name and surname of the property rights holder, as presented in detail in "Sheet A" (refer to Figure 5). Additionally, it contains information including the parcel number, as outlined in "Sheet B" (refer to Figure 6). Further descriptive data about the property are also included, such as the address, culture, class, and the total area of the parcel. The list of indications is structured into two sections. The left section represents the "old state" or "old version", which reflects the status before the land expropriation process. The right section represents the "new state" or "new version",

showing the status after the land expropriation process has been completed. Within this framework, the total area is subdivided into the portion of the parcel unaffected by land expropriation and the portion subjected to expropriation. Together, these subdivisions correspond to the total area of the cadastral parcel in its "old state" or "old version" (Figure 8).

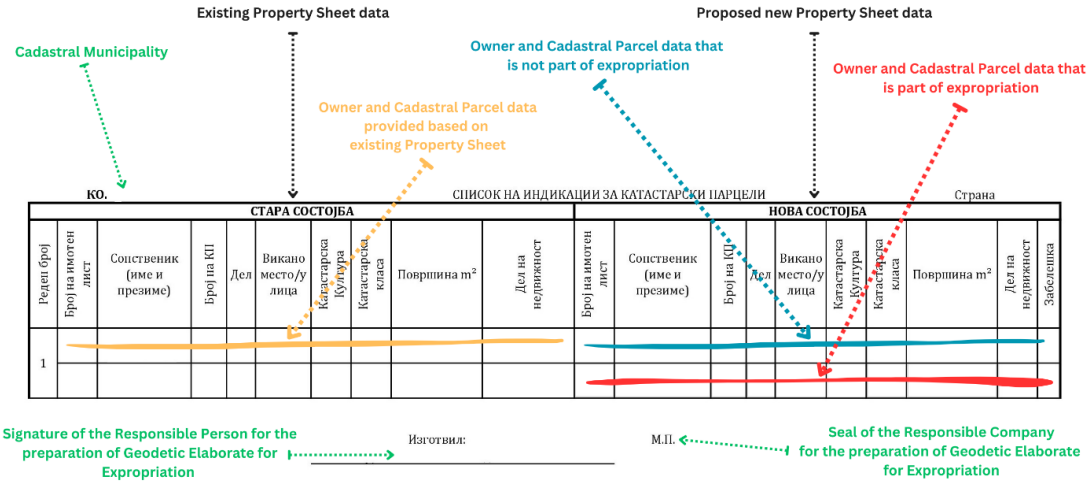


Figure 8. List of indications for cadastral parcels – part of geodetic elaborate for expropriation (provided by private office for cadastral–surveying services and engineering).

The list of data for the formation of a construction cadastral parcel is an integral component of the geodetic elaborate for expropriation as well. Like the list of indications, this list includes information, such as details about the property owner, the cadastral plot, and additional relevant data. Specifically, this part focuses on the portion that is subject to land expropriation and is going to change its status to construction parcel, providing details about the area undergoing changes in property rights, including the transfer of ownership. The list is organized into two sections: the left section contains data related to the property rights holder, while the right section provides information about the cadastral plot. This segmentation ensures clarity in identifying the affected portions of the cadastral plot and the associated changes to property rights (Figure 9).

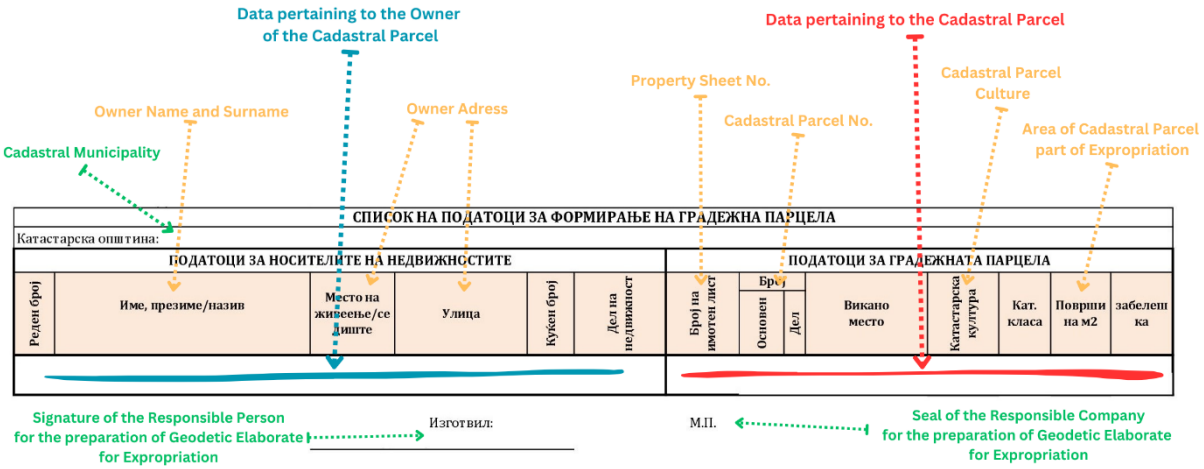


Figure 9. List of data for forming a building cadastral parcel – part of geodetic elaborate for expropriation (provided by private office for cadastral–surveying services and engineering).

Based on the structure and content of the Property Sheet and the geodetic elaborate for

expropriation, a database in MS Excel has been developed. This database captures the essential attributes required to track the land expropriation process from its initiation, namely, the preparation of the geodetic elaborate for expropriation, through the preliminary phase, culminating in the government decision and the publication of the expropriation decision in the official gazette. Using the Python programming language, a program to facilitate data entry into the table previously designed in Excel was developed. This program enables users to input expropriation–related data directly through the Expropriation Database Data Entry (Figure 11) interface without requiring a direct connection to the Excel database.

The expropriation process in the Republic of North Macedonia typically begins with the expropriating authority (the expropriator), often the state, government, or a state institution, initiating the procedures by applying to a private geodetic office for the preparation of an expropriation elaborate. Once the geodetic elaborate is prepared, it is forwarded to the expropriator, who subsequently submits it to the relevant institutions involved in the expropriation process. These institutions include the Appraisal Bureau, the Cadastral Department Office, the State Attorney's Office, and the Administration for Property Legal Affairs Office. After the preparation of the required documents by these institutions, the property owners affected by the expropriation are notified. They are presented with the decision and asked whether they consent to the expropriation of their property. If the property owner agrees to the expropriation, the procedure becomes relatively straightforward. It proceeds with the issuance of a government decision, publication in the official gazette, payment of the expropriation compensation, and registration of the expropriated property rights in the real estate cadastre, thereby concluding the process. However, if the property owner refuses to accept the expropriation decision for any reason, the procedure becomes more complex. In such cases, a court proceeding may be initiated to resolve the expropriation dispute, which can be prolonged until a court decision is rendered. Even after a court decision, the property owner retains the right to appeal, potentially escalating the case to higher courts. Notably, amendments to the expropriation law allow for situations where, despite ongoing court proceedings, properties can be effectively "expropriated" if the project is deemed to be of national significance. This provision enables the continuation of state–important projects, even before the completion of the legal expropriation process. A typical procedure, as commonly applied in practice during the expropriation process in the Republic of North Macedonia, is depicted in the following flowchart in the Figure 10.

The Excel database incorporates key data, such as the "Property Sheet Number". It also includes data from "Sheet A", which pertains to the owner of the real estate rights, such as "Owner" (the name and surname of the natural or legal person) and "Owner Personal No. (EMBG)". Address–related information, including "City" and "Municipality" are also recorded. Furthermore, data from "Sheet B", which relates to the parcel, are included as well, such as "Cadastral Department", "Cadastral Municipality", "Parcel No.", "Culture", and "Total Area of the Parcel". Information from "Sheet V" is also incorporated, specifically details about "Objects Part of Parcel". Additionally, the database captures information from the List of Indications for Cadastral Parcels and the List of Data for Forming a Building Cadastral Parcel, such as the "Total Expropriation Area" (Figure 11). The Python code designed to establish the path to the Excel database is illustrated in Figure 12.

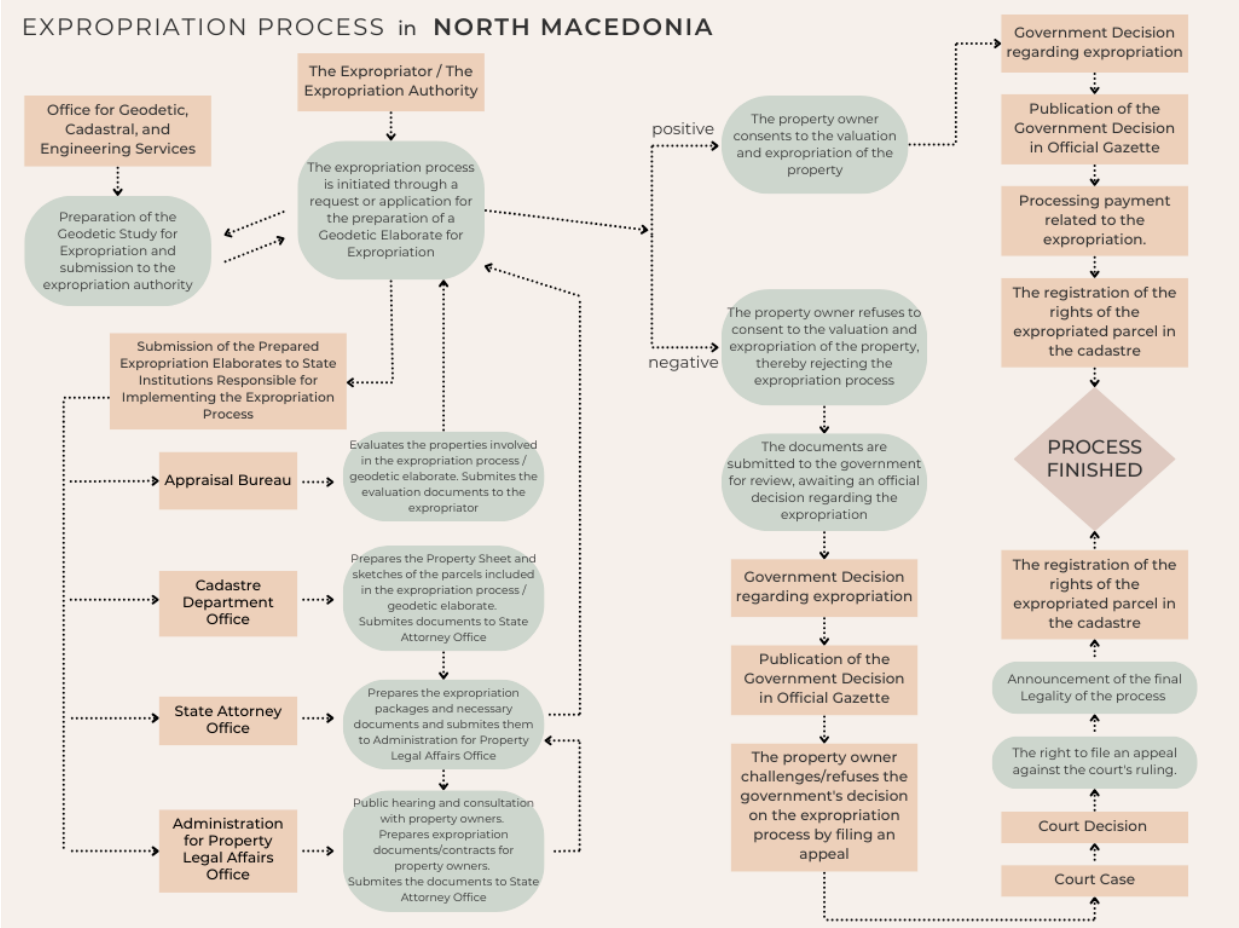


Figure 10. Designed Flowchart of Expropriation Process in North Macedonia.

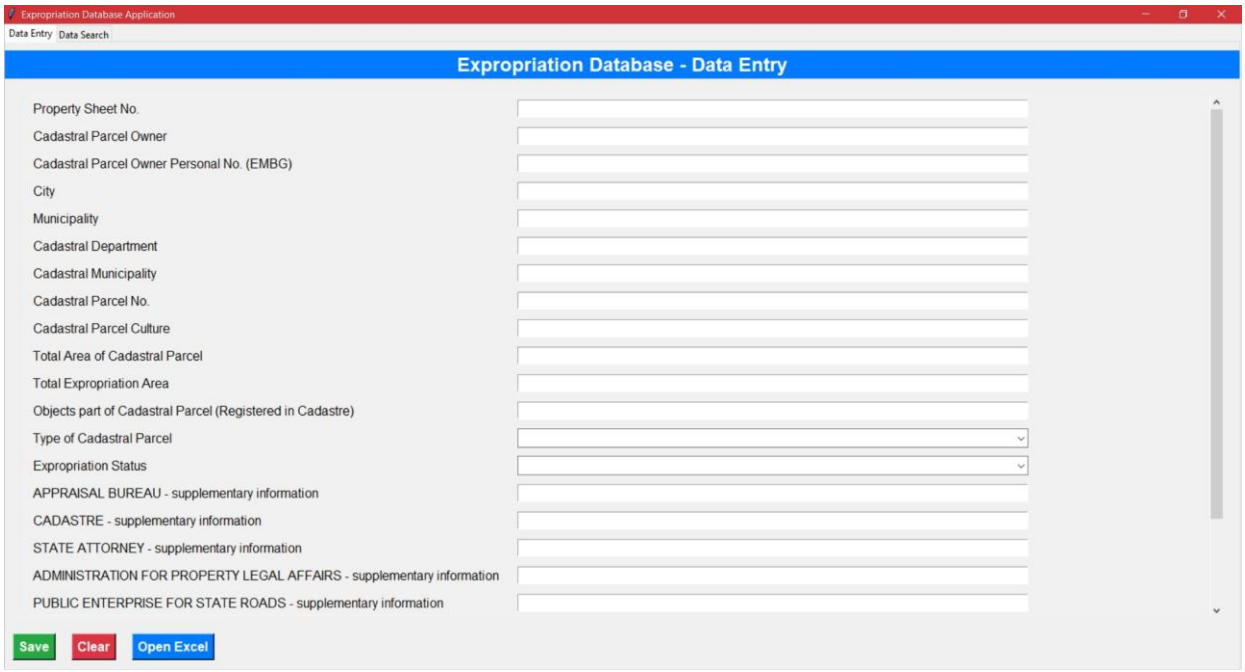


Figure 11. Data Entry form developed using Python.

```
# Path or Roat to Excel file

excel_file = "Expropriation_Database.xlsx"


# Column headers based on the Excel file structure

columns = [
    "Property Sheet No.", "Cadastral Parcel Owner", "Cadastral Parcel Owner Personal No. (EMBG)",
    "City", "Municipality", "Cadastral Department", "Cadastral Municipality",
    "Cadastral Parcel No.", "Cadastral Parcel Culture",
    "Total Area of Cadastral Parcel", "Total Expropriation Area", "Objects part of Cadastral Parcel (Registered in Cadastre)",
    "Type of Cadastral Parcel", "Expropriation Status",
    "APPRAISAL BUREAU - supplementary information", "CADASTRE - supplementary information", "STATE ATTORNEY - supplementary information",
    "ADMINISTRATION FOR PROPERTY LEGAL AFFAIRS - supplementary information", "PUBLIC ENTERPRISE FOR STATE ROADS - supplementary information",
    "GOVERNMENT DECISION - Document No.", "GOVERNMENT DECISION - Date of approval",
    "OFFICIAL GAZETTE - Document No.", "OFFICIAL GAZETTE - Date of publication", "COURT DECISION - supplementary information"
]
```

Figure 12. The Python code developed to establish the path to Excel function.

The program includes functionality to save the recorded data related to expropriation through a green "Save" button, which automatically transfers the information from the Expropriation Database Data Entry directly into an Excel file and saves them. Additionally, the program features a "Clear" button to reset the data entry fields and an "Open Excel" button to establish an automatic connection with the Excel database by opening it directly (as illustrated in Figure 11).

The database is designed to include supplementary materials and information from institutions directly involved in the land expropriation process. These supplementary resources, deemed essential, encompass data from entities such as the Appraisal Bureau, Cadastre (specifically the Real Estate Cadastre Department office), State Attorney's Office, Administration for Property Legal Affairs office, Public Enterprise for State Roads office and Court (for court decision regarding expropriation if any). These materials are integrated as additional data entry forms tailored to each institution (Figure 13). Furthermore, details concerning the Government of the Republic of North Macedonia's decisions on the land expropriation process, along with their publication in the official gazette, are incorporated as supplementary components within the database developed in Excel and the program generated using Python. Based on the Law on Expropriation [36], the State Attorney of the Republic of Macedonia is authorized to submit expropriation proposals on behalf of public enterprises, funds, agencies, directorates, public institutions, trade companies, and other state–established entities to advance the public interest. According to the Law on Expropriation, the Government of the Republic of Macedonia, based on a detailed proposal submitted by the proposer of expropriation, may authorize the transfer of possession of immovable property to the proposer before the expropriation decision becomes legally binding and after the decision becomes final. This is contingent upon the government determining that such action is necessary for the construction of facilities or execution of works specified in this law, or to prevent significant material damage, mitigate risks to public health and the environment, or facilitate the construction of projects of strategic importance.

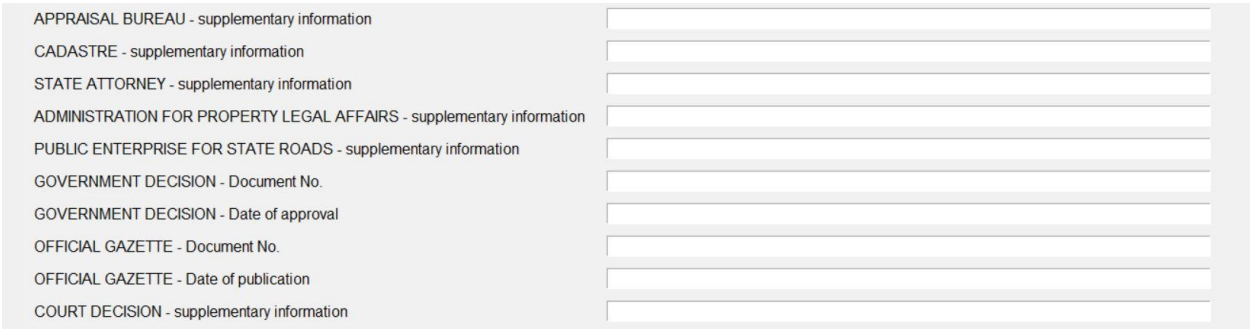


Figure 13. Generated data entries based on supplementary information from institutions that are involved directly in the land expropriation process.

Additional information regarding the status of the cadastral parcel is categorized into three distinct options: "Private", indicating that it is owned by a natural or legal entity under private ownership;

"State", signifying that the it is owned by a government institution; and "Unregistered/Unknown", denoting that the parcel that has no registered rights in the Real Estate Cadastre, and consequently, the owner is not documented (the name of the owner does not appear) in the Property Sheet (Figure 14).

Figure 14. Identification of Type of Cadastral Parcel within data entry form.

The expropriation status of cadastral parcels within the generated program into the database is categorized into three distinct options as:

a. "Expropriated (Process Finalized)": This applies to parcels where the expropriation process has been fully completed, all procedural stages have been finalized, and a government decision has been issued and published in the official gazette.
b. "Not Expropriated (Process Ongoing)": This designation is for arcels where the expropriation process has commenced but is still underway, progressing through the procedural stages leading to a government decision (or even other opportunities possible).
c. "Not Expropriated (Process Not Started Yet)": This status refers to parcels where the expropriation process has not yet begun and is not currently undergoing any procedural stages (Figure 15).

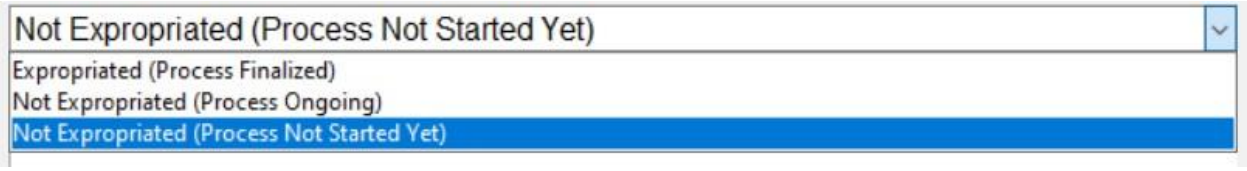


Figure 15. Identification of Expropriation Status within data entry form.

Considering and analyzing information platforms such as https://ossp.katastar.gov.mk/OSSP/ (Figure 16 and 17) and https://e–uslugi.katastar.gov.mk/ (Figure 18 and 19), including their design, methodologies, and search form formats for cadastral parcels and property sheets, a search form for the expropriation database using the Python programming language has been developed and implemented (Figure 20).

Figure 16 presents the search form for cadastral parcels and detailed information regarding them, which utilizes Cadastral Department, Cadastral Municipality, and Parcel Number as the required search parameters in https://ossp.katastar.gov.mk/OSSP/

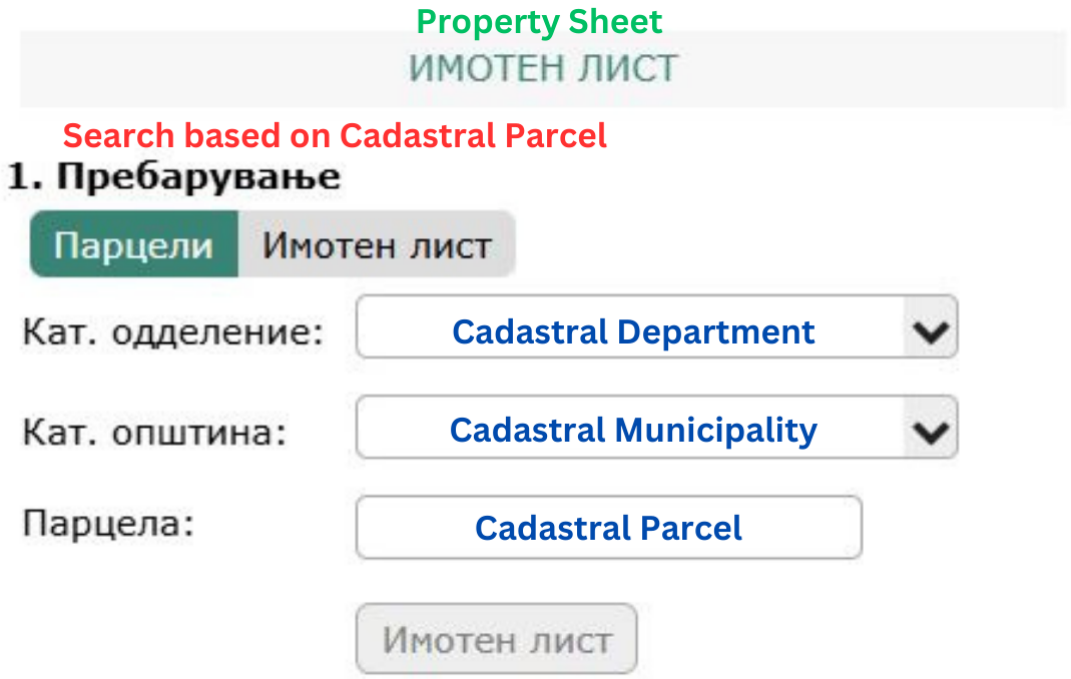


Figure 16. Search form for cadastral parcels by cadastral parcel number, available at https://ossp.katastar.gov.mk/OSSP/.

Figure 17 presents the search form for property sheet and detailed information regarding it, which utilizes Cadastral Department, Cadastral Municipality, and Property Sheet Number as the required search parameters in https://ossp.katastar.gov.mk/OSSP/.

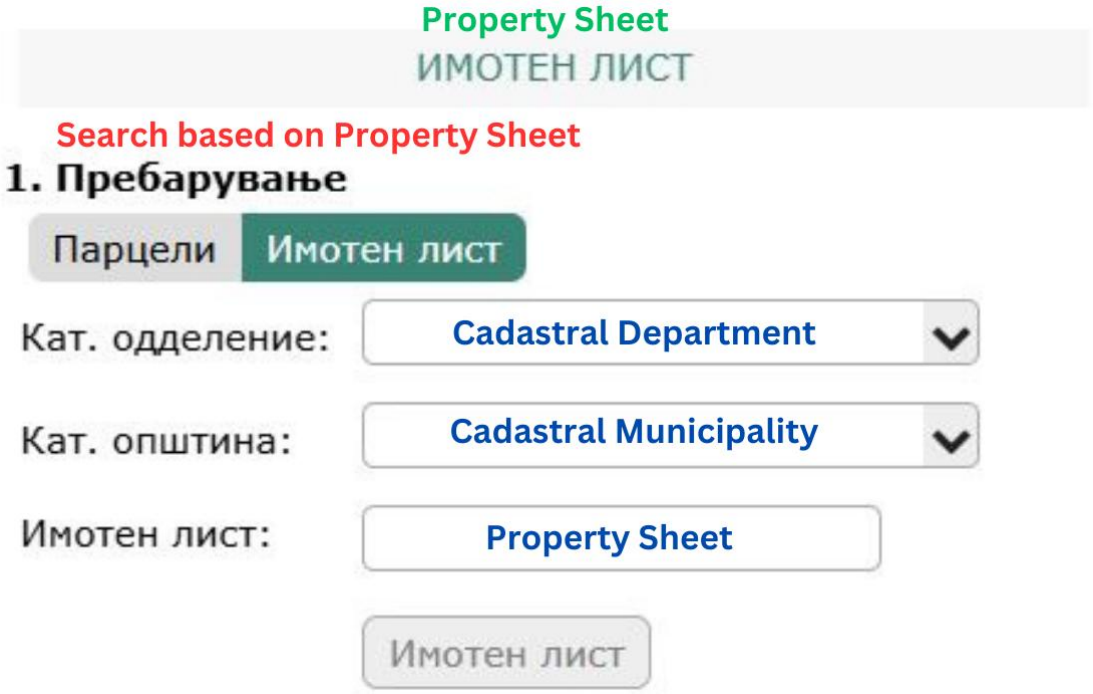


Figure 17. Search form for cadastral parcels by Property Sheet number, available at https://ossp.katastar.gov.mk/OSSP/.

Figure 18 presents the search form for cadastral parcels and detailed information regarding them, which utilizes Cadastral Department, Cadastral Municipality, and Parcel Number as the required search

parameters in https://e–uslugi.katastar.gov.mk/.

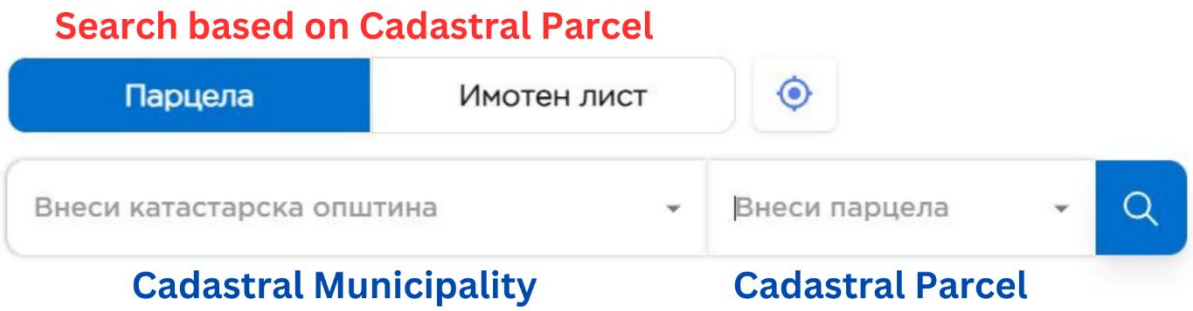


Figure 18. Search form for cadastral parcels by cadastral parcel number, available at https://e–uslugi.katastar.gov.mk/.

Figure 19 presents the search form for property sheet and detailed information regarding it, which utilizes Cadastral Department, Cadastral Municipality, and Property Sheet Number as the required search parameters in https://e–uslugi.katastar.gov.mk/.

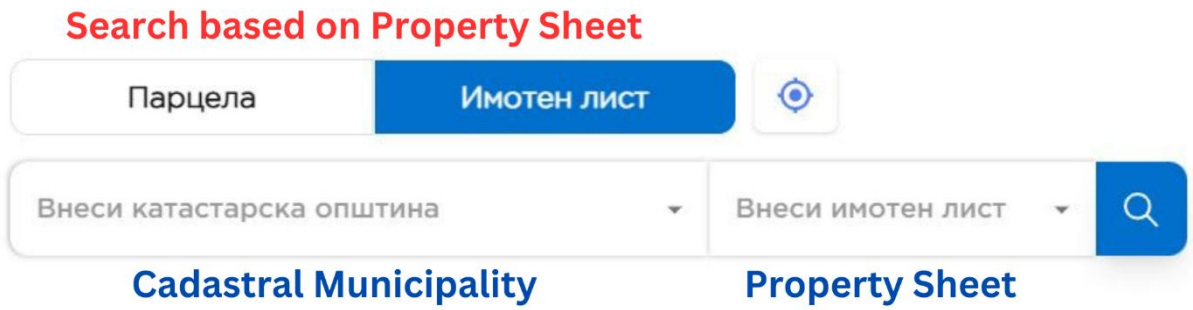


Figure 19. Search form for cadastral parcels by Property Sheet number, available at https://e–uslugi.katastar.gov.mk/.

The data search form, developed and implemented using the Python, integrates features inspired by existing search forms from information systems such as https://ossp.katastar.gov.mk/OSSP/ and https://e–uslugi.katastar.gov.mk/. The expropriation database search form includes essential attributes such as Property Sheet Number, Parcel Number, Cadastral Municipality, and Cadastral Department.

A key functionality of this search form is its requirement for all attributes to be completed. If any of the fields remain empty, the database designed in Excel and populated through the data entry form, cannot be accessed, and the search will return an error message. This mechanism ensures that the database can only be accessed when all required information is provided, thereby maintaining data integrity and accuracy. This design verifies the correctness of the requested data within the Excel database, ensuring precision in identifying the cadastral parcel, cadastral municipality, cadastral department, and corresponding Property Sheet number necessary for monitoring the land expropriation process. Among these, the that number serves as a critical element, guaranteeing the accuracy of the linked data for the cadastral parcel and associated attributes (Figure 20). The Python code designed to establish the Data Search related to the Excel database is illustrated in Figure 21.

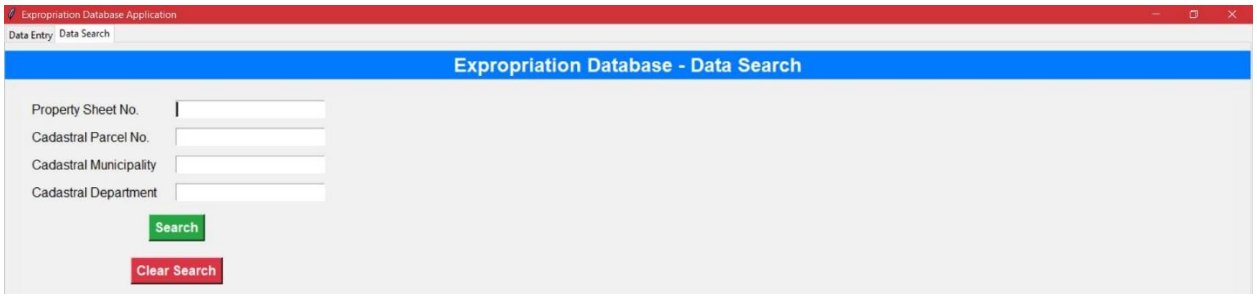


Figure 20. Data Search form developed using Python.

```
# Create the four search fields for "Property Sheet No.", "Cadastral Parcel No.", "Cadastral Municipality", and "Cadastral Department"

search_labels = ["Property Sheet No.", "Cadastral Parcel No.", "Cadastral Municipality", "Cadastral Department"]
for i, col in enumerate(search_labels):
    label = tk.Label(search_frame, text=col, bg="#f1f1f1", font=("Helvetica", 12))
    label.grid(row=i, column=0, sticky="w", padx=10, pady=5)
    entry = tk.Entry(search_frame, font=("Helvetica", 12))
    entry.grid(row=i, column=1, padx=10, pady=5, sticky="ew")
    search_entry_dict[col] = entry
```

Figure 21. The Python code developed to establish the Data Search related to Excel database.

The program incorporates functionality for searching recorded expropriation data via a green "Search" button, which provides automatic access to the Excel Expropriation Database. Additionally, it includes a "Clear Search" button to reset the data search fields.

Functionally, the proposed system is specifically designed for the management of expropriation–related data, offering customizable data entry and search interfaces that align with institutional workflows. In contrast, national platforms such as OSSP and e–Uslugi primarily function as citizen–oriented services, providing general access to cadastral maps, property status information, and legal documentation. From a backend perspective, the developed system currently operates within a local environment utilizing Microsoft Excel and Python, with a clear trajectory toward migration to more robust SQL and GIS platforms. Conversely, OSSP and e–Uslugi rely on centralized, government–hosted databases with standardized web–based APIs. In terms of data security, OSSP and e–Uslugi are secured through national authentication frameworks, whereas the prototype system incorporates encryption for sensitive data fields and proposes the implementation of role–based access control mechanisms tailored to institutional users. Search capabilities also differ significantly, OSSP and e–Uslugi employ fixed, form–based algorithms typically limited to parcel IDs or property numbers. In contrast, the Python–integrated system supports a modular search engine enabling multi–criteria filtering (e.g., city, parcel, municipality, cadastral department), thereby offering greater flexibility. Finally, while metadata in OSSP and e–Uslugi is embedded within a national cadastral schema, it does not facilitate integration with expropriation workflows. The proposed system, by contrast, supports the generation of customizable metadata fields, structured to enable legal, procedural, and archival integration, thus positioning it as a foundational component for a possible future Digital Expropriation Information System.

The proposed expropriation tracking system is structured using a three–tier software architecture, combining Microsoft Excel as the data storage layer, Python scripts as the logic and application layer, and Tkinter–based graphical user interfaces for institutional interaction. The application is composed of modular functional blocks, including a Data Entry Form, a Search and Query Module, and Excel file integration functions. Each module operates independently and communicates through a centralized Excel database. To ensure data quality and integrity, the system implements data validation routines within the Python backend. These include field constraints (e.g., non–empty fields, numeric validations for parcel IDs and areas), drop–down menus for standardized inputs (e.g., expropriation status, parcel type), and structured field mappings to align with official cadastral records. Error–handling mechanisms alert users to incomplete or incorrect entries before submission. Although the current version is designed for local and intern use, access control mechanisms are being incorporated.

The conceptual model of the proposed expropriation tracking system is designed around a set of

core entities that encapsulate the legal, spatial, and institutional dimensions of the land expropriation process. These primary entities include Property Owner, Property Sheet, Cadastral Parcel, Institution, Institutional Action, and Expropriation Status attached with its Legal Documents. Each Property Owner may be linked to multiple Property Sheets, which serve as official cadastral records associated with one or more Cadastral Parcels. These parcels represent the fundamental spatial units subject to expropriation and are characterized by attributes such as the area, culture, and expropriation status. Each parcel may be involved in one or more Institutional Actions, including valuations, approvals, or objections, executed by authorized Institutions such as the Cadastre, Ministry of Transport, State Attorney, Appraisal Bureau, or Administration for Property Legal Affairs. Legal Documents, including government decrees, official gazette publications, and court decisions, are associated with the parcels to ensure legal validation and procedural completeness. This relational framework enables traceable, modular, and scalable system architecture and ensures compliance with national expropriation laws and administrative procedures. Following, in the Figure 21 is represented the Relational Schema, which is designed as part of this study:

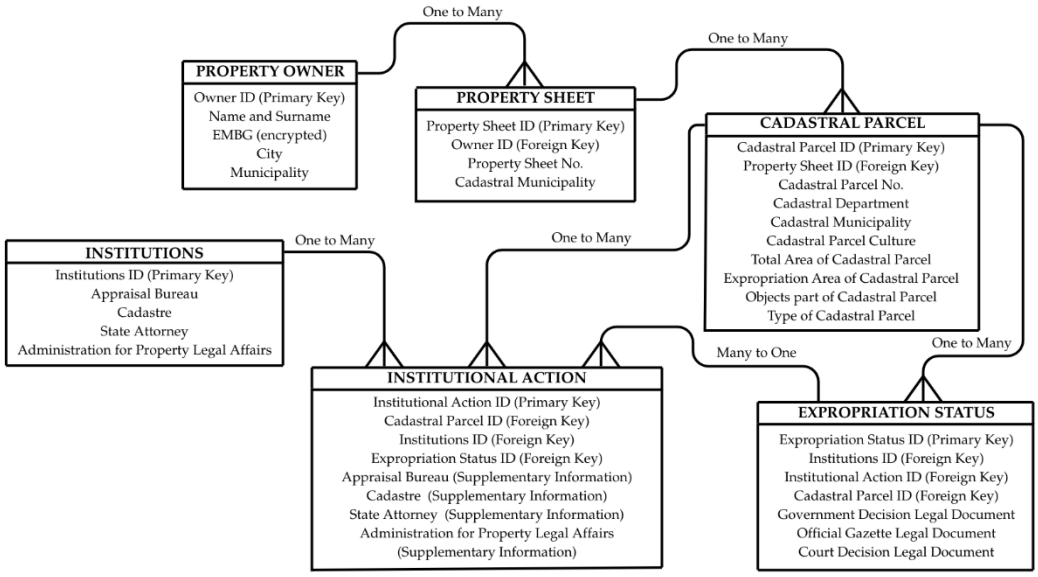


Figure 21. The Relational Schema designed related to the compiled Expropriation Database.

According to the Report on the status of INSPIRE in the Balkan countries (2014) [62], the reform of the Land Administration System in the Western Balkans, including North Macedonia, commenced in the late 1990s and primarily focused on institutional reorganization, digitization, systematic updating of maps and registers, enhancement of professional education and lifelong learning, and the development of information and communication technologies. Land administration systems serve as a dependable source of information for every stage of the land use planning process [63]. Land administration systems record implementation measures and conditional agreements in accordance with private law; they also provide citizens with information regarding the legal status of land, including public regulations, fundamental data for monitoring, control, and enforcement procedures, as well as details on the process of public land acquisition, ultimately serving expropriation purposes [64]. Based on the Law on Expropriation [36], after the Decision on Expropriation, the ownership rights of expropriated immovable property shall be registered in the Immovable Property Cadastre based on the agreement, referred to as the Hearing for Reaching an Agreement, which pertains to the Agreement on Compensation. Alternatively, registration may be based on a legally binding court decision on expropriation, as outlined in this law, referred to as the Decision on Expropriation. The expropriation process in North

Macedonia follows a comprehensive administrative and judicial framework designed to safeguard the rights of former property owners. The procedure is initiated by the issuance of an expropriation decision by the relevant authority, which includes an initial evaluation and an offer for market–based compensation. In cases where an agreement on compensation cannot be achieved, the matter is referred to the competent court, in accordance with the provisions of the Law on Non–Contentious Procedure [38]. Despite potential strong resistance from property rights holders, land expropriation serves as a critical mechanism influencing the economic and social development of a nation. It is indispensable for facilitating the implementation of infrastructure projects [12] and provides a solution for acquiring construction land essential to the urbanization process [11]. Expropriation is a necessary process for facilitating land development [65], even though the expropriation of property and the provision of compensation at market value inevitably evoke questions of distributive justice [66]. The compensation provided to affected landholders is frequently inadequate to restore their livelihoods following expropriation [67]. The primary condition that establishes the legal validity and legitimacy of the expropriation process, resulting in the termination of property rights, is the demonstration of public benefit [68]. Effective land management is critical to ensuring the efficient and productive utilization of land resources, safeguarding the environment, and maximizing social welfare [63].

The proposed database system encompasses sensitive information, including cadastral parcel data, land ownership records, and expropriation decisions. Accordingly, it is imperative that data security, privacy, and legal compliance are prioritized in both the design and implementation phases. As the Republic of North Macedonia is aligned with the European Union's accession framework, it is committed to the principles of the General Data Protection Regulation (GDPR) [69]. Therefore, any digital infrastructure managing personal or property–related data must adhere to core GDPR principles, including data minimization, purpose limitation, data integrity, and confidentiality [70]. Ensuring compliance with these standards is essential for safeguarding individual rights and maintaining institutional accountability. Furthermore, in North Macedonia, there is also the Law on Personal Data Protection [71], which is harmonized with the European regulation in the field of personal data protection, specifically: Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data. As the proposed system processes personally identifiable information, such as property owner names and unique EMBG identifiers, its design carefully considers legal and ethical obligations related to data protection and privacy. In alignment with the Law on Personal Data Protection of the Republic of North Macedonia (Official Gazette No. 42/20) [71] and harmonized with the European Union's General Data Protection Regulation (GDPR) [69], the database prototype integrates encryption mechanisms to secure sensitive information. Specifically, Python's cryptography library is used to encrypt EMBG data within the Excel database, ensuring that this information remains inaccessible to unauthorized users. The system is currently designed for local use within institutional frameworks, with clearly defined access boundaries, and is intended to evolve into a scalable platform based on SQL, GIS or other secure geodatabases. Future development will incorporate advanced access controls, audit logging, and secure multi–institutional data exchange protocols. These measures ensure that the proposed system not only improves the efficiency of land expropriation tracking, but also complies with modern standards for data privacy, ethical governance, and legal responsibility.

The design and implementation of the proposed expropriation database system have been guided by ethical principles of data protection, confidentiality, and institutional responsibility. The system processes sensitive cadastral and personal information strictly within the legal scope of public interest and government–mandated expropriation procedures. To ensure data confidentiality, sensitive fields are encrypted using secure Python–based methods and access is restricted to authorized institutional actors. User consent in this context is governed by national legislation, where institutions have legal authority to access and manage such data in accordance with the Law on Personal Data Protection (aligned with GDPR). The system is not designed for public access, and all data interactions are to occur within a controlled and accountable institutional framework. These safeguards ensure that the system respects

the ethical obligations related to privacy, necessity, and proportionality in public data administration.

The proposed database framework addresses a critical gap in North Macedonia, where the lack of a centralized system for managing land expropriation data has impeded transparency and operational efficiency. By centering on the Property Sheet and incorporating input from the geodetic elaborate for expropriation, the design ensures a holistic approach to land expropriation management. Employing Excel as the primary platform, supported by Python for advanced functionality, bridges the divide between technical complexity and practical usability. Its accessibility makes it suitable for diverse institutions, even in environments with limited technological infrastructure or expertise. Nevertheless, the reliance on manual data entry introduces challenges, including scalability constraints and a susceptibility to human error. Additionally, securing seamless cooperation among institutions for data sharing remains an ongoing obstacle. Despite these limitations, the framework marks a substantial step forward in modernizing land expropriation management in a developing country context, such as North Macedonia. The system's modular design allows for future integration with advanced platforms, while remaining functional for immediate implementation. Simultaneously, it serves as an indicator and initiator for the development of a more integrated, detailed, and advanced system within a technological context. The enhancement of institutional capacity, the integration of advanced technologies, and the adoption of digitalization are critical domains [72]. This focus on both practicality and scalability ensures that the framework addresses present demands while accommodating future advancements. Future advancements will likely involve more sophisticated and robust approaches to the compilation, design, and management of complex databases, utilizing advanced post–processing programs and specialized software for enhanced functionality and efficiency. Without any doubt, future solving should and must be established in databases advanced on SQL platforms or GIS based geodatabases, as they offer enhanced security, scalability, and sustainability for addressing the challenges databases, especially of expropriation, despite potentially higher economic, temporal and other copious costs.

The proposed system has been purposefully designed using modular architecture to ensure flexibility, ease of maintenance, and future scalability. Each core component, the data entry form, data search interface, and the Excel–based database structure, function independently, allowing for individual upgrades or replacements without disrupting the overall workflow. The existing database layer can be seamlessly migrated from Excel to more robust SQL or GIS platforms without necessitating substantial modifications to the user interfaces. Likewise, the data entry and search modules, currently developed in Python, can be extended into a web–based frontend utilizing various modern frameworks. Additional components, such as a GIS–based visualization panel and a document archive module for uploading and retrieving scanned government decisions or expropriation notices, can also be integrated without structural disruption. This modular architecture not only facilitates a phased and sustainable implementation strategy but also ensures the system’s adaptability to evolving technological, legal, and institutional requirements.

4. CONCLUSIONS

The proposed database design marks a transformative advancement in addressing the absence of an official system for managing land expropriation processes in North Macedonia. The design of a centralized expropriation database represents a substantial advancement in land management and institutional efficiency. This represents an initial step toward developing a more complex, comprehensive, robust, and detailed design in the near future. By leveraging foundational documents, this study establishes a framework that addresses North Macedonia's needs while remaining applicable to other developing countries facing similar administrative challenges. Developed using Excel and Python, the database balances simplicity with functionality, offering a cost–effective solution accessible even in resource–constrained settings. The practical implementation of the system proposed in this study incurs minimal or negligible costs, rendering it highly accessible and affordable for institutions involved in the execution of expropriation–related projects, as well as for the Republic of North Macedonia. Beyond its financial efficiency, the system offers significant time–saving advantages by

enabling all stakeholders to promptly engage in and monitor procedural developments in real time. The integration of institutional data inputs, government decision data regarding land expropriation and publication of official gazette ensures comprehensive coverage of all critical aspects of the land expropriation process. By creating a centralized repository of expropriation–related information, the database enhances transparency and accountability among institutions. This is especially critical for developing countries, where fragmented systems often hinder effective governance. The methodology presented provides a replicable framework for similar contexts, addressing common challenges such as limited technological infrastructure and inter–agency coordination barriers. Ultimately, this work underscores the value of integrating accessible, cost–effective digital solutions into administrative workflows. It demonstrates how simple tools can modernize essential processes, enhance decision–making, and promote institutional efficiency and transparency, contributing to broader governance objectives.

Based on the study, it can also be concluded that future work and studies should focus and should prioritize the following areas:

a. Transition to robust database systems, such as SQL–based databases, for improved scalability, enhanced data security, and the development of a real–time database for multi–institutional usage.

b. Integration of GIS tools to enable spatial analysis and visualization of cadastral parcels within the land expropriation process (an example can be open–source software such as QGIS, an analytical elaboration process which provides all necessary functionalities for spatial phenomena analysis [28]).

c. Design of a comprehensive Digital Expropriation Archive System for North Macedonia to systematically store and manage data and documents related to land expropriation.

d. Design and development of a comprehensive and robust Expropriation Information System tailored for North Macedonia, providing real–time insights and streamlined workflows.

e. Implementation of training programs for institutional staff to ensure adoption, effective utilization, and long–term sustainability of the Expropriation Archive System and Expropriation Information System.

Furthermore, the establishment of a robust Digital Expropriation Archive System and an Expropriation Information System is a critical and pressing requirement for the Republic of North Macedonia. These systems would constitute a transformative innovation within the country. Their development must align with ISO standards and the Sustainable Development Goals (SDGs), also known as the Global Goals, to ensure adherence to international norms and to uphold their associated values. The integration of these information systems aligns with several United Nations Sustainable Development Goals (SDGs) through the implementation of relevant ISO standards. Specifically, it supports Goal 8: Decent Work and Economic Growth by applying ISO 9001 [73]: Quality Management Systems; Goal 9: Industry, Innovation, and Infrastructure by implementing ISO 56002 [74]: Innovation Management – Innovation Management System; Goal 11: Sustainable Cities and Communities by adopting ISO 37101 [75]: Sustainable Development in Communities – Management System for Sustainable Development; Goal 15: Life on Land through ISO 14055–1 [76]: Environmental Management – Guidelines for Establishing Good Practices for Combating Land Degradation and Desertification, and ISO 38200 [77]: Chain of Custody of Wood and Wood–Based Products. Furthermore, such systems should be designed with inherent compatibility for integration into contemporary GIS, thereby enabling spatial visualization, geospatial querying, and dynamic monitoring of cadastral parcels subject to expropriation. Transitioning to cloud–based infrastructures would further facilitate real–time data accessibility, enhance inter–institutional coordination, and support secure, multi–user operational environments. From an interoperability standpoint, aligning the system architecture with the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive, particularly its spatial data themes concerning cadastral parcels and land use, and incorporating elements of ISO 19152 [78]: (Land Administration Domain Model) would promote semantic coherence, ensure legal–geospatial linkage, and foster long–term institutional trust. These integrations are not only technically achievable but also strategically imperative for harmonizing North Macedonia's expropriation framework with

broader European and international standards in digital land governance. These implementations foster sustainable development, innovation, and environmental stewardship within the context of land management and expropriation processes. Moreover, such systems could potentially integrate with the European Commission's INSPIRE (Infrastructure for Spatial Information in Europe) initiative, namely with the Real Estate Cadastre and cadastral system in North Macedonia. To ensure a structured and actionable trajectory toward national–level implementation, the proposed system must adhere to a phased technological roadmap. Initially, the prototype should undergo validation through institutional pilot testing, with iterative feedback mechanisms in place to refine the data architecture and operational functionality. In the short term, the system should transition from Microsoft Excel to a secure and scalable SQL–based or GIS–integrated environment, facilitating real–time data updates, spatial analytics, and multi–user accessibility. The medium–term development phase should prioritize the creation of a cloud–hosted Expropriation Information System and an accompanying Expropriation Digital Archive System. In the long term, full integration with national e–government platforms should be pursued, ensuring semantic, legal, and spatial interoperability in alignment with both national and European Union standards. This staged implementation strategy ensures long–term sustainability, technical robustness, and alignment with international best practices in digital land administration and governance.

Declaration of Ethical Standards

This paper has been prepared and conducted in compliance with the ethical standards outlined by the journal.

Credit Authorship Contribution Statement

Substantial contributions have been made by all authors in this paper; each author has been involved in the research methodology, conceptualization, and final approval of the manuscript.

1. **Edmond JONUZİ**: Methodology, Conceptualization, Research Design, Resources, Investigation, Data Analysis, Writing the Article, Review & Editing.

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Declaration of Competing Interest

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