ENGINEERING-ECONOMIC ASSESSMENT OF UKRAINE DIGITAL LAND CADASTRE: QUANTIFYING ADDED VALUE FROM GEODATA ACROSS AGRICULTURE, ENERGY AND TRANSPORT PROJECTS

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Abstract. Engineering projects in Ukraine depend on reliable land information before construction begins: parcel geometry, intended use, rights, easements, restrictions, valuation attributes, and administrative location all affect siting, corridor design, land acquisition, compensation, and schedule risk. Yet, cadastral studies usually discuss governance or land-market reform, while the engineering-economic value of reusable official geodata remains weakly quantified. This paper develops an assessment framework for the digital State Land Cadastre as production infrastructure for engineering. The method combines workflow decomposition of land-related tasks, time-driven activity-based costing, and risk-adjusted scenario analysis comparing a digital-official-data case with a fragmented or paper-based information case. The framework is applied to agricultural land-bank management and irrigation planning, energy infrastructure siting and servitudes, and transport corridor development. By the end of 2024, 44.9 million hectares, or 74.4% of Ukraine's territory, were recorded in the cadastre, including 33.0 million hectares of agricultural land; by early 2026 public reporting indicated more than 26.0 million registered parcels and continued growth of restrictions, functional zones, and e-services. Relating reported international financing for the 2003-2013 cadastre development project to the current inventory yields an indicative historical system cost of about USD 3.6-7.7 per parcel or USD 2.0-4.3 per recorded hectare. The results show that official parcel-level geodata reduce information search, repeated field reconciliation, re-survey, and exposure to late design changes and land disputes. The study novelty is that it treats the cadastre not only as a legal register, but as a reusable engineering data platform with value that grows through repeated cross-sector use; it also offers a transferable assessment procedure that can be applied in other countries where parcel, rights, and restriction data remain fragmented.

Keywords: digital land cadastre, geodata value, land banking, infrastructure planning, mass land valuation.

Introduction

Ukraine's State Land Cadastre started functioning on 1 January 2013 as a core component of land reform and digital public administration [1]. In engineering terms, this was more than an institutional reform: it created a national parcel-based spatial data layer that can be reused in feasibility studies, route selection, land acquisition, budgeting, permitting, and dispute prevention. By the end of 2024, 44.9 million hectares, or 74.4% of the country's territory, were registered in the cadastre, including 33.0 million hectares of agricultural land [4]. Public reporting issued in 2026 for 2025 results indicated more than 26.0 million registered parcels, expanded recording of restrictions and functional zones, and continued digital service development [2; 3].

International and Ukrainian literature already shows why this topic matters, but it does not yet quantify the engineering-economic effect considered here. Williamson, Enemark, Wallace and Rajabifard interpret land administration as infrastructure for land markets, planning and sustainable development, while Enemark, Bell, Lemmen and McLaren argue that fit-for-purpose land administration should deliver scalable and interoperable spatial-legal data rather than isolated registry functions [12; 13]. Hersperger et al. show that digital plan data in Austria, Germany and Switzerland primarily improve efficiency and transparency [14].

In Ukrainian scholarship, Putsenteilo, Kostetskyi and Bryk analyse world and domestic experience of land-resources digitalisation [11]. However, the added value of authoritative parcel-level cadastral geodata for agriculture, energy and transport engineering remains weakly quantified.

The practical relevance of such data is especially high in agriculture, energy, and transport. A designer who must reconstruct parcel boundaries from paper title documents, scan archive plans, and reconcile multiple unlinked registries faces additional field visits, repeated legal checks, delayed negotiations, and a higher probability of late design changes. Where official, legally verified geodata are digitally accessible and reusable, these transaction costs are partly converted into machine-readable inputs for engineering workflows. Ukraine's case is therefore important not only nationally, but also internationally, particularly for countries that still operate with partial digitalisation, separate legal and cadastral objects, or administrative agricultural-parcel systems that are not equivalent to authoritative parcel boundaries [7-9].

Accordingly, the aim of this study is to develop and test a transferable engineering-economic framework for quantifying the added value of official digital cadastral geodata in project preparation and land-acquisition workflows. The study specific scientific contribution is threefold: it operationalises the cadastre as reusable engineering data infrastructure; it combines workflow decomposition, time-driven activity-based costing, and risk-adjusted scenario analysis into a replicable assessment procedure; and it demonstrates the procedure in three project classes that are relevant not only for Ukraine, but also for other countries with incomplete digitalisation or fragmented land-information systems.

Materials and methods

The assessment combines official public statistics, publicly reported international project financing, and workflow mapping of land-related activities in real project environments. The cadastral maturity baseline was derived from official Ukrainian sources on cadastre operation, public reporting, e-services, and land-market indicators [1-4; 10]. International comparison was based on European materials discussing the legal status of cadastral boundaries, the persistence of paper deeds or maps, and the distinction between subsidy-control parcel systems and legally authoritative cadastral parcels [7-9].

Three case classes were analysed. The agricultural case uses parcel analytics for Bilotserkiv district and Bilotserkiv community in Kyiv region, an intensive farming area where official parcel geometry, ownership form, intended use, and tenant structure are essential for land-bank analysis and irrigation preparation.

The energy case is based on a 330 kV transmission-line project in Odesa region. For security reasons under wartime conditions, no geodata, precise support coordinates, or sensitive corridor characteristics are disclosed; only the structure of land-related engineering tasks is used. The transport case is based on the planned connecting section of the Greater Ring Road around Kyiv between the M-06 and M-05 highways.

For each case, two information environments were compared: a digital-official-data scenario and a fragmented-information scenario. The latter assumes incomplete digital parcel coverage at the project interface, greater reliance on paper title documents, more manual owner identification, higher rates of field reconciliation, and later detection of restrictions or boundary conflicts. A time-driven activity-based costing model was then applied to desk analysis, legal checks, field visits, re-survey, and risk exposure.

$$C = \sum \left(t_i \cdot r_i\right) + C_f + \sum \left(p_j \cdot I_j\right), \quad (1)$$

where t_i – activity time, h;
r_i – capacity cost rate, EUR·h^{-1};
C_f – direct field and survey cost, EUR;
p_j – probability of risk event;
I_j – cost impact of the risk event, EUR.

$$AV = C_{paper} - C_{digital}, \quad (2)$$

where AV – added value of official digital cadastral geodata for the analysed workflow, EUR.

To avoid false precision, all monetary results are presented as conservative ranges. Labour rates include employer overhead, software, and travel support; risk events cover late route or layout changes, additional land-documentation cycles, compensation disputes, or repeated negotiations caused by delayed discovery of parcel-level facts. The results should therefore be interpreted as decision-support estimates, not as tender prices.

The cross-sector reuse of the same cadastral data elements is systematised in Table 1. As the table shows, the same official parcel-level dataset is reused for different engineering purposes. This reusability is a central source of public value, because the same parcel geometry and attributes support not one transaction, but repeated project decisions throughout a system’s service life.

Table 1

Cadastre data elements and their engineering function by project class

Data element	Agriculture	Energy	Transport
Parcel geometry and area	Land-bank screening, field consolidation, irrigation block delineation	Tower footprints, access zones, temporary work areas, corridor checks	Permanent land take, interchanges, service roads, utility strips
Intended use and land category	Crop-land filtering, irrigation eligibility, lease portfolio structure	Checking compatibility with energy-infrastructure siting and required land-use change	Road right-of-way formation, design of compensatory land actions
Ownership and use-right attributes	Lease mapping, tenant concentration, negotiation sequencing	Owner and user identification for purchase, easements, or servitudes	Acquisition planning, compulsory-purchase preparation, stakeholder mapping
Restrictions and encumbrances	Irrigation, environmental, or heritage constraints	Protected zones, intersecting networks, registered use restrictions	Environmental, utility, and protection-zone conflicts along corridor
Valuation data and extracts	Normative value for rent and investment appraisal	Compensation and budgeting for land-right formalisation	Budgeting acquisition, compensation, tax and fiscal implications

Results and discussion

The first result is structural. Ukraine has achieved a level of cadastral digitalisation that is highly consequential for engineering delivery. The system combines a public cadastral map, electronic services, open-data publication, and interaction with related state registers [2; 10]. Public reporting for 2025 described new software functions, online service provision, continued population of functional zones and restrictions, and the pilot admission of certified land survey engineers into selected cadastral workflows [2; 3].

The second result is comparative. In many European land-information systems, cadastral parcels and legally conclusive property boundaries are not identical, and fully conclusive boundaries remain uncommon [7]. Historical comparative reviews also document that, in parts of Europe, deeds or cadastral plans continued to be kept partly on paper and digital coverage was uneven [8]. In parallel, agricultural support in the European Union often relies on LPIS reference parcels designed for subsidy administration rather than on legally authoritative cadastral objects [9]. Against this background, Ukraine's parcel-based digital cadastre has significance beyond land reform: it supplies a legally relevant spatial layer that can be directly reused in engineering and investment workflows.

The indicative historical cost benchmark reinforces this interpretation. If the 2003 World Bank-approved financing envelope of USD 195.13 million is related to the current parcel inventory, the historical creation cost is approximately USD 7.48 per parcel; using the later reported loan amount of USD 89.7 million yields about USD 3.44 per parcel [5; 6]. When expressed per hectare of the 45.20 million hectares discussed in this study, the implied range is about USD 1.98-4.32 per hectare. Such unit values are modest when compared with the costs of repeated manual boundary reconstruction, field reconciliation, or redesign on even a single medium-size infrastructure project.

Agricultural case

Bilotserkiv area illustrates how digital cadastral data support agricultural engineering (Fig. 1). In the district, 164 685 parcels covering 485 166.84 ha are mapped, of which 88.81% are agricultural land. In Bilotserkiv community, 10 989 parcels cover 28 844.66 ha, of which 77.30% are agricultural land; the community also contains industrial, transport, energy, water, and forest categories that matter for irrigation routing and facility siting. Service-layer analytics additionally reveal missing intended-use records for a small set of parcels and missing ownership information for part of the inventory, which is exactly the kind of pre-project data quality issue that must be detected early.

For a representative land-bank screening and irrigation-preparation campaign, the digital cadastre reduces four cost components: manual parcel search, digitisation of legacy boundary documents, unnecessary field visits to reconcile parcel outlines, and rework caused by late discovery of ownership or use constraints. Under conservative assumptions, the avoided cost is estimated at EUR 28-63 thousand per campaign, with the largest share coming from fewer repeated parcel checks and lower field reconciliation intensity. The international significance is clear: many countries possess agricultural reference systems for subsidy control, but not all provide equally reusable parcel-level legal-geospatial data for engineering design and land assembly [9].

Energy case

The energy case concerns a new construction of the 330 kV power line Novoodeska-Artsyz (Odesa region) NPC “UKRENERGO” project with approximately 16.29 km of line construction, support installation, temporary work sites, network crossings, land servitudes, compensation procedures, recultivation obligations, and multiple interfaces with local infrastructure. The project documentation shows that the contractor must identify landowners and users, determine where permanent or temporary rights are needed, formalise servitudes, manage compensation, obtain extracts from the cadastre and rights register, and, where necessary, prepare land-use change and subdivision documentation. These are quintessential land-information tasks, but in engineering practice they are on the critical path of design and construction rather than merely legal formalities.

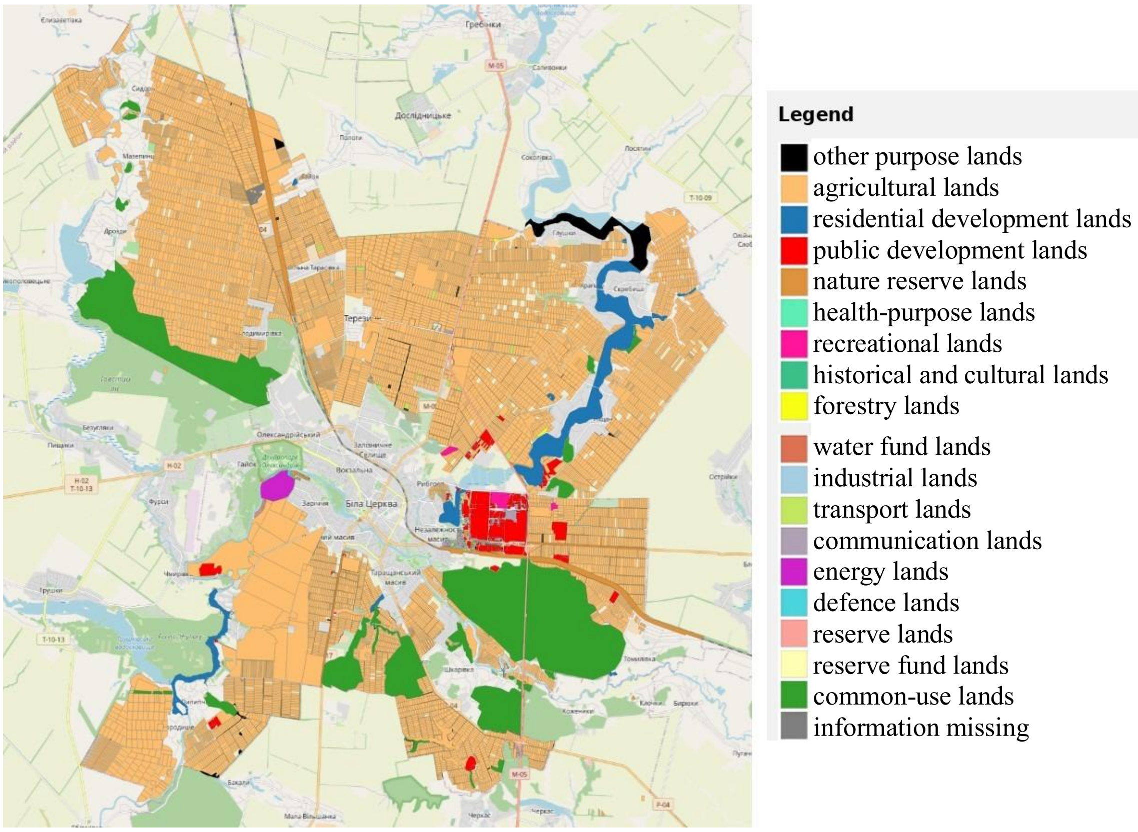

Fig. 1. **Visualization of completeness of the cadastral coverage of the Bila Tserkva community of the Bila Tserkva district of the Kyiv region:** created using “Vkursi Zemli” cadastral analytics service; the basic cartographic layer is OpenStreetMap

Because of wartime conditions, no route coordinates or detailed geodata are reported here. Even so, the structure of the workflow is sufficient for economic assessment. The official digital cadastre reduces the time spent on owner identification, parcel-status verification, overlap checking, preparation of support-site documentation, and discovery of restrictions affecting line layout. For the analysed scenario, expected avoided cost is EUR 92-211 thousand, while a probable schedule gain is about 1.7 to

4.0 months. The main benefit does not arise from one database query, but from preventing late design changes in a high-consequence project environment.

Transport case

The transport case is the planned 35.2 km connecting section of the Greater Ring Road around Kyiv (from the Kyiv – Chop (M-06) highway to the Kyiv-Odesa (M-05) highway in Kyiv region). Approximate length of the construction section – 35.2 km, a category I road with six lanes, 6.00 m median, additional technological strips, future utility corridors, fauna fencing, and the need to prepare land-allocation documentation for permanent use. In such a corridor project, cadastral geodata are required not only to calculate land take, but also to structure acquisition sequencing, identify parcels requiring subdivision, distinguish private and public ownership, and prepare compensation or compulsory-purchase packages. The road case is therefore especially suitable for testing large-scale value creation from official parcel geodata.

The scenario analysis shows the highest gains in this case: EUR 0.43-1.06 million of avoided cost in the pre-construction and land-acquisition interface. The saving comes from fewer manual parcel reconstructions across a long corridor, lower probability of alignment changes triggered by late land-information discovery, and faster preparation of documentary packages for authority decisions and negotiations. For applied engineering science, this is the key message of the paper: digital cadastral maturity is not only an institutional achievement, but also a determinant of corridor-delivery efficiency.

Across all three cases, the economic logic is cumulative. Even if only a limited number of medium and large projects reuse the cadastre each year, the avoided costs over the system life can exceed the initial public investment benchmark. The conservative base-case results are summarised in Table 2. It excludes wider macro-effects such as lower financing friction, faster commissioning of productive assets, improved tax administration, and the value of reusing the same parcel data for operation, maintenance, or later network expansion.

Table 2

Scenario-based estimate of added value from official cadastral geodata

Project class	Main avoided activities	Avoided field effort	Avoided cost, EUR	Indicative schedule gain
Agriculture	Parcel search, legacy-plan digitisation, repeated ownership checks	Reduced by about 60-70%	28 000-63 000	2-5 weeks
Energy	Servitude screening, owner identification, overlap checks, redesigning loops	Reduced by about 35-50%	92 000-211 000	1.7-4.0 months
Transport	Corridor parcel reconstruction, acquisition-package preparation, late alignment changes	Reduced by about 30-45%	430 000-1 060 000	3-7 months

A direct one-to-one monetary comparison with other European countries is methodologically difficult because public reporting usually measures transaction time and service speed rather than project-level engineering costs. Nevertheless, the Ukrainian estimates are consistent with documented European effects of cadastral and land-information digitalisation. In Norway, the Infoland portal reduced property-information searches from a process that could take weeks to a one-stop workflow in which the required data are typically available within hours [15]. In England and Wales, HM Land Registry reported that, in migrated areas, local land charges search results fell from days or weeks to instant online availability [16]. In Serbia, cadastral modernisation reduced average property transaction registration time from 48 days in 2015 to 6 days [17]. These benchmarks are not directly commensurable with the present EUR estimates, but they confirm the same mechanism identified in Ukraine: authoritative digital land data create value by compressing search time, reducing rework, and lowering downstream delay risk.

Conclusions

1. Ukraine's digital State Land Cadastre should be interpreted as an engineering data infrastructure as well as a legal land register, because parcel-level official geodata are repeatedly reused in project preparation, land acquisition, and risk control.
2. The unit benchmark derived from historical cadastre financing - about USD 3.4-7.5 per parcel or USD 2.0-4.3 per recorded hectare – is low relative to the avoided cost generated on medium and large agricultural, energy, and transport projects.
3. Compared with countries where cadastral, legal-boundary, or agricultural-parcel systems remain only partly integrated, Ukraine's cadastre offers a stronger basis for applied engineering workflows, especially where authoritative geodata must support route selection, servitudes, compensation, and compulsory-purchase procedures.
4. The highest engineering-economic effect arises not from single extracts, but from fewer repeated field checks, less manual reconstruction of parcel facts, and lower probability of late design changes and land disputes.
5. Further integration of mass land valuation, restrictions, functional zoning, and machine-readable service interfaces would increase the international significance of the Ukrainian model for agricultural investment planning, infrastructure recovery, and land-related fiscal management. The assessment sequence developed here is transferable to other countries that need to quantify the engineering-economic return on cadastral modernisation under incomplete digitalisation.

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