Beyond Cadastre 2014 – Advancement of a mature system

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Key words: Cadastre; Digital cadastre; e-Governance; GSDI; Digital twin; Land administration; BIM; Digital transformation

SUMMARY

The property register and cadastral system in Switzerland evolved in several stages, progressing from a cadastre for tax purposes in the 19th century, to a property cadastre, and finally to a multi-purpose cadastre in the 20th century. The digitisation process, initiated in the 1980s, led to the development of forward-looking, optimised structures, creating an essential foundation for the national geodata infrastructure in terms of both data quality and standardisation. Thanks to its up-to-date nature, geometric and content accuracy, and highly efficient processes for boundary determination and updates, the property cadastre enjoys a very high reputation in Switzerland today. The objectives of the C2014 cadastre have also been implemented nationwide. The cadastre is widely recognised as a central pillar of Switzerland's prosperity (De Soto, 2002). Compared internationally, the Swiss system is said to have a high level of maturity, except in the handling of easements and the third dimension (property and easements) (Itäinen, 2025).

Nevertheless, the cadastral system must be regularly adapted and further developed in line to reflect changing circumstances. A situational analysis has identified the following drivers for adaptation: First, the changes relate to the evolving explicit and implicit needs of users. Cadastral data must continue to support important societal challenges, such as climate adaptation, inclusion, and the efficient use of limited land resources. Cadastral data should also be recognised as a relevant legal basis for developing policies in other areas. Second, data collection processes must align with the significant advances in digital construction (BIM-based data) and machine learning-based information extraction from imaging techniques. This increase in efficiency is also essential in order to continue offering civil society a strong alternative to large internet corporations with their extensive and rapidly growing data sets. Third, growing international tensions necessitate adjustments to the resilience of the cadastral infrastructure, improved control over data and algorithms, and a response to the growing pressure of legitimacy over law (Steudler, 2015).

In this paper, we demonstrate how these factors can be leveraged to advance the cadastral system in the City of Zurich after its digitisation.

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1 INTRODUCTION

1.1 State of cadastral system in Switzerland

Historical development

The historical development of the Swiss cadastral system represents a steady evolution from a fiscal taxation tool to a legal land ownership system, and last of all to a sophisticated, digital national infrastructure. This journey began in the mid-17th century with the creation of large-scale maps designed primarily for fiscal purposes. As the mid-19th century brought rapid urbanization, the functional requirements of these records shifted; the "juridical cadastre" began to dominate the traditional fiscal cadastre as the legal security of property ownership became paramount for the economic growth. This transition culminated in a landmark constitutional shift in 1912. With the entry into force of the Swiss Civil Code, cadastral land surveying was elevated to be a federal task. However, but crucial, the execution of this task was transferred to the cantons through a Public-Private Partnership model, creating a collaborative framework that remains a defining characteristic of the Swiss system today.

The late 20th century heralded a digital transformation. Between 1980 and 1993, the project "Reform of Cadastral Surveying" was launched, leading to the influential "AV93" ordinance. By 1993, conventional paper property maps were officially replaced by digital databases, transforming the cadastre into the essential reference layer for modern Land Information Systems. This digital maturity was solidified between 2004 and 2008 with the introduction of Article 75a into the Federal Constitution, followed by the Act on Geoinformation, which provided the legal foundation for a National Spatial Data Infrastructure (Kaufmann, 2017).

In recent years, the system has expanded to address the increasing complexity of land-use regulations. Driven by the Act on Geoinformation, work began in 2012 on the Cadastre of Public-law Restrictions on landownership (PLR-cadastre), also known as Cadastre 2014. This initiative ensured that legal constraints - such as noise protection zones or contaminated sites - become as transparent as legal rights, i.e. property boundaries. Full national coverage for the PLR-cadastre was achieved in 2020 (Besse, 2021)

Achievements

In view of the comprehensive digitisation of cadastral plans and the cadastral data that is now available, those involved in cadastral surveying can be proud of what has already been achieved. The cadastre not only contains property information, it is designed as a comprehensive (multi-purpose) cadastre including land cover, addresses, public laws and restrictions as well as subsurface utilities (Luethy, 2024). The cadastre has an excellent reputation among users. They appreciate the reliability, the accuracy, the fact that it covers many requirements, and the high degree of timeliness (with constant data updates). Ten years ago, easy access to data, whether via map services or open government data, was hardly conceivable, but today it is taken for granted by many users. The high level of reliability is reflected, among other things, by the fact that in 2023, mortgage loans worth CHF 1,250 billion (the national GDP is approx. CHF 800 billion) were secured with the land register and that only very few cases of disputed boundaries are brought before the courts.

Due to the high costs associated with data collection and the decentralised and federal organisation of the cadastral system, it was clear from the outset that data exchange between the systems was necessary. To this end, a conceptual data model was developed so that the data could be easily harmonised. Secondly, the data collection orders were linked to the obligation to deliver the data in a system-neutral format, structured according to a standardised, object-oriented data model. This ensured semantic interoperability at an early stage and initiated the change from plan-oriented thinking to structured data at an early stage. Those same conceptual principles were later adopted for the development of the NSDI.

Missed opportunities

Thirty years after the start of the digitisation of the cadastral system, however, it must be stated that the willingness for innovation and change in related sectors has been higher than in cadastral surveying. Despite the freedom of method, the same measuring and recording methods are still being used as 20 years ago. For example, drone surveying or mobile laser scanning are not used in the city of Zurich for ongoing data updates.

The authorities of the city of Zurich, as well those at the cantonal and federal levels, are confronted with various challenges to sustainably secure the prosperity of society and our living space. The overarching strategies to address these challenges look into topics such as the digital provision of government services and the promotion of innovative solutions through the broad availability of data and data-based algorithms, e.g. artificial intelligence. In addition to increasing the effectiveness of government processes, the protection of natural resources and resilience to climate change have also been identified as key challenges. Resilience should primarily be achieved through the so-called green-blue transformation, which includes converting roads into green spaces (reducing soil sealing), planting additional trees and improving water retention capacity to reduce the risk of flooding. This raises the question as to what extent the cadastre can contribute to these overarching strategies and to the green-blue transformation.

As the highest supervisory authority for the cadastre, the federal government has taken the opportunity to develop a new vision for the cadastral system with a working group. The vision was adopted and implemented in the summer of 2025 (Swisstopo, 2025). From the perspective of the city of Zurich, the statements in the new vision are not concrete or targeted enough. Based on current needs and the high demand for change, the statements must be further concretized and condensed.

The aim of this paper is therefore, on the one hand, to highlight the desired developments in the cadastral system of the city of Zurich and, on the other hand, to stimulate discussion on how the cadastral system can continue to make significant contributions to the further development of society.

2 NEEDS AND DRIVERS FOR ADVANCEMENTS

In order to advance the development of the cadastre, it is essential to understand the current needs of users and anticipate future developments in society and the living environment. A good synthesis of user needs can be obtained from urban strategies (legislative objectives), which highlight the most important challenges and developments, in particular the umbrella strategy "Zurich 2040" and the "Smart City Zurich" framework. These initiatives are designed to secure long-term prosperity by actively exploiting the opportunities of digitization while championing sustainable development. A central pillar of this vision is the digital provision of state services—often referred to as "Smart Government"—which aims to make administrative processes more efficient, transparent, and accessible to the public. By fostering a culture of innovation, the city seeks to realize cutting-edge solutions, including the integration of machine learning to optimize urban management and the transition toward a circular economy.

These technological advancements are inextricably linked to the city's commitment to protect the climate and natural resources. Zurich faces the dual challenge of a growing population and increasing demands for infrastructure within its limited geographical area. To address these, the city has implemented effective measures for climate change adaptation and to set ambitious targets for a sustainable energy supply and ecological agriculture. By pursuing an effective environmental policy that preserves biodiversity and reduces greenhouse gas emissions, Zurich aims to meet its climate goals while maintaining a high quality of life. Based on these user needs, the cadastre must evolve from a ‘simple land register’ to a more comprehensive ‘Digital Twin’ of the city (Schrotter, 2020, Luethy, 2025). Such a virtual representation provides the accurate and appropriate spatial data required to manage densification, coordinate renewable energy or monitor environmental protection in a rapidly changing urban landscape.

In addition to questions regarding the scope of information in a future cadastre, there is also the question of the impact of technical developments, both in terms of data collection and processes related to cadastral surveying. The key aspects are described below.

2.1 Growing relevance of cadastral data in governmental decisions

Developments

As already mentioned in the introduction, cadastral data in Switzerland is much more than just information on landownership property and tax-relevant buildings. The aim of digitising the cadastre was to enable it to serve as a multi-purpose cadastre providing the basic data for the emerging GIS and spatial data infrastructure (SDI). Thanks to the high quality and reliability of the data, cadastral data is used for much more than just orientation purposes. In fact, it is used as a basis for various legally binding official decisions (rulings). An everyday example of this is in the area of building permit procedures, where evidence of the distances between new buildings and existing objects such as buildings, forests, roads or parcel boundaries (clearance) is required. Cadastral data is used to prove that the clearances are being complied with.

In some municipalities, soil sealing affects the fees for rainwater drainage via the sewer system. Cadastral data is used for this purpose, as green areas are classified separately in land coverage. Even if the cadastral data is not included in the legal act, it nevertheless forms the legally relevant basis for the corresponding regulations.

Cadastral data is legally relevant if at least one authority uses it to formulate a public interest in spatial terms that must be considered in a (subsequent) constitutional dispute – for the subsequent general or case-specific legal force – and if it is publicly accessible. In addition to the aforementioned buildings, other land coverage types such as forests, vineyards or water bodies are also typical examples in Switzerland.

Figure 1 Lines in blue indicating clearing form street and river as part of the cadastral data

Thesis

In the future, the importance of cadastral data will shift even further away from reference data towards spatial data with legal relevance. Cadastral data increasingly serves as the basis for a wide range of governmental activities and is therefore an indispensable foundation for legally binding government decisions and acts.

Consequences

The high level of trust that already exists in the quality of cadastral data can be further strengthened by making the cadastral organisation more aware of this. In the future, cadastral data will be categorised as follows:

- *Legally valid*: the right is guaranteed (in the case of the property cadastre in the sense of civil law). Examples: property boundaries, easements;
- *Legally binding*: they reflect directly an administrative act – administrative boundaries (municipal, district boundaries), address, "Perimeter permanent land displacement", most data in the PLR-cadastre;
- *Legally relevant*: at least one government (specialist) agency bases its decision on this data. Examples: building, forest boundaries (in urban areas), waterbodies;
- *Georeference data*: (cadastral) data that the state requires for important tasks (in the European Union declared as "high-value datasets");
- *Other data*: some of the data will remain as situational information only. Examples: benchmark points, stairs, pools, traffic islands.

2.2 Digital Construction

Developments

Construction activity in the public domain is increasingly based on the BIM methodology, which means that high-quality, structured data in the form of a BIM model is already available before and for the construction phase. Construction work is often carried out using machine control (or even robots), which is only possible with correct, consistent and accurate data. Once construction is completed, the BIM model must match the actual reality and therefore may need to be updated based on surveying data. Most constructions are included in the cadastre in a generalised form, meaning that cadastral data must also be updated. Until now, the newly built infrastructure has been surveyed twice, each time with different purposes: once for the as-built documentation and once for the cadastre.

Thesis

In the future, new buildings and new (public) infrastructure will not be surveyed by the cadastral authority. But project and inventory data will be transferred, validated and integrated into the overall cadastral database.

Consequences

The significance of *cadastral surveying* will fundamentally change in the coming years. Surveying tasks will increasingly focus on determining (recording and staking out) property boundaries and spatially defined easements, or to random checks to ensure positional accuracy. The decline in surveying tasks will be offset by increased tasks in data management. The following tasks will become increasingly important to maintain high quality standards:
- Validation of data quality, including random checks for positional accuracy and data integrity;
- Format conversion;
- Semantic transformation;
- Integration into overall database;
- Reconciliation with existing data – no transitions;
- Homogenisation of level of detail and level of information.

Particular attention must be paid to the granularity of the information. The level of detail (LOD) and level of information (LOI) differ considerably between an object-oriented BIM model and area-wide cadastral data. Even if more data were available, an excessive level of detail in a cadastre would make little sense, as this information is not required from an overall perspective. Nevertheless, as will be shown later, the scope of information will increase in the near future.

Due to the high importance of legal certainty, the surveying and management of property boundaries and easements must continue to be carried out by the cadastre organisation (single source of truth). In the event of boundary disputes, the surveyor remains obliged to stake out the boundary recorded in the land register to the real world and can fulfil this role as a neutral authority. To ensure this, delegating the boundary surveying is not an option.

Figure 2 Project data for new tramline and street realignment, fusion of BIM data and existing 3D city model

2.3 Away from departmental silos – once only

Developments

In an increasingly complex world, the responsibilities of individual administrative departments are no longer strictly separated from one another. Since administration is also highly digitised and much of the spatial information is managed using GIS, it can happen that the same facts are documented multiple times and in different ways in an urban SDI.

While comprehensive harmonisation of building data has taken place (and data from over 20 data sets can now be easily linked), there is no harmonised approach for other topics. A prominent example is soil sealing: sealing and unsealing are relevant to different administrative departments and from different perspectives:

- Environmental protection agency (department) – impact on the climate (perspective);
- Green City of Zurich – expansion of public green spaces, planting of additional trees, biodiversity;
- Civil engineering office – public road space, efficient transport, maintenance and street cleaning;
- Housing agencies – local climate;
- Waste water utilities – drainage, surface runoff.

Today, each department has its own definition of soiled surfaces and maintains its own data set. Multiple data collection and management not only incurs unnecessary costs, but also leads to inconsistencies between the data sets, which can result in incorrect decisions or additional work.

Thesis

Real-world issues and objects that are documented differently by different departments and therefore managed multiple times will in the future be organised using the inter-organisational data structure of the cadastral system. The neutral role of the cadastral agency helps to mediate between the needs of the various stakeholders. The principle of a *"single source of truth"* will thus be achieved throughout the entire urban SDI.

Consequences

In the future, all topics for which several authorities collect data will be coordinated by the cadastral organisation and managed in a single database. However, this does not necessarily mean that the cadastral organisation will also be responsible for data collection. As explained in the previous section, it is expected that most changes in public spaces will be planned using BIM methodology and that data will therefore be provided by the organisation responsible for the project in question. In addition to the aforementioned tasks, the cadastral system will have to assume the following additional duties in the future:

- Identify objects or topics with overlapping demands and processes;
- Initialize development of a data product including collecting and coordinating the requirements of different users and stakeholders (data product specifications);
- Coordinating data collection;
- Quality audits;
- Continuous review of user needs and active product management;
- Data provision.

2.4 Ever-growing demand for more data

Developments

In order to achieve the ambitious goals outlined in the city's various strategies, the tasks of the administration will have to change. This also entails different requirements for reference data, which is usually provided by the multi-purpose cadastre. These requirements relate, on the one hand, to aspects of data quality characteristics, such as higher geometric resolution or more up-to-date data, and, on the other hand, to new objects that are not yet managed as structured data. Examples of the latter are:

- Building facades are identified in the strategies as having potential for both green facades and photovoltaic installations. In today's 3D city model, this data is generated from the building footprints, meaning that both window areas and the vertical structure of the facade are missing, making it impossible to check their suitability for further use.
- When promoting slow traffic, and pedestrian traffic in particular, it must be considered that certain pavements are not suitable for vulnerable groups, either because stairs present an obstacle or because street furniture makes it impossible to pass through with a wheelchair. Most of such critical objects are not included in the current SDI.

Thesis

In the future, the cadastre must meet the ever-growing demands for higher spatial resolution and up-to-dateness without compromising the homogeneity, accuracy and reliability of the data. The need for additional information must be identified on the basis of the strategies. The cadastre, as a basic data set, must therefore be regularly reviewed and continuously developed in collaboration with its users. This will also ensure the financing of the additional tasks.

Consequences

The consequences are both of an organisational and technical nature. On the organisational side, the focus is on greater user involvement. Orchestrating the data requires a good knowledge of the various subject-specific strategies and personal contacts in the relevant administrative departments. The cadastral organisation also needs the ability to analyse requirements and describe them in data product specifications.

On the technical level, higher spatial and temporal resolution means that other methods must be found for initial data collection and updating. Current methods are not designed for this. In addition to the changes already mentioned, such as the integration of project data (BIM) and the merging of different data sources, the capabilities of imaging techniques combined with machine learning-based object extraction and attribution will become an important pillar for data collection and change detection.

Public spaces are currently surveyed and documented every two years using street view mapping. In the future, municipal vehicles, such as street cleaning vehicles, will be equipped with inexpensive camera-based sensor systems so that comprehensive data collection can take place every two to four weeks. With suitable data analysis algorithms, the effort required for data collection and updating will remain manageable despite higher resolution and higher information content.

3 FROM MULTI-PURPOSE CADASTRE TO GOVERNMENTAL DIGIAL TWIN

The above arguments suggest that the cadastre is further evolving from a land ownership cadastre to a multi-purpose cadastre and now to a governmental digital twin. What does this mean in concrete terms? The most immediate change is a multi-dimensional expansion that goes beyond traditional 2D mapping into 3D and 4D data spaces. The advantages of the third dimension are undisputed, and since its inception, the processes, technologies and algorithms for data collection and management have improved significantly, so that the cost-benefit ratio has become reasonable nowadays. The fourth dimension facilitates the tracking of developments, supports various simulations, and the design of development scenarios. In addition to the incorporation of these two dimensions, the content will also be expanded. This will be consistently tailored to the needs of the users. Possible examples of content expansions have already been identified: spatially defined easements (currently only recorded in the cadastre in certain cases), street furniture and green-blue infrastructure.

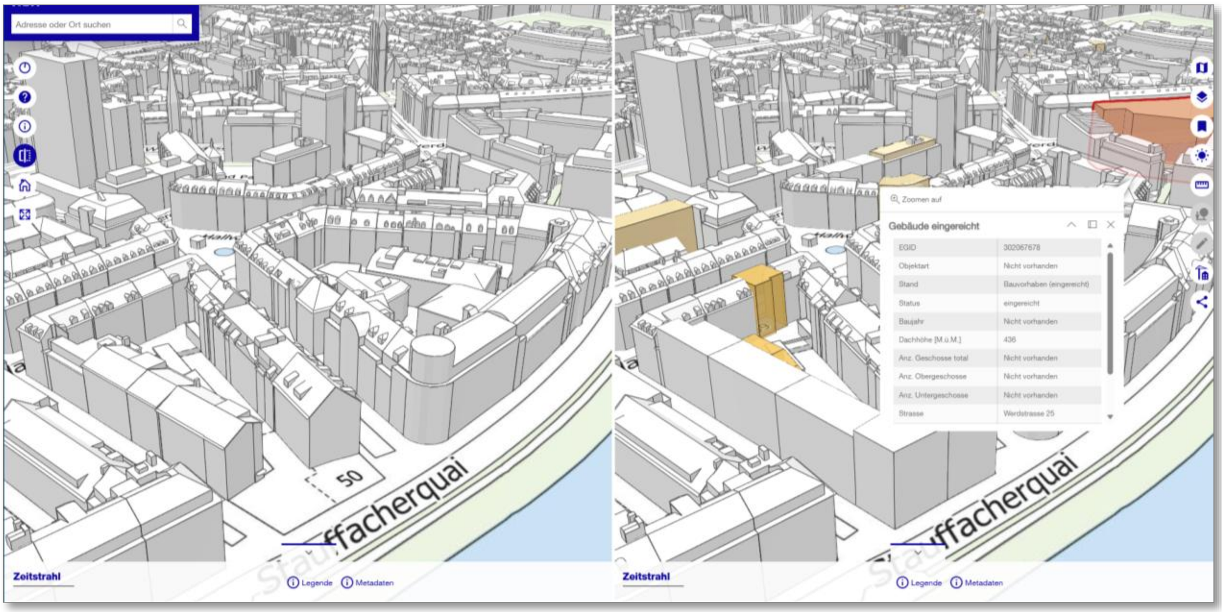

Figure 3 Digital Twin with current building structure and outlook with future developments

Impact on cadastral organisation

Looking to the future, the role of the cadastral system is evolving in such a way that the focus is shifting from surveying and data collection to taking responsibility for the governmental digital twin via data management. This transition marks a significant organisational change, while maintaining the fundamental trust that underpins the traditional cadastral authority. In contrast to previous methods based on independent data collection, the future will be characterised by data integration and fusion. The many years of experience in ensuring data quality enables the cadastral system to guarantee the reliability, accuracy, completeness and homogeneity of the data even with modern data collection methods and the integration of BIM data. This strengthens the position of the governmental digital twin as a legally relevant basis for official administrative decisions.

To ensure the success of these developments, communication with users must be intensified. This includes identifying specific needs for cost-effective product development, offering expert advice and highlighting the monetary value and added value of the cadastral work. To ensure that user needs are properly considered in product development, a change advisory board is to be set up, representing various user groups. This board will enable new needs to be identified and implemented more quickly, while continuing to guarantee content stability (existing data must not be eliminated).

Fundamentals of continuity
Despite these advances, some tasks of cadastre organisations remain unchanged. Securing land ownership is and will remain a core task; property boundaries and easements will continue to be marked out and checked exclusively by professional land surveyors and indicated by physical boundary markers. The high level of trust in the reliability of cadastral data and the commitment to open government data (OGD) remain unchanged. Since not every change can be planned digitally using BIM, traditional surveying remains indispensable. Finally, their long-standing experience with digital transformation makes cadastral organisations important advisors to other government agencies and society.

Impact on skills
This transformation requires the industry to strengthen specific competencies, particularly in the areas of data integration and machine learning supported by analytic methods, such as image recognition. Extending data structures into the third and fourth dimensions also requires additional knowledge. Furthermore, the use of cadastral data as a legally relevant data basis also necessitates new legal expertise. Together with the need for knowledge about the effects of the PLR-cadastre and the growing complexity of easements due to denser building development, legal knowledge will become increasingly important in the training of cadastral experts. This, in turn requires new, in-depth training and continuing education programmes.

Key challenges
The path to the future is not without obstacles. Cadastral organisations, leaders and professional associations must take a proactive leadership role in winning users over to these new systems, while at the same time managing the complexity of adapting the legal framework and securing transitional funding.

At the technical level, the following challenges are at the forefront:
- Development of a comprehensive cadastre of underground infrastructure: while structures on and above the earth's surface, as well as subsurface utilities, are well documented, the

digital documentation of most underground structures (like tunnels, underpasses, underground garages, basements) is inadequate. Construction plans and building permit plans can play an important role, but traditional digitisation and georeferencing are not feasible for cost reasons.
- Data in the field of BIM is still far from being sufficiently standardised. As a result, data transfer is disproportionately time-consuming and a homogeneous product is currently not achievable. The complexity of 3D objects should not be underestimated either. Good guidelines need to be developed to simplify the complexity without losing relevant knowledge about a structure. Cadastral organisations can make an important contribution here with their knowledge of data modelling and structures.
- Algorithmic reliability: Ensuring that image recognition and automated data processing meet the highest standards of reliability.

Benefits of the governmental digital twin

The implementation of this system offers significant advancements over current methods, primarily by reducing the manual effort required for data collection and continuous updating. By establishing an explicitly defined and legally relevant data basis, administrative decisions are better supported, ensuring that actions are grounded in verifiable facts. Central to this transition is the achievement of data integrity. By eliminating contradictions across multiple systems, the organization can rely on a single source of truth. This reliability directly translates into the better fulfilment of urban strategy objectives, particularly in the following ways:
- Advanced problem-solving: Complex urban issues can now be addressed more effectively by leveraging from existing, high-quality data.
- Improved visual communication: A governmental digital twin serves as an ideal tool for engaging stakeholder and, through intuitive visualization, allows for a faster "green-blue" conversion of urban spaces.
- Systemic resilience: Ultimately, these integrated processes lead to increased resilience, allowing the urban environment to adapt more effectively to future challenges.

4 OUTLOOK

The transition from a traditional two-dimensional digital cadastre to a comprehensive digital twin represents a significant transformation overall. The collection of new data and the conversion of 2D geometries to 3D geometries will be associated with considerable costs, for which funding must first be secured. Therefore, it will be necessary to adapt the legal basis to new data quality, data scope, responsibilities, and procedures.
As discussed in Chapter 2, various factors influencing the future direction of cadastral surveying are already a reality (legal relevance of cadastral data) or under development (digital planning and construction using BIM). Therefore, the first step is to describe a medium-term target state in detail. The appropriate processes for data collection must then be evaluated for all data elements. The identified methods for data generation (single-case recording, data retrieval from BIM, image recognition, etc.) can be classified according to complexity, accuracy requirements, etc. This allows the key technological challenges to be grouped together. From this, various work packages can then be derived. Within these packages, the new technologies

can be developed, tested and validated in the form of pilot projects. The greatest challenges identified today are the transfer of BIM data (due to the inhomogeneity of the source data), object extraction from imaging processes using machine learning (ensure the reliability of the processes) and the generation of 3D geometries with the same quality as today's 2D geometries (especially regarding topology and integrity).

For data for which financing has already been arranged, and for which the legal basis and the technical foundations are also in place, the transformation should be initiated. A good example of this is the expansion of the basic data on property boundaries, buildings and addresses to include historical dimension. In addition to the daily updated, structured data from the cadastre, all documents relating to changes over the last 100 years are also available. These digitised documents can be analysed using a machine learning-based process to extract the necessary information in a structured form and merge it with the current cadastre.

At an organisational level, it is important to strengthen cooperation with other administrative departments and users outside the administration. Various change advisory boards already exist within the general SDI, so their experience can be drawn upon.

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BIOGRAPHICAL NOTES

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Dr. Daniel Steudler is a former scientific associate at Federal Office for Topography swisstopo (1991-2023) and lecturer at ETH Zurich (2006-2021). He was active in FIG and the Commission 7 for many years. He published widely in the cadastral field and consulted internationally in land administration and cadastral issues. From 2015–2023 he was chair of the EuroGeographics "Cadastre and Land Registry" Knowledge Exchange Network.

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