Accelerating instead of Waiving Planning: Opportunities and Challenges of Digital Building Land Cadastres in Urban Digital Twins

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DOI: 10.48494/REALCORP2026.5053

1 ABSTRACT

Building land registers have the task of providing potential areas for construction activities and developing them for the demand for residential, commercial and open space. They are therefore an essential basis for the ability of municipalities to plan strategically for future land use and to help implement development objectives. The emergence of artificial intelligence, open and free geodata and new technologies in data collection is creating new possibilities and business models for capturing potential areas. The data integration, evaluation and provision of the collected information, in turn, benefits from the development of Urban Digital Twins (UDT). Model projects show that UDTs potentially strengthen cooperation between authorities, the private sector and stakeholders. Existing software solutions already contain relevant data, which makes it easier to design the information model for a UDT.

This article focuses on the adaptation, scaling, and establishment of these solutions in the process management of land management. For this purpose, the current state of development for two common software solutions (ArcGIS Urban©, Urbanistic©) is compared for the requirements of land management. The focus is onthe design of land registers that conforms to the criteria of a new norm on digitals twins for cities and municipalities (DIN SPEC 91607). The results show that methodological approaches are mostly designed as GIS functions and challenging to implement. This learning from our test was further substantiated in discussions with experts, where the seamless integration of benchmarking functions and scenario indicators in UDTis seen as a main requirement for the technical progress and added value for planning. Artificial intelligence is of particular importance in the collection, processing and integration of auxiliary data.

The recommendations in the article conclude that new requirements for information management in urban planning have emerged. They require investments in the development of enhanced land management cadastres which benefit from UDT functions. Their introduction in local planning requires that organizations adapt new process management techniques. The accelerated activation of building land, which has recently been introduced through reforms of the building law in Germany ("Bauturbo"), requires a speedier and more comprehensive evaluation of urban development quality criteria if sustainability criteria are still to play a role. Over time, we expect that UDT technologies will help in this context.

Keywords: Digital Twins, Land management, Infill development, Climate adaptation, Process management

2 BACKGROUND

There is broad support in the literature on sustainable urban development for models and concepts of redensification and infill development (e. g. Heinig 2021; Barton 2016; WBGU 2016). The building land requirements of cities and municipalities should primarily be met within planned inner areas and harmonized with climate adaptation measures and the functional networking of sustainable infrastructures (Umweltbundesamt 2023, see Figure 1).

In planning practice, however, resolving conflicting goals is a challenge. In this context, one author describes the clash of narratives on sustainable urban development as follows:

"The guiding principles [of infill development] are well-founded in each case, and some measures can be implemented without conflict. However, they must enable sustainable socioeconomic development and measurable growth in prosperity. Private investors and project developers are concerned with market-driven utilization concepts, space efficiency, technical constructability, cost-benefit calculations, financial viability, and marketability. Without a promising business case, no one will invest. Where this understanding cannot prevail, where radical, uncompromising demands from isolated individual interests clash, decisions cannot be made, plans cannot be drawn up, and construction cannot begin, resulting in valuable time being lost" (translated from the German original, see Achilles 2024). In order to bridge this gap, newer approaches focus on a digitally supported flow of information that is specifically practiced between urban development stakeholders (Brade 2025).

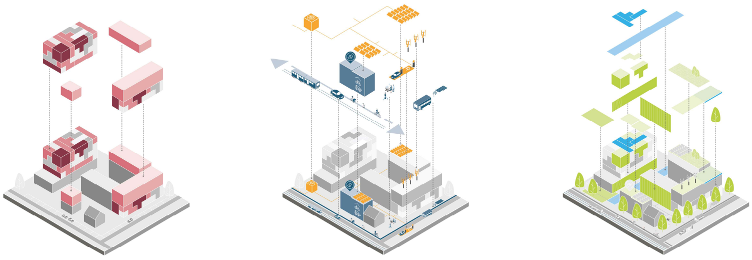

Figure 1: The three challenges of infill development (from left to right: building redensification, sustainable infrastructure, climate adaptation; source: courtesy of Must Städtebau https://must. eu/ [18. 01. 2026]).

UDTs provide new technologies for this purpose. They are currently being introduced in local government as a building block of smart city strategies (Etezadzadeh 2020). In this context, Figure 2 shows two frequent and legally requried tasks in local government for land management which can be supported by UDT technologies in the future:Issuing building permits (left) and setting building regulations through the development of local areaplans (right).

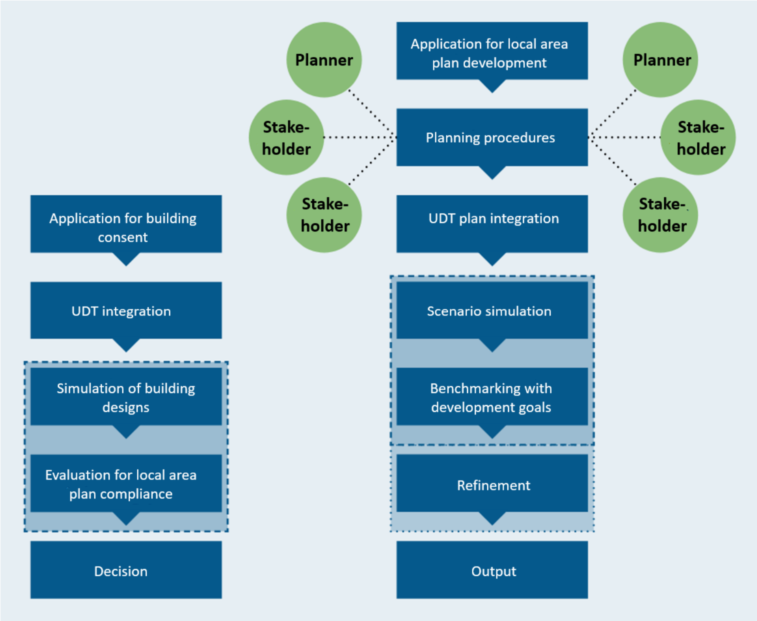

Figure 2: Schematic representation of the process for reviewing a building permit (left) and the process for drawing up a development plan (right) with the support of a digital twin (adapted from BBSR 2025, p. 22).

The workflows depicted in Figure 2 are taken from pilot projects where UDT technologies are currently being introduced (here: City of Kirchheim near Munich). In general, however, there is not much empirical knowledge about UDTusage in planning practice(Guckenbiehl et al. 2021). It is largely unclear what technologies or functionalities constitute a UDT and what makes it unique in comparison to other GIS applications. The term originally comes from industry and is used to create digital representations of products or machines. These serve as virtual replacements for physical prototypes, which can be used to create simulations and analyses (van der Horn and Mahadeva 2021). Applying this concept to the UDT gives cities and municipalities a comprehensive virtual representation of their structural elements and functional networks. This opens up new possibilities for projecting planning goals and building land development designs into the future (Schubbe et al. 2023). Accordingly, a smart city requires a dynamic, digital representation that not only integrates the physical building fabric, infrastructure, urban processes, and citizen feedback. The intelligent digital image also knows about the business processes (e. g. , informal and formal urban land-use planning), responsibilities (role and user concept), and interfaces to systems at partners that map the state of the city for their needs (Brandt et al. 2023). This means that not only does the city provide the twin with up-to-date information, but the twin can also transmit data and insights from other systems back to the city (Guckenbiehl et al. 2021).

In summary, UDT technologies have the potential to improve land management procedures in planning practice. This comes at a time where remaining infill land potentials in German cities have become more difficult to activate, since many larger potentials have already been developed over the last decades. Interviews with experts in Northrhine-Westphalia explain that remaining potentials are more difficult to activate. Cities like Munster have been successful in the past to direct growth to derelict sites within the urban compound. Now, continued growth pressure forces city planners to develop new suburbs on the outskirts and expand the urban footprint (Fina et al. 2020). In this context, some authors argue that proactive land management needs to focus more on land potentials that are likely to become available in the future and plan for its reuse at an early stage. Newer methodological approaches from pilot studies show that continued urban transformation trends can lead to new obsolete land uses (e. g. petrol stations, car parks, retail and offices, Wenner und Thierstein 2024; Rettich und Tastel 2023). In the past, federal and state research and funding programs have provided valuable impetus to plan for the reuse of such potentials, which has led to improvements in the information base in recent years (BBSR 2022). In planning practice, however, dealing with conflicting planning law objectives in the activation of infill potentials remains a challenge (Preuß und Böhnke 2024).

In 2025, political targets to provide housing for residential use and economic development have led to policy reforms in the building code (“Bauturbo”, i. e. Construction Acceleration Act). Many planning requirements are not required anymore, local planning authorities can or even must provide building consents to applicants without environmental impact assessments or other forms of planning regulation compliance that are usually spelled out in local area plans. This leads to uncertainties about the legal status of building consents in conflicting situations. Many experts predict that such cases will be subject to subsequent legal conflicts that have to be decided in court, counteracting on the target to accelerate land activation. For instance, the tasks of climate protection and climate adaptation and the associated requirements for land use have increasingly being regulated over the last years (Mitschang 2021). It is unclear how the resulting conflicts in legislation can be resolved. Planning asscociations and planning pracitioners warn that the reform falls short from ensuring associated sustainable urban development requirements(SRL 2025). The main line of argument, on one hand, revolves around a large consensus that does support the debureaucratization of planning procedures for faster activation of land potentials. On the other hand, this should not come at the cost of giving up on planning controlsand risk new forms of land speculation(von Lojewski 2025).

Based on this background, we address the question whether (1) UDT technologies can contribute to accelerate the activation of land potentials for infill development and (2) still ensure sustainable development targets at the same time (“accelerating instead of waiving planning”). In the following sections we posit that the emergence of new norms and standards will help to innovate digital planning in urban land management.

3 METHODOLOGY

In the first step, we evaluate these questions based on a review of UDT norms and standards. In the second step, we evaluate two widely used software options (ArcGIS Urban©, Urbanistic©) against criteria taken from the DIN SPEC, focusing on aspects of data interoperability and integration, indicators and benchmarks as well as workflow requirements for planning practice. A special focus is on indicators for climate adaptation. The work was carried out in a third-party funded research project[1] at THA where this perspective is of particular importance.

Our initial findings lead to insights about the importance of digital innovation and process management in local government (Will und Winter 2024). We address this viewpoint in a separate chapter and in the discussion section.

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[1] Digital Planning Support for carbon-neutral urban development (DiPukS), https://www. tha. de/Architektur-und-Bauwesen/DiPukS. html [18. 01. 2026].

4 NORMS AND STANDARDS

Since the end of 2024, DIN SPEC 91607 "Digital Twin for Cities and Municipalities" has specified a UDT standard that was developed by municipalities, associations, business, politics, and science in the Connected Urban Twins cooperation project (Munich, Leipzig, Hamburg). In addition to technical issues, the standard also incorporates ecological, economic, and social aspects, including topics such as building permits and sustainable neighborhood development. It defines usage scenarios and methods for accessing and displaying data (Schonowski et al. 2025; DIN SPEC 91607). Another standard, "Municipalities and Digital Transformation – Overview of Fields of Action," serves as a guide for the digital transformation of municipalities. Among other things, DIN identifies digital infrastructures, digital administration, mobility, construction and housing, as well as energy and the environment as areas for action (DIN SPEC 91387).

While developing DIN SPEC 91607, a similar methodology was established to systematically define concrete application cases for the Urban Digital Twin. The approach followed a four-step process to derive use cases addressing municipal needs:

(1) Structuring by establishing initial frameworks through the preliminary identification of application cases

(2) Capturing usage scenarios by collecting input from municipal stakeholders

(3) Grouping application cases according to thematic relevance and alignment with defined fields of action

(4) Developing case profiles to describe selected use cases in detail and to prepare subsequent implementation steps

The resulting set of use cases compiled within DIN SPEC 91607 demonstrates that the five most frequently mentioned municipal needs concerning usage scenarios are similar to DIN SPEC 91387: environment, building and housing, mobility, digital administration, and energy, are all directly linked to spatial and land management. Regardless of the specific use case, the geospatial base twin consistently constitutes the foundational layer and is likewise developed based on a municipal target vision. This process relies on municipally curated datasets in the domain of geospatial base data, including infrastructure and 3D building models, which are implemented using open source data models compliant with OGC standards (e. g. , CityGML, json, gml) as well as XÖV standards (e. g. , XBau, XPlanung). An XÖV standard is a German e-government data exchange standard for interoperable electronic communication between public administrations.

Building upon this foundation, municipal requirements are subsequently integrated in the form of application-oriented use cases as additional modular components of the UDT. Within the domain of digital land management, the digital building permit process plays a decisive role. The current building permitting process requires substantial effort to research, consolidate, and evaluate approval-relevant data from various municipal sources as well as from legal and regulatory frameworks. Delays often occur due to complex coordination among multiple stakeholders and the iterative, human-centred nature of decision-making. UDT technologies address these challenges by digitally supporting all phases of the permitting process. By integrating property and building-related information from public registries, GIS, and BIM data models, the UDT enables partially or fully automated, transparent, and accelerated decision-making. Through the digital representation of legal and regulatory evaluation criteria, formerly analogue workflows can be efficiently parallelized and simplified. Application scenarios include decision support based on indicator-driven data visualization, simulation-based assessment of planned projects, digital communication and collaboration among stakeholders, automated issuance of digital permits, and ongoing digital monitoring and documentation of construction progress. Furthermore, the UDT serves as a training platform for authorities and professionals to build competencies in managing digital permitting processes and assessing construction-related risks.

However, practical implementation examples remain scarce, with current developments largely limited to the application of XÖV standards and the solution DIPlanung that is currently being introduced by state authorities, amongst others in Bavaria (DIPlanung 2026). Following Kaushal (2022), initial international research on application of an UDT in urban planning can be observed. In his work, ArcGIS Urban© is employed in combination with a Spatial Urban Quality Framework that transfers urban quality indicators from first tier to second-tier cities, enabling spatial analyses to support data-driven urban planning. Our own tests with this and alternative software solutions shows that data integration of legally binding district and local area plans are technically laborious. To date, there is no clear added value of UDT applications for the efficiency of building permitting processes. One main obstacle are the delays in the introduction of the subject-independent and interdisciplinary XÖV standard XPlanung, a data format for use in municipal GIS software solutions for urban land-use planning (Brade 2025). The corresponding legislation for XPlanung was already passed by the federal and state governments in 2017 and should have become the basis for a more direct and cross-system form of cooperation in digital planning by 2023. However, due to implementation problems, interim solutions are currently being pursued which define partial vector capture as a minimum standard in stage 1 of the introduction and only represent the georeferenced scope of a development plan with undefined essential information from a plan in accordance with XPlanung. Only in a later stage 2 will full vector-based recording of all spatial data (e. g. , areas, specifications) as digital objects become mandatory (STMBW 2025). The current data landscape therefore continues to be characterized by formats and tools that are subject to specific domain knowledge and system barriers and create barriers to communication between the actors involved. Land management planning processes will therefore only become fully machine-readable with the delayed introduction of the full range of features in development plans. Furthermore, this regulation only applies to plans that have been drawn up in development planning procedures since 2017. Important planning law indicators that provide decisive information about the permissible extent and scope of development (e. g. , floor area ratio and floor space index) in older plans must therefore continue to be interpreted manually.

In this context, the question arises wether XPlanung-compliant digitization should extent to cover legally binding older development plans. It is mostly in these plans where crucial building regulations for existing development based on the principle of infill developmentcan be found. Efforts to fully digitize these plans require the allocation of considerable time and financial resources within the administration or for the commissioning of service providers. In the process, technical standards with sample directories are being reinterpreted in order to achieve the best possible results for specific urban land-use planning applications, depending on feasibility (cf. NRW. Urban 2021 STMBW 2021). Pilot studies show that artificial intelligence (AI) can be a game changer in this context. A technological leap is being observed in this area, with the use of AI to transfer a new generation of digital building land and brownfield site registers to UDTs. In a pilot study Schwarz (2024) concludes that current AI tools are already capable to interpret text and images in local area plans in high quality. Prerequisites are that the resolution of the documents is high and location specific markers help to interpret map legends and other plan signatures. Additional domain-specific training material is likely to emerge over the coming years to further improve results.

5 EVALUATION OF UDT APPLICATIONS FOR LAND MANAGEMENT

Software tools to capture, store and administer infill potentials in cities have evolved signficantly over the last few years. Initial database and spreadsheet driven approaches have increasingly integrated GIS functionalities to visualize land potentials on maps. Advanced GIS functionalities help to better understand and analyze the geographic context for building land activation, e. g. to inform and provide conditions that enable future usage according to development plans(Fina et al. 2023). Figure 3 shows selected parts of the software interface of the government funded research project KFMplus© (“Kommunales Flächen- und Ressourcenmanagement”, i. e. local planning land and ressource management) for the data-driven assessment of development options for the city of Dachau, Germany. The establishment of such software developments does not necessarily include 3D visualized objects. More importantly, they require interfaces to digitally map infill potentials and auxiliary information on land activation prerequisites, and to supply algorithms for data-driven assessment and visualization technologies. The software design of pilot projects like KFMplus© provided the path for innovations that are currently being rolled out in parts of Germany. One example is the introduction of new land management software with a similar design in the State of Baden-Württemberg.[2]

Sample indicators in the frame on the right of Figure 3(enlarged and translated from the German original) are compiled from a range of geodata inputs and compared between the current situation and a range of development options that the user can select from (in this case “dense built-up”). The Figure focuses on indicators on the acccessiblity of amenities and aspects of climate change. The colour coding of the

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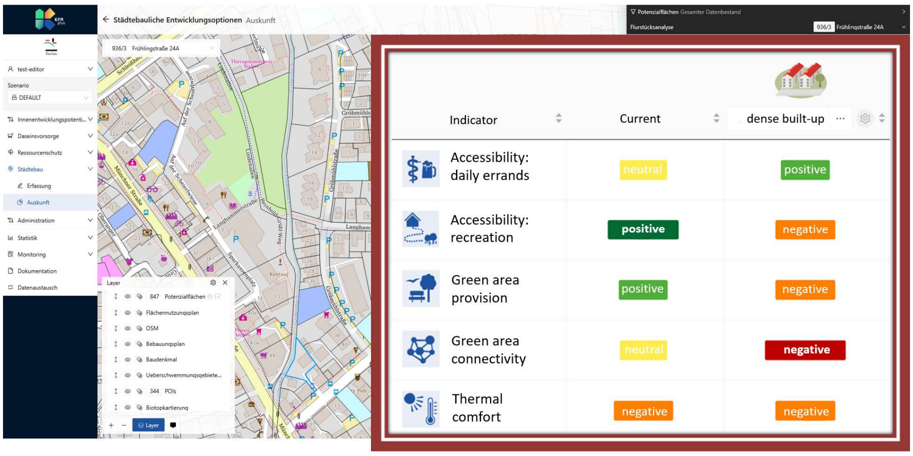
[2] https://mlw. baden-wuerttemberg. de/de/landesentwicklung/flaechenmanagement/digitales-flaechenmanagement.

comparison can help to better understand negative and positive effects when implementing a certain development option (shades of red: indicator values show negative effects; yello: neutral; shades of green: indicator values show positive effects). There are also a range of other indicators available in modules on urban amenities ("Daseinsvorsorge") at the location of a selected infill potential, and other important informaton to activate the site for reuse ("Innenentwicklungspotenziale"). The integration of planning regulations is limited to data fields for users to store and manually interpret permissible land use types, the ground area index, the floor area ratio or the building volume ratio. Spatial delineations like construction lines and building delineations are usually only available in linked documents (PDF) and have to be interpreted manually.

More advanced UDTs provide the possibility to integrate such spatial information from standards like XPlanung. Having the corresponding information fully integrated in the application provides possibilities to automatically test designs for building code compliance, in some cases with rule-based tools that deliver compliant design. Indicator-based comparisons of urban development scenarios and public participation to tag and label design and environment features enhance these applications further. In this context, we have tested two software options (1) ESRI's ArcGIS Urban© (supported by ArcGIS Pro/Online and ArcGIS City Engine) and (2) Urbanistic©. Both were used to set up UDT applications for specific use cases in the City of Augsburg in Southern Germany (pop. approx. 300,000). The city has successfully activated former military sites for infill development over the last few years and uses urban planning and architectural competitions to ensure high quality and economically feasible planning.



Indicator	Current	dense built-up
Accessibility: daily errands	neutral	positive
Accessibility: recreation	positive	negative
Green area provision	positive	negative
Green area connectivity	neutral	negative
Thermal comfort	negative	negative

Figure 3: Data-driven assessment of development options in infill development (own design).

Figure 4 shows a UDT with a fully functional building design imported from Autodesk Revit©for the curent situation in an area known as the Prinz Karl area. The area is designated for a new campus for the Faculty of Architecture and Civil Engineering at the University of Applied Science. Results show that setting up the UDT in ArcGIS Urban© with relevant data is time consuming and requires expert knowledge at the interface of geoinformation science and urban planning. The bullet points in Figure 4 depict a summary of the steps in the workflow that need to be managed. After successful data acquisition and integration, the challenge is to harmonize and transform the data into required formats. This applies to context layers like digital elevation models and existing building representations (OpenStreetMap or LoD2 – Level of Detail 2 (LDBV 2026), vegetation and infrastructure. It also applies to the building code imported from XPlanung (if available) or digitized local area plans (Source: City of Augsburg). Architectural designs can currently only be imported as drawings that have to be located manually, with limited accuracy (Source: student projects at THA). Direct imports for object-oriented desing representations (e. g. BIM models in the IFC standard, see Figure 4) cannot be functionally connected to the context layers. In order to achieve this, BIM models have to be duplicated with ArcGIS Urban© modelling techniques.

In the same project, we have evaluated the software option of the Munich-based startup Urbanistic© (Urbanistic 2026). This cloud solution is pre-equipped with data from OpenData BY (LDBV 2026), using API calls for seamless data integration. It has a growing client base in planning practice which values the ease of use for data interoperability between GIS and CAD/BIM software. The graphics performance is higher compared to ArcGIS Urban© and many functionalities address the competencies of CAD/BIM users better than the GIS based software design of ArcGIS Urban©, including building code regulations based on state legislation ("Landesbauordnung") and specialized tools to model the land area requirements of fire brigades or emergency services. In contrast to ArcGIS Urban©, the business model of Urbanistic© requires subscriptions for additional data (e. g. local area plans, cadastral data) to be integrated by consultants rather than having a generic software that the user can equip with data from own GIS workflows.

- Integrate urban context layers (e.g., tree population by species)
- Set up and check building regulations (local area development plan)
- Prepare building sites (building demolition or preservation, surface editing)
- Create or import architectural designs
- Add additional "assets" (e.g., street furniture, vegetation)

Figure 4: Current situation with a selected new redevelopment design in the Prince Karl area in Augsburg, Germany (own design).

Datum: 4 Mai
Zeitzone: UTC+2
Uhrzeit: 14:00
Abstandsflächenfaktor: 0,40
Mindesttiefe: 3,0m

Figure 5: Urbanistic© UDT Prinz Karl, Augsburg (own design, Urbanistic 2026).

Based on the software evaluations of the DiPukS project, one of the authors of this article proceeded to work on an another area development in Augsburg, namely at the former Reese baracks. The Reese development is divided into two separate developments. The southern part has already been subject to an urban design competetion with a winner, the northern part is set to go through the same process in the near future (Stadt Augsburg 2022). As is common in planning practice, the local area plan to regulate building and construction will only be developed once a design has been chosen. As already depicted in Figure 2, UDT applications can be used to inform this process. Figure 6 shows examples for the setup of a UDT for the design of the southern part.

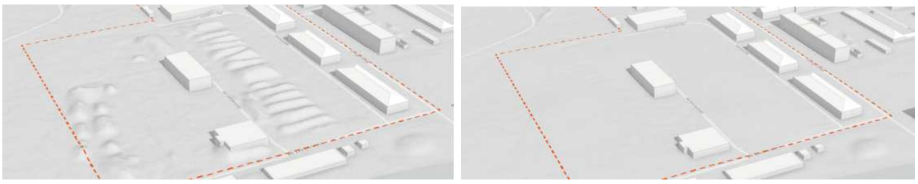
In summary of these learnings, both ArcGIS Urban© and Urbanistic© have the potential to set up UDTs specifically for urban planning. Data integration in ArcGIS Urban© is quite flexible, many datasets can be prepared and integrated. This process is laborious and requires expert knowledge, whereas Urbanistic© is already equipped with many relevant datasets, additional ones require consultant contracting. Both software options work with indicators that can inform planners on design scenarios. We will discuss further insights from this evaluation in the discussion section of this article.

6 INNOVATION AND PROCESS MANAGEMENT

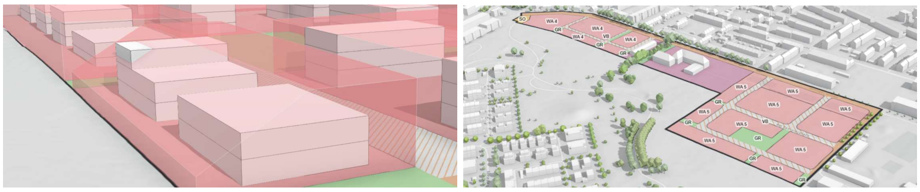
As shown in the previous sections, the handling of new UDT technologies requires specific skillsets to set up, run and maintain the corresponding applications. Organizational structures are needed that support cooperation between administrators, geoinformation officers and urban planners in a range of tasks, including hardware and software provision, data integration and the domain-specific development and usage of results. Figure 7 provides an overview of the correponding development stages depicted in DIN SPEC 91607.

Experience from model projects shows that the interdisciplinary coordination of the underlying digital business processes benefits from professional process management consulting expertise (Schubbe et al. 2023).

1: Building models derived from OpenStreetMap, 2: Level of detail 2 buildings from OpenData BY



2: Digital elevation model from OpenData BY, 3: Modificationsconducted in ArcGIS CityEngine



4: Building envelopes derived from local area plan digitization, 5: Zoning derived from local area plan digitization

6: Building types based on the winning design, 7: Combined tree canopy (existing + planned)

Umbauter Raum in Plangebiet (m³)
239.085

Durchschnittliche Baukosten (€)
95,63 Mio.

Kinder
241,66

Tägliche Fahrten
1.733,31
/ d

CO2-Emissionen (Nutzung)
1.910,82
kg / d

☑ Boden

Länge	Zunahme	Verlust
326,2 m	3,5 m	3,7 m
Min	Max	Mw
475,9 m	477,2 m	476,6 m
Max. Neigung	Durchschnittl. Neigung	
↑ 1,9° ↓ 1,9°	↑ 0,7° ↓ 0,7°	

8: Indicators on size, cost, demography, mobility and emissions, 9: Selected shading and viewshed analyses.

Figure 6: Selected steps of a workflow to establish an UDT for the Reese barracks in Augsburg (Finger 2025, unpublished).

The successful adaptation of innovations requires new forms of "digital governance" which not only provides users with digital planning support tools and helps them learn how to use them (Przeybilovicz und Cunha 2024). It is also committed to the sustainable acquisition of knowledge infrastructures in the concrete accomplishment of tasks and establishes new, digitally supported forms of cooperation (Weber und Ziemer 2022).

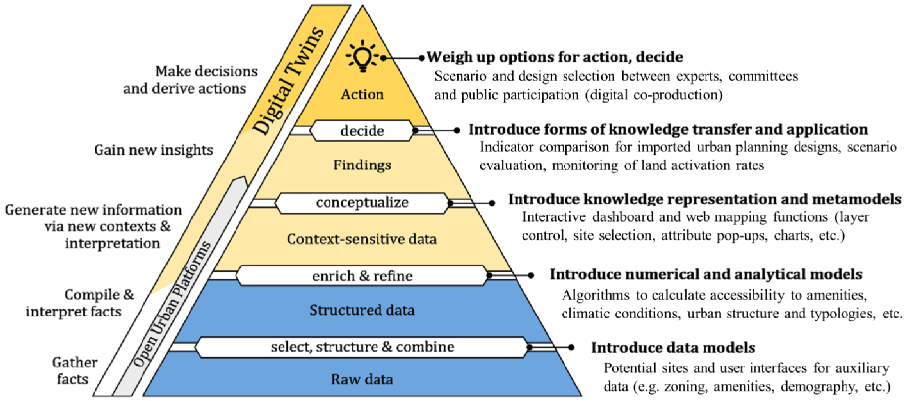


Figure 7: Development stages for UDTs, adapted for land management processes (modified from DIN SPEC 91607, p. 32).

The cooperation requirements are described as an innovation potential that still poses numerous challenges in the transfer and long-term establishment of pilot applications (cf. e. g. Prognos AG 2025). The institutional settings of public authorities with contractors and other stakeholders vary greatly in structure, for example between large, medium-sized, and small cities (Milbert und Fina 2021). Land management and location planning are also subject to urban-rural dynamics, which cause relocation effects to the urban periphery and peripheral locations (Zimmermann et al. 2025). The implementation of UDT technologies to activate infill potentials for sustainable urban development is thereoforealso a challenge for the cooperation between the different departments within one organisation and the cooperation beween neighbouring local governments and planning tiers like regional and state planning authorities. On the technical side, one main hurdle is the interoperability between the different land management systems and the applications of stakeholders, including government organizations, private industry and educational facilities. Data from one stakeholder often cannot be integrated into the platforms of others. This hinders the merging of data and information for joint use, such as analysis or planning. Another problem is the lack of clarity about what data and technical solutions are already available and what they can do. Because projects are often limited to a single sector, cross-sector effects are frequently neglected. The standardization of data structures and content is often inconsistent, which can lead to problems during integration (Donaubauer et al. 2023).

Geoinformation centers often make a cross-cutting contribution in administration to improve the interaction between geobasis data and specialist data from the departments. They are tasked with linking several application-specific UDTs into a “system of systems” during the development of UDTs. Independent data infrastructures and systems thus become a common information platform that supports application-specific scenarios. In addition to tools that allow practical access to available data, access to standardized and up-to-date planning and location data is required. To implement a UDT, data, tasks, and processes from various specialist departments and actors must be integrated. Effective project management organizes clear responsibilities and takes into account the requirements for communication, process planning, and financial resources. It establishes a common understanding of tasks to enable context-oriented communication and citizen participation across different organizational areas (Abt und Hohmann 2025).

The project of developing a UDT is therefore characterized by a high degree of uncertainty of a visionary nature. It can be expected that new requirements will continuously emerge from new usage scenarios that, at the present point in time, are very likely still unknown. Changes in requirements arise, among other factors, from political dynamics, changing climatic conditions, and newly explored technological possibilities in the construction sector. These aspects, together with the resulting complexity of such a project, argue strongly in favor of an agile approach to project execution.

Iterative development means that the development stages for UDT implementation are repeatedly carried out. At the end of each development cycle, a usable increment is produced that contains valuable enhancements compared to the previous version (Schwaber and Sutherland 2020).

Strictly speaking, projects are characterized as unique undertakings with a limited budget and a defined timeframe (“competence-based project managementPM4”,Deutsche Gesellschaft für Projektmanagement e. V. 2019). In view of the expected dynamics in this field, however, UDTs must be developed in such a way that, after project completion, they can be continuously further developed either within follow-up projects or within a permanently established organization.

In cases like land management, the highest stage ('action') of UDT implementation is interpreted as enabling the derivation of adaptive approaches for individual cases of land development activation based on the developed UDT. In industry, this is understood as a reference model from which context individual process models – in this case, checklists – can be derived. This includes the analysis described in Figure 10, but extends beyond it in the following manner. Figure 11 shows how the development stages of fig. 10 can be matched with the objectives of the proposed case. The boxes are placed below the related use symbol (current use, expected use, continuous improvement) they adress.

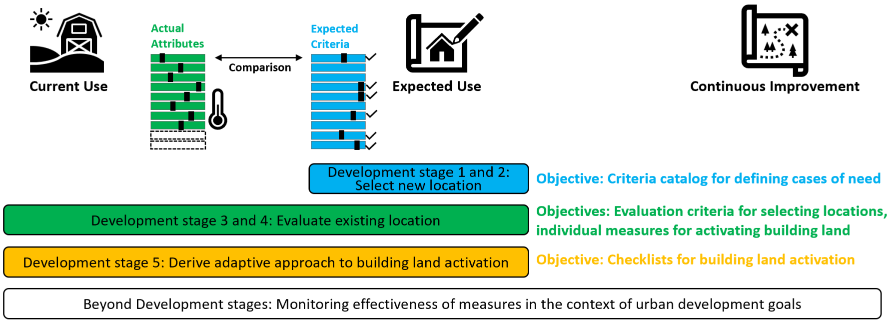


Figure 8: Matching of proposed project with development stages for UTD implementation after DIN SPEC 91607

Within stages 1 and 2 (raw and structured data), profiles consisting of several expected criteria for new development land are identified. These can then be compared to the attributes that describe current usage profiles. Existing UDTs already provide a substantial number of current attributes and their respective characteristics for existing areas (Figure10). However, the number of recorded attributes is not yet sufficiently comprehensive to assess whether the currently anticipated "expected criteria" – profiles are feasible. This goes well beyond a simple evaluation of a site based on predefined criteria (or, speaking in the UDT terminology, indicator values), as profiles made up of multiple criteria must be weighed against one another.

To enable this, in stage 3 (context-sensitive data) the systematic collection of criteria profiles as well as additional evaluation criteria must be consistently pursued. These profiles form the basis for the development of measures for land development activation (stage 4, findings). Building on this, a mechanism can be developed that adaptively derives sets of measures as context-individual approaches from the UDT. The UDT serves as a comprehensive reference model for deriving context-specific approaches(Königbauer 2021). Land development activation can be managed by orchestrating these approaches consisting of individual measures into a context-specific process, which can be understood as a checklist or a project plan(stage 5, action). This approach potentially accelerates planning,especially in more complex cases involving numerous stakeholders and many required individual steps. Such systematic measures have the additional benefit that the effectiveness of individual measures can be consistently recorded. Corresponding optimization measures can then be incorporated into subsequent land development activation projects.

Since neither project management nor UDTs are established practices within public administration, organizational structures must be introduced that support continuous improvement processes over extended periods of time. It cannot be expected that highly committed individuals will drive further development on their own or, in extreme cases, exhaust themselves in the course of implementation. Instead, the commitment of the involved organizations is required, expressed through leadership engagement in combination with subject-matter experts, to ensure that UDTs can evolve into practice-oriented and user-friendly instruments.

7 DISCUSSION AND CONCLUSION

This article discusses the potentials and challenges to implement UDT technologies for more efficient workflows in urban planning in general and sustainable urban land management in particular. Current political trends to waive planning requirements for speedier consenting procedures and critical comments from planning scholars on potential effects set the scene for this requirement: Can UDT technologies help to ensure high quality urban planning without placing new bureaucratic hurdles on the resources of urban planning departments,can they improve and accelerate planning processes in the long run? Are they transferable from piloting local government to a wider range of authorities with limited resources?

Our learnings from document and literature review and our own tests of software options show that norms and standards are urgently needed to provide user orientation. Difficulties to introduce the standards, especially for local area plans ("XPlanung") can potentially be overcome with new initiatives and AI support. The new DIN SPEC 91607 on UDTs is a good starting point to transfer learnings from pilot projects to the community. Available software options like KFMplus©, ArcGIS Urban© or Urbanistic©all run in cloud-based backends and browser-based frontends, but have been designed for different business models (e. g. KFMplus©: open source components, ESRIs ArcGIS© stack of software, Urbanistic©: native application). One main obstacle for easy-to-use UDTs are the requirements of data integration and the establishment of data-driven urban planning indicators. Where KFMplus© provides prefabricated indicator variants for a limited set of typical urban planning typologogies (e. g. densely built up, commercial, open space, etc.), ArcGIS Urban© and Urbanistic© work with variable designs based on building typologies that the user can select from (and, in the case of ArcGIS Urban©, enhance with custom typologies).

Apart from a few very generic indicators (e. g. volume, size, etc.), more advanced indicators require that the user sets up the calculation routines for inputs and outputs. Without going through this effort, the added value of UDT applications seems to be limited. Planning practice needs to know about the number of dwellings or floor area in a new building, derived number of required parking spaces, district heating demand, carbon dioxide emissions, etc. If this information is not available and/or the results are not credible for stakeholders, UDTs cannot reach their full potential for urban planning. We found in our tests that, at this stage, these tasks are laborious if standardized data is not available or supported. Users have to revert to digitizing PDF documents or scans, and subsequently deal with attribute generation, relationship modelling between object classes, and inaccuracies based on manually generated inputs. Interoperability between CAD/BIM on the one hand and GIS on the other needs to be further improved for seamless data exchange, including object-oriented attribution and relationship modelling.

A special focus of our evaluation was on indicators on climate change and climate adaptation, as shown for the software KFMplus©. ArcGIS Urban© can provide information about carbon dioxide emissions or soil sealing for urban planning designs if calculation routines are set up. More domain-specific information (thermal stress, air ventilation, stormwater runoff) is currently not available. New software options like the QGIS plugin Climate Scanner© (an AI trained software tool for climate effect assessments of urban designs) are being developed for UDT integration in emerging new research projects. Their evaluation is the next step in the currently running research project that we reported from in this article.

8 ACKNOWLEDGEMENTS

Funding was provided by the Bavarian Ministry of Science as part of the programme for the promotion of applied research and development at universities of applied sciences (Chap. 15 49 TG 82).

9 REFERENCES

Abt, Jan; Hohmann, Theresa (2025): Die Organisation von smarten Städten und Regionen. In: Raumplanung (231 / 2-2025), pp. 8-14.

Achilles, Heiko (2024): Clash der Narrative zur nachhaltigen Stadtentwicklung. In: Heiko Achilles (Hg.): Stadtentwicklung mit einem Developer Mindset. Wiesbaden: Springer Fachmedien Wiesbaden, pp. 77-109.

Barton, Hugh (2016): City of Well-being. A Radical Guide to Planning: Taylor & Francis.

BBSR (2022): Bauland- und Innenentwicklungs-potenziale in deutschen Städten und Gemeinden. BBSR-Online-Publikation 11/2022. https://www. bbsr. bund. de/BBSR/DE/forschung/programme/exwost/Studien/2019/baulandumfrage/01-start. html;jsessionid=21F0BD17A628E59871069A32F964B910. live11292#Veroeffentlichungen, [18. 01. 2026].

Brade, Alexander (2025): Die Digitalisierung der Bauleitplanung: Eine verpasste Chance? In: J. Botta, M. Feldhaus, K. Goldberg und S. Hartmann (Hrsg.): Rechtsfragen virtueller Welten. Nomos Verlagsgesellschaft mbH & Co. KG, pp. 71-84.

Brandt, Sarah; Henningsen, Jens; Hess, Steffen; Jedlitschka, Andreas; Hellmuth, Rene (2023): Digitale Zwillinge: Potenziale in der Stadtentwicklung: Bundesinstitut für Bau-, Stadt-und Raumforschung (BBSR): Bonn.

Broschart, Daniel; Eder, Christoph; Fischer, Marina; Ishtiaque, Jabid; Jubanski, Juilson; Siegert, Florian (2024): TwinCity3D–Neue Möglichkeiten zur Planung der Stadtentwicklungfür Klein-und Mittelstädte. RealCorp Proceedings 2025. DOI: 10. 48494/REALCORP2025. 6049 [18. 01. 2026].

Deutsche Gesellschaft für Projektmanagement e. V. (2019): Handbuch für Praxis und Weiterbildung im Projektmanagement. Deutsche Gesellschaft für Projektmanagement e. V. : Nuremberg.

DIN SPEC 91607, November 2024: Digital twins for cities and municipalities. https://www. dinmedia. de/en/technical-rule/din-spec-91607/384414386[18. 01. 2026].

Donaubauer, Andreas; Knezevic, Marija; Willenborg, Bruno; Bobinger, Stefan; Morich, Lutz (2023): LeitfadenUrbaner Digitaler Zwilling nach der Methodik der SDDI (Version 1. 2). Bayerisches Staatsministerium für Digitales.

Etezadzadeh, Chirine (2020): Smart City – Made in Germany: Springer Verlag: Berlin.

Fina, Stefan; Henger, Ralph; Siedentop, Stefan (2020): Erfolgreiche Wege für mehr Wohnungsbau. Eine Analyse der Mobilisierung von Baulandpotenzialen in NRW. IW Berichte Nr. 41. Institut der deutschen Wirtschaft: Köln.

Fina, Stefan; Kudekar, Aditya; Adamski, Sylvia; Franke, Michael; Lanig, Sandra (2023): Digitale Planungsunterstützung für die klimasensible Bestandsentwicklung in Städten und Gemeinden. In:gis. science (4), pp. 139-148.

Guckenbiehl, Pascal; Hess, Steffen; Mumme, Carl-Moritz; Swarat, Gerald; Vogt-Hohenlinde, Sophie; Burton, Simon; Roscher, Karsten (2021): Der Digitale Zwilling für smarte Städte-zwischen Erwartungen und Herausforderungen. Fraunhofer ISE. file:///C:/Users/stefa/Downloads/smart-city-digitale-zwillinge-fuer-smarte-staedte-fraunhofer-iese. pdf[18. 01. 2026].

Heinig, Stefan (2021): Integrierte Stadtentwicklungsplanung: Konzepte-Methoden-Beispiele: transcript Verlag.

DIN SPEC 91387, November 2024: Kommunen und digitale Transformation – Übersicht der Handlungsfelder. https://www. dinmedia. de/de/technische-regel/din-spec-91387/326373721[18. 01. 2026].

Königbauer, Martina (2021). Adaptives Referenzmodell für hybrides Projektmanagement, Dissertation. Universität Würzburg.

LDBV-Bayerisches Landesamt für Digitalisierung, Breitband und Vermessung. https://geodaten. bayern. de/opengeodata/ [18. 01. 2026].

Lojewski, Hilmar von (2025): Zwischenbilanz zum § 246 BauGB -E („Bauturbo"). Bauplanungsrechtlicher Untergang oder Impuls für eine neue Planungsrechtkultur? In: PlanerIn 1/2025, pp. 18-21.

Milbert, Antonia; Fina, Stefan (2021): Methoden der Kleinstadtforschung. Definitionen, Daten und Raumanalysen. In: Annett Steinführer, Lars Porsche und Martin Sondermann (Hg.): Kompendium Kleinstadtforschung. Hannover: ARL – Akademie für Raumentwicklung in der Leibniz-Gemeinschaft (Forschungsberichte der ARL, 16), pp. 24-49.

Mitschang, Stephan (Hg.) (2021): Klimaschutz und Klimaanpassung in der Regional- und Bauleitplanung. Fach- und Rechtsfragen. Berliner Schriften zur Stadt- und Regionalplanung, Band 40. Nomos Verlag: Baden-Baden.

Preuß, Thomas; Böhnke, Robert (2024): Bund/Länder-Dialog Fläche-ein Zwischenfazit. Anhang 2: Status quo Bericht: Innenentwicklung stärken. Texte 22/2024. Umweltbundesamt: Dessau-Roßlau.

Prognos AG (2025): Innovative Lösungen oder teure Spielerei? Smart City nach der Experimentierphase – Sind wir bereit für den nächsten Schritt? TRENDreport 2025: Prognos AG. Berlin.

Przeybilovicz, Erico; Cunha, Maria Alexandra (2024): Governing in the digital age: The emergence of dynamic smart urban governance modes. In:Government Information Quarterly 41 (1), DOI: 10. 1016/j. giq. 2023. 101907.

Rettich, Stefan; Tastel, Sabine (2023): Urbane Obsoleszenzen: Zukünftige Transformationsfelder erkennen und vor Spekulationen schützen. In: Stadterneuerung und Spekulation: Jahrbuch Stadterneuerung 2022/23: Springer, pp. 19-42.

Schonowski, Joachim; Haber, Gundula; Kelnberger, Stefan (2025): Standard für die digitale Zukunft von Kommunen. In:Innov Verwalt 47 (5), S. 22–24. DOI: 10. 1007/s35114-025-2212-y.

Schubbe, Nicole; Boedecker, Mathias; Moshrefzadeh, Mandana; Dietrich, Jana; Mohl, Markus; Brink, Marina et al. (2023): Urbane Digitale Zwillinge als Baukastensystem. Ein Konzept aus dem Projekt Connected Urban Twins (CUT). In:ZfV – Zeitschrift für Geodäsie, Geoinformation und Landmanagement (zfv 1/2023). DOI: 10. 12902/zfv-0417-2022.

Schwaber, K. and Sutherland, J. (2020) The Scrum Guide: The Definitive Guide to Scrum: The Rules of the Game. Scrum. org & Scrum Inc. https://www. scrumguides. org/scrum-guide. html[18. 01. 2026].

Schwarz, Michael (2024): Digitale Bauleitplanung. Wie KI Systeme Bebauungspläne verstehen. Masterarbeit im Studiengang Informatik M. Sc. Technische Hochschule Augsburg [27. 01. 2026].

SRL (2025): Wohin des Weges, BauGB. Die Baugesetzbuch-Novelle und die Magie der Beschleunigung. PlanerIn 1/2025 ,p. 1.

Stadt Augsburg (2022): Städtebaulicher und landschaftsplanerischer Wettbewerb mit Ideenteil Reese-Kaserne Ost in Augsburg. https://www. augsburg. de/fileadmin/portale/stadtplanung/Publikationen/St_Kriegshaber/pdf/2022-02_Reese-Kaserne_Ost_Wettbewerb_Dokumentation_komp. pdf[18. 01. 2026].

STMBW (2025): Digitale Planung Bayern. Hg. v. Bayerisches Staatsministerium für Wohnen, Bau und Verkehr. Online verfügbar unter https://www. digitale. planung. bayern. de/xplanung/index. html[18. 01. 2026].

Umweltbundesamt (2023): Dreifache Innenentwicklung. Definition, Aufgaben und Chancen für eine umweltorientierte Stadtentwicklung. https://www. umweltbundesamt. de/sites/default/files/medien/1410/publikationen/230515_uba_hg_dreifacheinnenentwicklung_2auflg_br. pdf[18. 01. 2026].

Urbanistic (2026): https://www. urbanistic. de/ [18. 01. 2026].

VanDerHorn, Eric; Mahadevan, Sankaran (2021): Digital Twin: Generalization, characterization and implementation. In: Decision Support Systems 145, S. 113524. DOI: 10. 1016/j. dss. 2021. 113524.

WBGU (Hg.) (2016): Der Umzug der Menschheit. Die transformative Kraft der Städte. Hauptgutachten. Wissenschaftlicher Beirat der Bundesregierung: Globale Umweltveränderungen. Berlin: WBGU.

Weber, Vanessa; Ziemer, Gesa (2022): Die Digitale Stadt: Kuratierte Daten für urbane Kollaborationen: transcript Verlag.

Wenner, Fabian; Thierstein, Alain (2024): Potenziale der Innenentwicklung in München. Technische Universität München. https://mediatum. ub. tum. de/doc/1737396/m2u6hc9125lrsrqfq6iif9oks. Potenziale-Innenentwicklung_WEB. pdf[18. 01. 2026].

Will, Jens; Winter, Florian (2024): Der digitale Planer. Schnittstellenkompetenz und Tools in digitaler Planung. In: PlanerIn , pp. 7-9.

Zimmermann, Thomas; Braunschweig, Björn; Henn, Sebastian (2025): Stadtregionales Flächenmanagement: Grundlagen und Instrumente. In: Stadtregionales Flächenmanagement: Springer Verlag: Berlin. S. 1-22.