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Trends in The Adoption of New Geospatial Technologies for Spatial Planning and Land Management in 2021

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Abstract

Changes in spatial planning and land management practices, regulations and operations have frequently relied on the uptake of innovations in geospatial technologies. This article reviews which ones the spatial planning and land management domains has effectively adopted and which new ones might potentially disrupt the domain in the near future of 2021 and beyond. Based on an extensive concept-centric trends synthesis and meta-review, the analysis demonstrates that whilst geospatial technologies are clearly gaining wider societal recognition and while private companies are indeed developing promising applications, its adoption in office work of public officials and public decision makers remains almost as limited as before. The potentially most disruptive technologies for the domain are however BIM, Block chain and Machine learning.

1.   Introduction

Although geospatial technologies have changed continuously in the past 30 years, the uptake, adoption and integration of these in spatial planning and land management practices, regulations and agencies have not always been effective and lasting. Since the emergence of geographic information systems (GIS) and the uptake of remote sensing technologies in spatial planning and land management literature, one can only conclude that some technological advancements and conceptualisation artefacts have been more persuasive than others have. This has partly to do with natural evolution and adoption (or the lack thereof) of technologies in general, but also with the specific nature and demands of spatial planning and land management practices, regulations and agencies at large.

This article poses three questions: Which geospatial technologies do spatial planning and land management practices, regulations and agencies currently (in 2021) effectively employ and integrate?; What are the geospatial technology trends of 2021 which have the potential to change (or even disrupt) spatial planning and land management practices, regulations and agencies significantly?; Which evidence, artefacts and manifestations exists that spatial planning and land management practices, regulations and agencies are fundamentally changing because of these technologies?

This article first describes the boundaries of the conceptualisations of geospatial technologies on the one hand and spatial planning and land management practices, regulations and agencies on the other. It then explains how this research is addressing each of the questions within the scope of this paper.

1.1.   Conceptualising Geospatial Technologies for Spatial Planning and Land Management

The term geospatial technologies is concrete and ambiguous at the same time. This paper distinguishes the following functional categories of geospatial technologies that are relevant for spatial planning and land management.

Integrative and analytical technologies. These include Geographic information systems (GIS), in the form of proprietary systems, or through web based or open source based systems. Goals of these technologies have always been to detect and deduct locations, spatial patterns and spatial clusters on the one hand, and to register, record, allocate, adjudicate and assign properties to spatially distributed artefacts and objects on the other hand.

Data acquisition and data processing technologies. These include all surveying, photogrammetry and remote sensing technologies at large. Increasingly these technologies converge, especially with more cloud and point based systems. Goals of these type of technologies have always included establishing reliable and accurate georeferenced foundation data and associated geodetic networks, geometric descriptions and classifications of objects and changes in objects, and to acquire systematically and dynamically georeferences during or for navigation purposes.

Smart and artificial intelligence technologies. This overarching category refers to technologies, which generate new results and scenarios and also can independently and autonomously derive and execute decisions. In addition to the more conventional spatial decision support systems (SDSS) and planning support systems (PSS), these include autonomous sensor and surveillance technologies, machine learning and artificial intelligence.

Visualisation, representation and simulation technologies. These type of technologies are both constructing data models and converting these into graphic static and dynamic images and other types of representations, which provide a more comprehensive perspective on a particular matter, or a set of phenomena. Besides the conventional cartographic visualisation technologies to display objects and processes in 2D, 3D, or 4D, these include virtual, augmented, immersive and mixed reality, and new types of hardware such as decision support tables, hologram tables and head mounted displays in order to visualise, feel, touch, hear and perceive dynamic simulated environments.

Data management technologies. These technologies structure and store data in such a manner that their inter-relations can be easily accessed, queried and analysed. Traditionally these referred to relational or SQL-based (geo) databases, but recently also non-relational or NoSQL data management technologies have advanced. These include graph stores, column stores, key value stores and document stores.   Additionally, data architectures and access technologies have evolved, culminating in for example decentralised blockchain architectures.

Spatial planning and land management practices, regulations and agencies encompass all activities, decisions, government and non-government organisations, guided and unguided behaviour which have the aim to intervene in socio-spatial and bio-physical artefacts, constructions and relations which are needed to benefit from the land, housing and shelter. (de Vries, 2018a) would refer to these encompassing people-to-land/space interventions as fundamental changes, which are both functions of and dependent relations of the respective changes in governance, law, social-spatial relations, economic opportunities and dependencies, perceptions and beliefs and behaviour. These chances are also visible in the manner in which functions of spatial planning and land management are currently carried out. There are various types of functions and aims of spatial land interventions, and the execution of interventions typically takes place in both a consecutive, iterative and integrated manner (GIZ, 2012; Metternicht, 2018). Table 1 provides an overview of such functions (including spatial structure and design, spatial monitoring, administration of land and properties and compliance and coercion) a number of article references which highlight ongoing or recent changes in how these functions are carried out.

Table 1. Functions and aims of spatial land interventions

Spatial planning and/or land management function	Examples	Recently described in -amongst others-
Spatial structure and design	(City) Master planning	(Li et al., 2021)
	Physical planning	(Bakır et al., 2018)
	Spatial localization	(Pokonieczny, 2016)
	Land use zoning	(PU et al., 2013)
	Land consolidation	(Demetriou, 2018)
	Land redistribution	(Hentze and Menz, 2015)
	Urban development boundaries	(Liu et al., 2017)
	Urban form and shape	(Williams, 2017)
Spatial monitoring and assessment	Land use change detection	(Wang et al., 2020)
	Urban growth	(Setyono et al., 2016)
	Urban greening	(Heckert and Rosan, 2018)
	Urban blight	(Mireku, 2020)
	Vacancy of houses / unused land	(Zou and Wang, 2020)
	Informal settlements growth	(Estoque and Murayama, 2015)
	Risks and impact assessments	(Buchori et al., 2018)
	Land encroachment	(Thapa and Bahuguna, 2021)
Administration of land/properties	Land registration	(Budiman, 2020)
	Land recordation	(Chipofya et al., 2021)
	Land valuation and pricing	(Elmanisa et al., 2017)
	Spatial / land restrictions	(Kitsakis and Dimopoulou, 2017)
	Communal, customary tenure	(Chigbu et al., 2021)
	Land grabbing	(Petrescu et al., 2020)
	Conservation of cultural heritage	(Pepe et al., 2020)
Compliance and coercion	Housing permit compliance	(Offei et al., 2018)
	Sanctions and penalties	(Boodhoo, 2021)
	Evictions and relocations	(Desai et al., 2018)
Participation and mobilisation	Stakeholder needs analysis	(Giuffrida et al., 2019)
	Handling of complaints	(Dhini et al., 2017)
	Collaborative design	(Jankowski et al., 2021)
	Community participation	(Kusmiarto et al., 2020)

A few comments to explain and describe the content of the referred articles and associated changes in functions in Table 1. Spatial structure and design encompasses both finding the right location for new structures as well as the spatial allocations of land (use) rights, restrictions or responsibilities. Geospatial technologies can typically support these activities by querying and modelling spatial phenomena with the purpose to create a rational design in desired or anticipated land use outputs or spatial forms. Spatial monitoring is an evaluation and assessment type of activity, which is usually needed to measure the degree of progress of a spatial policy intervention. Geospatial technologies typically support the measuring and clustering of variations in spatial phenomena. Land and property administration is a branch of spatial planning and land management which records and registers relations between subjects and objects, in terms of rights, restrictions, responsibilities, values, development activities. Often this sector relies on robust relational (geo) databases and domain models. Compliance and coercion functions refer to the policing and regulatory actions leading to an intervention by force or by penalties. Participation and mobilisation is a typical activity of both spatial planning and land management, which connects political and societal goals and needs to spatial planning and land interventions. Typically, those geospatial technologies, which are available, accessible and operable for all citizens at all levels and registers of society, could support this activity.

2. Data and Methods

In order to reveal which technologies have become mainstream in spatial planning and land management practices, regulations, for the analysis of where and how the new geospatial technologies may disrupt spatial planning and land management practices and agencies and in order to describe, highlight and synthesize current 2021 trends in geospatial technologies we have relied on: a concept-centric summary of cited evidence and referrals from scientific literature (journals) and geospatial conferences. The selection of journals was based on the listed GIS and RS journals by (Biljecki, 2016), added with the list of https://3d.bk.tudelft.nl/journals/ on the one hand, and an internal list of land management journals maintained by the Chair of Land Management at TUM; a selection from relevant conferences, grey literature and strategic (national) policy documents. These include the land related and geospatial technology conferences (such as FIG, ISPRS, PLPR, EALD, RSA, AGILE); and a synthesis of various systematic government information sites (e.g. NOAA), review papers, geospatial magazines (e.g. GIM International, Geospatial World), yearly or regular trend watcher blogs and opinion pieces in relation to geospatial technologies. The aim was to select manuscripts and electronic sources published in 2014 or later, which connect geospatial methods to specific functions of land management and spatial planning.

3. Result and Discussion

3.1. Currently employed geospatial technologies in spatial planning and land management practices, regulations and agencies

Table 2 shows the synthesis of historical references and review papers, describing what sort of geospatial technologies and algorithms have been used for in relation to spatial planning and land management activities and models. Table 2 is by no means complete or fully inclusive. The emphasis in the selection of examples has been to display the variety and broadness in both the technologies and the applications. As such, the references, which represent specific studies connecting the technologies to specific applications, are also exemplary. Still, however the table 2 provides a summary of which technologies have become mainstream in spatial planning and land management practices, regulations and agencies.

What is obvious is that the combination of (open) GIS and the embedding of different kinds of data models has become conventional and fully accommodated in different phases and functions of spatial planning and land management processes. This enables the development of geoweb applications with tools such as the JavaScript Openlayer APIs, Geoext, Leaflet, and with OpenLayer API as the development environment for Geo Web 2.0 software applications. GIS servers such as Geoserver, Mapserver, and DEGREE are supporting the distribution of spatial data into various web services formats such as Web Mapping Services (WMS). PostgreSQL with an extension of POSTGIS provides the open source object relational database system. Finally, models such as (City) GML and LADM are addressing the problems of geospatial conventional data model standards, such as the disconnect between different geometric representations for the same objects and processes.

Some words of caution and reflexivity are nevertheless necessary for the adoption of open source technologies in combination of big data. Vast amounts of geospatial literature tends to remain focused on the technical modelling and simulation aspects of the physical spatial environment and not so much on the political, discretionary and behavioural aspects of the social spatial environment which are also crucial for spatial planning and land management. An exception to this are the agent-based modelling (ABM) techniques, model and evaluate dynamic behaviour. In essence, ABM simulates complex systems through detailed assumptions in behaviour and interactions of people, animals or vehicles (Kieu et al., 2020), and it has therefore been applied in for example urban traffic simulation, disaster responses and evacuations. In combination with data assimilation techniques, which provide continuous updates with real-time data, real-time forecasts and predictions improve.

Table 2. Mainstream geospatial technologies in spatial planning and land management

Type of function	Examples of technologies, algorithms	Type of applications	References
Integrative and analytical	(Open) GIS	City master planning	(Gong et al., 2014)
	Digital Surface Model (DSM)	Land use change detection	(Asokan and Anitha, 2019)
	Object based nearest neighbour	Land cover change detection	(Aslami and Ghorbani, 2018)
	Rational Polynomial Coefficients (RPCs)	Urban built-up expansion	(Prakash and Bharath, 2020)
	Discrete mathematics, migrating bird algorithms	Land redistribution	(Tongur et al., 2020)
Data acquisition	Multispectral image processing	Land monitoring, land conservation	(Radočaj et al., 2020)
	GNSS		
	Auto Correlation Function (ACF) change detection method	Detecting human settlements	(Kleynhans et al., 2015)
Smart and artificial	Cellular automata	Urban flood modelling	(Ahmed et al., 2018)
	Agent-based modelling		(Mustafa et al., 2017)
Visualisation and simulation	Urban SIM modelling	Urban transportation expansion	(Di Zio et al., 2010)
	3D digital photogrammetry	City modelling and visualisation	(Litwin et al., 2017)
	Geometric modelling	Urban expansion	(Purevtseren et al., 2018)
	Virtual reality	Participatory planning	(Meenar and Kitson, 2020)
Data models and management	Relational data domain models	Land administration	(Pržulj et al., 2019)
	Open source databases (e.g. Postgresql/PostGIS)		(Teja et al., 2020)
	(City) GML, LADM	City management	(Beil and Kolbe, 2017)

3.2. *Potentially disruptive geospatial technology trends of 2021*

Various research review papers, blogs and opinion pieces summarize the 2021 trends and developments in the geospatial technologies landscape and refer to a distinct selection of technologies as being disruptive. We define 'disruptive' here as drivers and changes, originating from technological innovations which displace and replace existing socio-organizational structures and workflows, interpersonal and inter-institutional relations, utilization of technologies, and societal situations (de Vries et al., 2020). This implies that not every technology is disruptive, but only those, which result in fundamental, and lasting changes. The trend watchers are particularly interested in those technologies, because they also provide new market shares and revenues (Abdullah, 2021a; Richardson, 2017; GeoCTRL, 2021). Table 3 provides a synthesis of the potentially disruptive geospatial technologies.

With regard to the integrative and analytical technologies one can argue that the technologies such as Building information modelling (BIM) and opensource GIS , and the emergence of big and linked data are not new, as they have been existing within separate technological domains. However, the volume of the uptake and the persuasive embedding of these technologies are starting to disrupt and fundamentally change the processes and structures in which they are used. One of such disruptions concerns the adoption of cloud computing solutions, in the form of Cloud computing SaaS (Software as a Service), in particular for geospatial applications. GIS as SaaS provides Cloud based mapping tools, open data platforms, AI integration, geospatial data editing and sharing and helps handling big data. Current geospatial cloud services provide ready-to-use geospatial datasets and images whereby users can conduct different types of analyses at a variety of geographic scales. Companies like ESRI, Google Maps (Google), Bing Maps (Microsoft), Super Map, Zondy Crber, GeoStar, Hexagon Geospatial, CARTO and GIS Cloud are participating in GIS Cloud computing technology. Companies such as Amazon (AWS), Google (Google Earth), and Microsoft (Bing Maps) are already providing these

information architectures for the past 10 years, but the Google Earth and Bing Maps mapping tools are not suitable for large enterprise-wide GIS applications. Instead, a geospatial cloud, providing GIS as SaaS is able to give many analytic and visualisation capabilities and ready to use map or imagery layers. Integrated with AI and machine learning, the GIS cloud can automate techniques like classification, change detection, clustering etc. The extensions of Saas are PaaS and IaaS, i.e.' Platform as a service' and 'Infrastructure as a service'. SaaS delivers applications without downloading or installation (e.g. Google Apps, Dropbox and Concur). PaaS provides a framework for developers. It is built on virtualization technology (e.g Windows Azure, Google App Engine). IaaS gives infrastructure to organisations. In IaaS resources are available as a service (e.g. Microsoft Azure, Amazon AWS, Digital Ocean etc.).

Table 3. Functional categories of potentially disruptive geospatial technologies

Type of function	Examples	References
Integrative and analytical	BIM connected to GIS	(Kaden et al., 2020; Goyal et al., 2020)
	Geospatial analytics	(Lin et al., 2020)
	Big and linked geospatial data	(Werner and Chiang, 2021)
Data acquisition	(Open) LiDAR	(Ye et al., 2020)
	Drone technologies	(Yunus and Azmi, 2020)
	Miniaturized sensors	
Smart and artificial	Machine and deep learning	(Muhammad et al., 2021)
	Pattern recognition	
	Bayesian network modelling	(Marcot and Penman, 2019)
Visualisation, representation and simulation	Digital twins	(Ketzler et al., 2020)
	Mapping as service	(Abdullah, 2021b)
	CityGML3.0	(Kutzner et al., 2020)
	Extended, immersive and mixed reality	(Çöltekin et al., 2020)
Data management	Blockchain	(Verheye, 2020)
	noSQL	(Bennett et al., 2019)
	Cloud computing	
	Graph databases	(Zheng et al., 2017)
	Data warehousing	

The branch of geospatial analytics extend the application of GIS functionalities. In addition to relying on traditional maps and georeferenced objects, Geospatial analytics uses data from all kinds of technology, including location sensors, social media, mobile devices, satellite imagery. The main purpose of geospatial analytics is to build data visualizations for understanding phenomena and finding trends in complex relationships between people and places, in order to make predictions on socio-spatial and bio-physical spatial changes easier and more accurate. Examples of where geospatial analytics may become useful include making more informed choices about building or expanding facilities, speeding up logistics by running routing scenarios, finding patterns of criminal activity within a region, or minimizing risks from hazardous location-based events like powerful storms (USC (University of Southern California), 2021).

Specifically for the domains of spatial planning and land management the role of BIM connected to GIS is crucial. The Open Geospatial Consortium (OGC), supported by buildingSMART International (bSI) are now preparing an initiative to explore geospatial and BIM data integration based on meaningful real-world use cases. So far, the two communities rely on different data modeling approaches with respect to fundamental concepts, semantics, access, level-of-detail, and several other aspects. The next step is however to verify how to connect and integrate the geospatial open standards such as CityGML, LandInfra/InfraGML, IndoorGML, and IMDF with the BIM open standards such as IFC (Industry Foundation Classes), ISO19650, and the openCDE API portfolio, such that digital models for the built environment can be interchanged.

Of particular interest in the emerging data acquisition technologies is Light detection and ranging (LiDAR) technology. Compared to using traditional stereophotogrammetry relying on 2D aerial photos or images images to generate a 3D digital terrain model, LiDAR creates such a digital terrain model using a large amount of points collected by a laser, a scanner, and a specialized GPS receiver. Although the raw data are discrete-return, classified point-cloud data provided in LAS format, LiDAR data products are often created and stored in a gridded or raster data format. The raster format can be easier for many people to work with and also is supported by many different commonly used software packages. Originally designed for 3D terrain mapping, the range of applications relevant for spatial planning and land management is growing fast, including coastal floodplain mapping, forest and green area mapping, hydrological assessments, landscape ecology, urban planning, survey assessments, volumetric calculations of buildings and constructions, and design and evaluation of coastal engineering structures (NOAA, 2021). Point-cloud data acquisition, such as Lidar, and the variety of drones have significantly altered and extended the data acquisition techniques. Abdullah (2021b) describes an increasing uptake of Lidar due to improvements in lidar data density, quality and accuracy. Pauschinger and Klauser (2020) list both public users of drones (such as emergency services, police, archaeology and urban planning), and private ones (such as filmmaking, security, land surveying, infrastructure development and agriculture).

For the development of smart cities and regions, the machine learning community applies artificial neural networks. Deep learning is a type of machine learning, which is a subset of artificial intelligence. Deep learning can analyze images, videos, and unstructured data in ways machine learning can't easily do. Muhammad et al. (2021) provide a taxonomy of currently available deep learning methods applied in smart city development and discovered that generally the use of convolutional neural networks are highly popular in deep learning based smart city applications. The applications of deep learning algorithms are especially in the domains of road, transportation and mobility management, but also emerging in monitoring of air pollution and real estate management. The major disruption related to smart and artificial technologies is the fact that and increasing number of people are 'plugged in' as compared to ever before. This allows for smart tech solutions which are more effectively targeting spatial planning and land management issues in real time, due to the vast amount of active and passive data generation, which is stored and analysed by interconnected systems (Brode 2021).

In the field of visualisation, representation and simulation technologies one can observe many changes and improvements, such as digital twins, mapping as service CityGML3.0 and extended, mixed and immersive reality. Digital twins are the digital surrogate, replica or representation of a physical object, process or service. These can include specific objects, such as buildings or wind mills, but also represent larger and abstract objects, such as projects sites or entire cities. Representing these objects and phenomena in a digital environment, connected with digital programs, models and algorithms enables predictions and simulations of how changes or interventions play out (without an actual intervention or disturbance). Kutzner et al. (2020) describe how the CityGML version 3.0 has extended its core modules with the new modules Construction, Versioning, and Dynamizer, as well as the revised Building and Transportation modules. Common in all the new representation techniques is that one can more easily than before simulate, experiment, test and visualise expansions, risks, movements and behavioural scenarios. The concepts related to extended realities, referred to as XR, is an umbrella term for the virtual, augmented, and mixed reality (VR, AR, MR) refer to technologies and conceptual propositions (Çöltekin et al., 2020). The technologies do not only help to envision alternative scenarios, especially relevant when planning cities or landscapes, but can even change people's realities, as most of these systems are interactive and with cognitive effects and impacts.

The changes in data handling and management technologies particularly address the limitations of relational databases. Blockchain technologies are particularly well equipped to address transparency, access and accountability problems, which are often tied to centralised relational databases. This type of technology is particularly suitable for applications whereby regular transactions take place and whereby these transactions need to be accurate and systematically monitored. As such, the field of land administration, highly dependent on reliable transactions and mutations, is a very suitable application field. Blockchain would also be applicable for

setting which depend on participatory processes. Therefore there is also a high potential of blockchain technologies for participatory processes, needed in spatial planning in general (Muth et al., 2019). In a similar vein as blockchain, graph databases ironically address the problems of finding relations and correlations between data, which in relational databases are only possible by constructing the appropriate queries. As such, graph data structures are better capable dealing with unknown and hidden patterns and are more flexible in constructing and analysing relations.

3.3. Current evidence of changes and disruptions in spatial planning and land management practices, regulations and agencies due to innovations in geospatial technologies

There a clear difference between where which technologies have already a major impact and those technological advancements where the impact is still limited or being disputed. Clearly, advancing and integrating for the domain are the visualisation and modelling technologies. The connection of BIM with (open) GIS, and the CityGML models are not only fostering more accurate and up-to-date representations of the building environment, but also fostering a connection between architectural, planning and land management processes and professionals. This trend is visible through the increasing professional and scientific publications on 3D Cadastres, making use of the connection of BIM and GIS (Sun et al., 2019), and in the combination of housing permit or land use compliance activities (Altıntaş and Ilal, 2021). Furthermore. Insurance and construction companies are increasingly investing in BIM in combination with GIS as this combination can make both an assessment of the volumes and shapes of property assets, which are underlying the property value and possible loss assessments, as well as cater for possible evacuation routes. Hence, fire disaster plans can rely on these technologies. Nevertheless, in practice the legal adoption of 3D cadastres using these technologies is still limited worldwide. Paasch and Paulsson (2021) argue a clear and unambiguous legal definition of 3D property remains difficult.

The extended reality technologies are equally disruptive, as they provide entirely new cognitive experiences, real-life-like alternative scenarios for stakeholders in the spatial planning process. Datta (2019) predicts especially an uptake of these technologies in tourism, architecture and construction, but also foresees a realistic adoption in retails management and safety management. The Holocity example (Lock et al., 2019) shows how planners virtually wander through the city of Sydney and explore possible re-design alternatives interactively. Similarly, a virtual walk through a never built project of a century ago based on 92-year-old drawings interpreted and digitally recreated in Halle shows how one can experience alternative and timeless realities (Fuhrmann, 2021).

The alternative modelling and data processing technologies such as the use of graph technologies and blockchain-based data handling are also on the rise, and seem to be especially relevant for areas where there is a high need for large-volume and reliable and transparent transactions. This applies in particular for the land registration and land recordation functions (Ameyaw and de Vries, 2020; Bennett et al., 2020), even though there are not many operational examples of where administrations truly rely on blockchain. The role of big data and big data analytics, combined with artificial intelligence and machine-learning algorithms is furthermore growing, especially in the activities of (automated) land use mapping, automated monitoring and spatial (change, risk) assessments, collaborative planning and community participation (de Vries, 2018b).

Currently still disputed for one or more reasons are the embedding of digital twins in planning processes, the use of artificial intelligence for compliance and enforcement, and the veracity of big data. Regarding digital twins Marcucci et al. (2020) argue that in a planning process there must be an active role of planners and decision makers, which should at least be familiar with the basic tenets, functionalities benefits and limitations of the technologies. As long as this is not the case, a full adoption in participatory planning and decision-making phases is still hampered. This corresponds to the critique of Tomko and Winter (2019) among others, who argue that the metaphor of a digital twin seems to neglect a fundamental aspect in the digital environment, namely people and the cyber-social ecosystem connected to the cyber-physical ecosystem. People can influence and alter both ecosystems, whilst being a passive or active change agent of it.

There are several discourses about the use of artificial intelligence in the context of compliance and enforcement. Whilst some applaud its use, for example for the managing and enforcement of conservation and maintaining public spatial restrictions (Fang et al., 2019) , others warn for certain types of misuse (Maas, 2019; Hoffmann-Riem, 2020) and the need for more ethical considerations (Georgiadou et al., 2020). Despite the fact that geospatial data are now directly uploaded through mobile platforms and active sensors, the mere existence of data does not necessarily produce a direct benefit. It still requires complex methodologies, continuous accuracy and validity feedback loops and some form of accountability checks to make these data meaningful, especially in a spatial governance context. Veracity and reliability are therefore still crucial issues, as well as informational privacy and human dignity. The compound word (geo) privacy suggests that the location of an individual does not only relate to traditional geographic coordinates, but can be inferred from people's connotations, expressed interests, activities, and sociodemographic profiles.

Finally, the actual adoption of the technologies in spatial planning and land management processes is still largely in an experimentation and testing phase. For example, the Bavarian Survey Authority (Bayerische Vermessungsverwaltung) do apply Lidar Measurements, and shifted from relying on stereoscopic pictures. Additionally, they apply their own BIM integrated GIS System achieving higher levels of Details for their digital maps and storages, and apply machine-learning algorithms in identifying newly built houses and constructions comparing two consecutive taken images of the same area. Nevertheless, final decisions on land use zoning, compliance and administration are still made by the human staff members. This also includes Big Data analytics.

4. Conclusion

The synthesis of documented evidence demonstrates that a broad range of geospatial methodologies, instruments and technologies exist, which the fields of spatial planning and land management are currently already employing. The uptake of GIS-based and image processing algorithms are especially evident for the functions of spatial monitoring and assessment and the administration of land and properties, but also for the functions of spatial structuring and design, coercion and compliance and participation and mobilisation for example agent-based modelling and the use of cellular automata are effectively used. Despite the significant advancements in planning and management capabilities, most of these technologies still have a number of problems. They are too rigid, too inflexible and lack capabilities of capturing and finding non-standard models, relations and uncertainties. In spatial planning and land management, and especially when dealing with dynamic stakes, interests and behaviour of people on the one hand, and complex ecological systems on the other, handling such dynamic uncertainties is crucial.

The novel technologies, which are most likely to affect and possibly disrupt current functions and processes of spatial planning and land management, include machine-learning, LIDAR, BIM in connection with GIS, Blockchain, Big data analytics, Extended, immersive and mixed reality, different types of operational research and digital twins. These technologies are better able to handle dynamic uncertainties and provide alternative access authorities. The prime advantages are faster and more accurate mining and analysis possibilities, decreased dependence on centralised storage of data, easier and more democratised access to analytical functions and algorithms and more automated integration of technologies and services. It must also be noted that despite its advantages, blockchain technology for example must never be a goal in itself for innovating land registration. Downside of this technology is also higher ecological footprint connected to its decentralised data storage, data processing and data volumes, and continued steep learning curves for practitioners.

There is increasing evidence that spatial planning and land management practices, regulations and agencies are fundamentally changing because of the disruptive technologies. Active stakeholders such as construction companies, insurance companies, developers, building owners, municipalities, and professionals increasingly invest in BIM in connection with GIS for their 3D models, assessments, plans and developments

and hence increasingly rely on BIM with GIS for their business, private and/or public financial and economic decisions. Also, deep learning algorithms find a broadening set of application domains. Whilst technologies keep on developing, there is an increasing need to reflect on the ethical dilemmas related to the technologies. Whereas technical professionals could previously always rely on relatively value-neutral technologies and technological products, issues such as uncontrolled automated judgments, surveillance, deep fake and (geo) privacy infringements are more at stake than ever. The legal and societal impacts are yet still relatively underrepresented in current research.

5. Acknowledgements

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