New Trends in 3D Cadastre Research - a Literature Survey

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SUMMARY

During the last decade, several literature surveys on trends in 3D property research have been published. The latest publication is Paasch and Paulsson (2021), examining 530 research related publications from 2012 to 2020. It showed that 3D cadastre publications mainly have focused on technical and registration issues, even if there is an increase in research concerning legal and organizational topics compared with a similar survey from 2013. The Paasch and Paulsson (2021) survey identified some 3D cadastre topics that have gained increased focus during the investigated period but were not analysed in detail in the study. These research topics are investigated further in this paper. The topics are analysed in the same manner as in the 2012 and 2021 surveys, i.e. classifying them into Legal, Technical, Registration and Organizational classes. The publications are part of the 2021 study but are analysed more in detail in this paper in relation to some of the topics.

This paper is an addition to this study where we have identified areas that we think should be of interest for further research, but not yet investigated in detail. These areas are BIM (Building Information Modelling), 4D cadastre, marine and water applications, and valuation. Out of the 530 publications in the Paasch and Paulsson study, 22 publications were identified as BIM related, 11 as 4D cadastre related, 11 related to marine and water applications, while 8 publications dealt with valuation topics. The paper shows that there seems to be an increased interest for the presented themes, but it is too early to say whether they all are part of trends in 3D cadastre research or whether they are only expressing temporary interests as such for the 3D cadastre community.

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1. INTRODUCTION

During the last decade, several literature surveys on trends and development in 3D property research have been published. The first study, to our knowledge, was an initial study on the occurrence of legal topics in publications by Paulsson and Paasch (2013), followed by an analysis and classification of 3D research topics by the same authors (Paulsson and Paasch, 2013), also from a legal perspective. Other literature studies on 3D cadastre research during the period are Döner (2021) and Tekavec et al. (2018). The latest publication is, to our knowledge, Paasch and Paulsson (2021) conducting a follow-up study of the eight years that have passed since the 2013 survey covering 2001-2011. Paasch and Paulsson (2021) examined 530 research related publications from 2012 to 2020. The study showed that 3D cadastre publications mainly have focused on technical and registration issues, even if there is an increase in research concerning legal and organizational topics compared with the 2013 survey.

In our previous studies, we have seen that there are some recurring themes and topics in the published research. We thought that it would be of interest to study these research topics more in detail in order to find out what is included in them, where the 3D cadastre research seems to be heading in these fields, and what could be interesting to study and develop further. We chose these topics among those identified in the Paasch and Paulsson (2021) survey, which identified some 3D cadastre topics that have gained increased focus during the investigated period but were not analysed in detail in the study. They are, for example, marine and water applications, valuation, Building Information Models (BIM) and 4D cadastre. These research topics are investigated further in this paper. The topics are analysed in the same manner as in the 2012 and 2021 surveys, i.e. classifying them into Legal, Technical, Registration and Organizational classes. The included publications are part of the 2021 study but are analysed more in detail in this paper in relation to some of the topics.

The aim of this paper is to identify and describe some recent trends in 3D property research, based on a literature survey of publications on 3D property research from the years 2012-2020. The purpose is not to make a full identification and description of all current trends, nor to outline future trends in 3D property research, but rather to show examples of recent trends issues, their contents and other aspects that could be of interest. We noticed that sub-topics appeared with some regularity in the survey and we judged it to be of interest for the scientific community to present a first, preliminary analysis of them to describe some possible current trends in 3D cadastre research. Examples are picked from the publications found in the mentioned literature survey, although there is much more ongoing research.

2. LITERATURE SURVEY

The literature survey by Paasch and Paulsson (2021) made a classification of the surveyed publications into the main groups; legal, technical, registration and organizational. Of the total of 530 publications identified during the analysed years, 77 publications were assigned to the legal category, 254 to the technical category, 165 to the registration category and 25 to the organizational category. The survey also showed that many of the publications could be assigned to more than one of the main categories. The study also investigated the occurrence of some sub-themes such as visualization and standardization. Furthermore, the results were compared with the previous study by Paulsson and Paasch (2013) of the years 2001-2011.
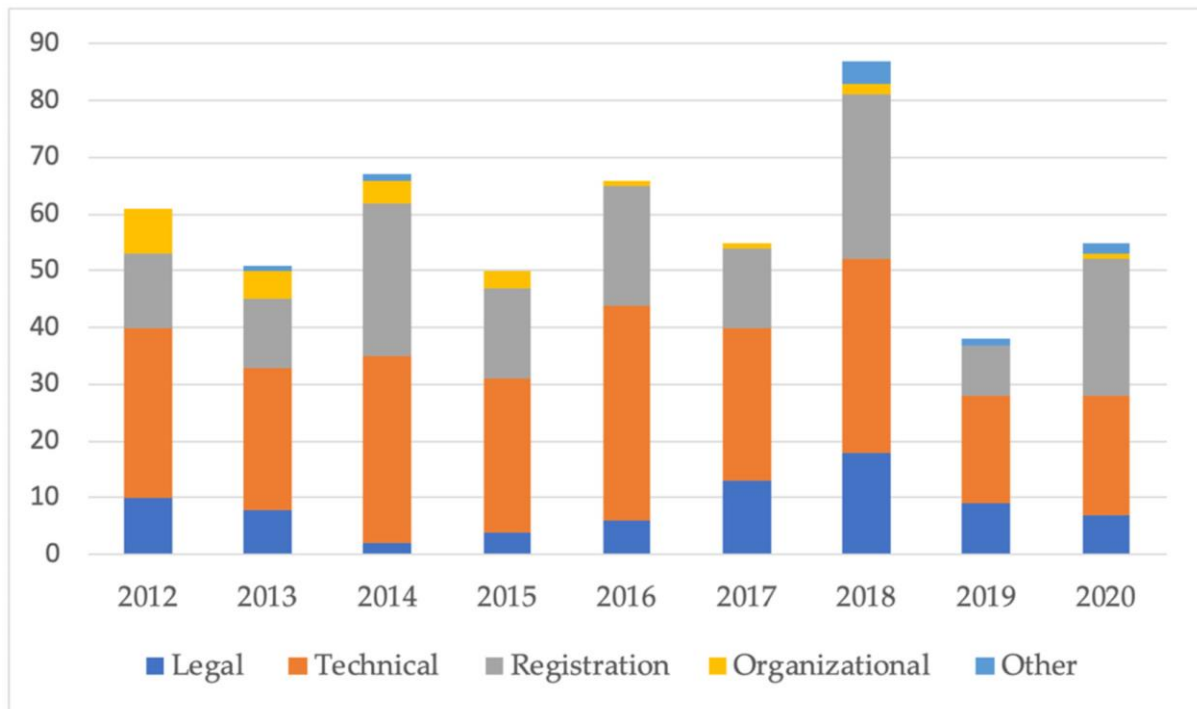

Figure 1. Distribution of main topics in the Paasch and Paulsson survey. Paasch and Paulsson (2021)

This paper is an addition to this study where we have identified areas that we think should be of interest for further research, but not yet investigated in detail. These areas are BIM (Building Information Modelling), 4D cadastre, marine and water applications and valuation. Out of the 530 publications in the Paasch and Paulsson study, 22 publications were identified as BIM related, 11 as 4D cadastre related, 11 related to marine and water applications, while 8 publications dealt with valuation topics. The contents of the selected areas are presented more in detail below.

2.1 BIM

BIM is a relatively modern process for generation and management of digital representations of physical (and e.g. legal and other functional) characteristics of geographic objects. The BIM principle is based on digital information being collected and maintained by numerous stakeholders during the project lifecycle. A number of countries are active within this research

topic, such as Australia, the Netherlands, Greece, Croatia, Turkey, Korea, Sweden, Malaysia and Kosovo.

The publications cover a wide field of activities, such as the use of BIM as a tool for property formation, registration and visualization of cadastral information. It is the largest category in the survey with 22 publications, with the first identified 3D cadastre BIM publication in 2014 (El-Mekawy et al., 2014), followed by 1 to 6 publications per year the following years and covering a number of topics. For example, case studies were made concerning the development of a 3D underground cadastral system with indoor mapping for as-built BIM, which has been described in a case study of Gangnam Subway Station in Korea by Kim et al. (2015). Another example is the development from 2D representation of the buildings into cadastral maps towards 3D GIS applications and BIM in Pristina in Kosovo (Loshi, 2018).

Further examples are strategic lessons learned on 3D enabled urban land administration from a BIM initiative in Singapore (Ho et al., 2016) and the description of a BIM-based approach for Swedish 3D cadastral management (Sun and Paulsson, 2020). Considering the classes presented in Paasch and Paulsson (2021), the largest group (9) of the BIM publications belong to the technical class, while six of them can be classified as registration, five as legal and two publications belong to the organizational class.

The publications listed above are representative for the majority of the 22 publications identified as belonging to the BIM theme. Focus in the publications is also on modelling, such as the comparison of three types of BIM-based models for managing 3D ownership interests (Atazadeh et al., 2016), and extending a BIM-based data model to support 3D digital management of complex ownership spaces (Atazadeh et al., 2019). Other topics are the use of open BIM standards to source legal spaces for a 3D cadastre (Oldfield, 2017), how BIM can be used to visualise 3D property (Andree et al., 2018), and using 3D BIM modelling for value-based land share calculations (Simsek, 2017). Further examples are BIM-enabled spatial queries for retrieving property boundaries (Barzegar et al., 2020) and the feasibility to use a BIM-driven approach to support building subdivision workflows (Olfat et al., 2019), providing a mechanism for stakeholders to document, visualize, analyze, share and reuse 3D digital cadastral data.

2.2 4D Cadastre
The 4D cadastre topic focuses on the development of the concept of 3D cadastre by adding a time element. 4D cadastre is, in principle, identical to 3D cadastre but with a time component added. The 11 publications originate from a number of countries active within this research topic, such as Australia, the Netherlands, Turkey, Hungary, China, Indonesia, Argentina, Croatia and Indonesia. One example is Suhari et al. (2020) describing the implementation of the concept of 4D cadastre for land disputes and natural disasters, such as earthquakes, where time is a vital factor for managing these man-made or natural changes in the nation's land management system(s). Another example is Thompson et al. (2019), who discusses the implementation of a data schema for 4D/5D cadastre. They believe that there is a need for time-related information in the cadastre, such as being able to track patterns of subdivision and land use through the past.

The 11 publications identified in the study that belong to this category describe different aspects of 4D cadastre. The identified publications are rather evenly distributed through the investigated period with one publication per year during the first 7 years, except in 2016 where we did not identify any publication focusing on 4D cadastre. The years 2019 and 2020 showed a small increase in publications to 2 and 3 annually. It would make no sense to analyse these few publications statistically, but they may be indicative of coming research interests concerning 4D cadastre. Examples are data and implementation issues from conventional systems to multipurpose 3D and 4D cadastral systems (Paixao et al., 2012). Considering the classes presented in Paasch and Paulsson (2021), the majority (6) of the 4D cadastre publications belong to the registration class, while four of them can be classified as technical and one publication in the organizational class. We did not identify any 4D cadastre publications belonging to the legal class.

A topic within the 4D cadastre area is national studies on implementations of 4D cadastre, such as in Croatia (Vucic et al., 2014), Germany (Seifert et al., 2015) and the conformity of LADM for modeling 3D/4D Cadastre situations in Turkey (Döner and Biyik, 2013). Other topics are LADM related, such as the implementation of an LADM versioned object class for representing spatio-temporal 4D objects (Sulistyawati et al., 2018).

Constructing topological models for three-dimensional and dynamic cadastral management systems based on generalized maps are also focused upon in the studied research, see e.g. Ding and Shao (2020).

2.3 Marine and water applications

The marine and water applications topic is focusing mainly on the different issues that affect the construction of a 3D LADM compliant marine and water cadastre, such as legal and technical aspects, as well as developing an institutional framework and administration system. Out of the 11 publications that were identified in this area, they were distributed rather evenly between the years in the studied period. A few countries are active in this research topic, from countries such as Trinidad and Tobago, Greece, Argentina, Malaysia, Ukraine and Poland. Considering the classes presented in Paasch and Paulsson (2021), the majority (7) of the marine publications belong to the registration class, while two of them can be classified as organizational and one publication each in the legal and technical classes.

The publications present research on different aspects of marine and water applications. The concept of using water cadastre as a subsystem of the 3D cadastre by investigating the contents of water cadastre databases in Poland and possibilities of using them in building the 3D cadastre is also discussed (Mika et al., 2018). The authors present a Real Estate Cadastre model based on synchronisation of the Land Register databases with the water cadastre databases carried out in District Water Management Boards. Hisham Omar et al. (2015) present the Malaysia perspective on sustainable marine space management and propose a method of implanting marine space governance. Dubnytska et al. (2018) discuss 3D cadastre as a tool for water bodies account, analysing the problems of cadastral systems in Ukraine and providing examples of water objects representation in a three-dimensional geoinformation environment. Alberdi et al. (2018, 2020) address modelling of legal land objects for water bodies in the context of 4D cadastre, i.e. considering the time aspect. They describe rivers as

legal land objects in the 4D cadastre and evaluate the need to implement multidimensional registers with the example of the Argentine cadastre.

A related question is how the international standards and practices of the land administration domain can be used for managing the marine environment. Sutherland et al. (2016) study the development of LADM-based marine cadastres and assess how applicable LADM as a published cadastral data standard is to marine cadastres. Griffith-Charles et al. (2014) examine the different issues that affect the construction of a 3D LADM compliant marine cadastre in Trinidad and Tobago, with both legal and technical considerations. A profile is proposed to extend the current LADM to incorporate juridical, fiscal, and marine components of the land administration together, incorporating the Social Tenure Domain Model, STDM (Lemmen, 2010), as well as valuing the informal parcels in order to uniquely define a profile for the country (Griffith-Charles et al., 2018).

Athanasiou et al. (2015, 2016, 2017) claim that the complexity of interests in marine space is similarly encountered in land and that the extension of cadaster functions from land to marine space is reasonable. They propose to organize the RRRs included in marine space and to develop a marine administration model, based on LADM, followed by a database implementation. They discuss how the legislation can be included into a marine administration system based on international standards, and how RRRs relating to marine space may be defined and organized. Furthermore, they propose several modifications to the S-121 Maritime Limits and Boundaries (MLB) Standard (IHO, 2018), which refers to the international standard for land administration, LADM (ISO, 2012), with the introduction of class marine resources into the model, the integration of data on legal spaces and physical features through external classes, as well as the division of law and administrative sources.

2.4 Valuation

The valuation topic deals with the use of 3D cadastral data for real estate valuation. The data sources and geospatial analyses can be used to visualize value spatial distribution. The eight publications on valuation from the studied period were distributed rather evenly between the years. The authors of these publications represent countries such as the Netherlands, Turkey, Germany, USA, United Kingdom and Croatia. If applying the classification from Paasch and Paulsson (2021), half of the publications belong to the technical class, and the remaining half is divided equally between registration and organizational. No publication belongs to the legal main class.

Various aspects of valuation are dealt with in the 8 publications from the studied years. Tomic et al. (2012) examines the possibilities of mass real estate valuation based on a 3D Vector Terrain Model created from the digital cadastral map. They claim that data derived from the system can be used for better understanding and explanation of real estate value spatial distribution. Isikdag et al. (2014a, 2014b, 2015) analyze current valuation practices in some countries and explore the role of semantically rich 3D building models and 3D cadastres in relation to valuation and taxation. Furthermore, they investigate the utilization of building/cadastral information models in derivation of valuation-related information and information requirements for valuation related to 2D and 3D geometries and rights, restrictions and responsibilities (RRRs) associated with land lots and buildings. One

publication (Asiama and Voss, 2020) looks back at the development of valuation approaches in relation to cadastres, to interrogate the needs for a 3D property valuation approach.

Toppen (2016) describes why and how the 3D CityGML modelling standard can be used in real estate valuation and transaction applications. This is achieved by examining how (3D) Geographic Information Systems (GIS) in real estate is used, e.g. by using 3D city models to visualise information per building storey. Kara et al. (2018, 2020) study the use of 3D data for better property value estimation in the context of the LADM Valuation Information Model and to develop 3D valuation unit profiles. They examine which geospatial analyses, especially 3D analyses, that can be used to provide information about immovable properties including environmental and locational characteristics for property valuation activities. Furthermore, they investigate how property valuation can benefit from data sources including semantically rich 3D building, city and cadastral models for deriving environmental and locational characteristics of property units, and to what extent it is possible and meaningful to include derived 3D characteristics of property units in valuation registries. Asiama et al. (2020) investigate the needs for a 3D property valuation approach in relation to cadastres with the independent 3D property as the basic unit and further need for research on valuation.

3. ANALYSIS AND DISCUSSION

The purpose of the paper has not been to analyse specific problems related to 3D cadastre research, but rather to show some current trends in 3D cadastre research. Of the four topics in focus, BIM accounts for the same number of publications as 4D cadastre and marine and water applications together, while valuation topics has the smallest number of publications. BIM is a popular topic in many fields of research at the moment and therefore the larger number of publications is not surprising. Since BIM is a rather new process that has increased in several different areas in recent years, it can be considered a new development. Valuation, 4D cadastre and marine and water applications are not new phenomena and have been subject to research before, but mainly not that much related to 3D cadastre.

Valuation of real property, including 3D real property, is of vital importance in land management, but research on valuation has, as mentioned above, only in recent years been subject of interest in the 3D cadastre community, judging from the identified publications.

Valuation issues might be discussed more in other research communities than specifically related to 3D cadastre. Valuation is however coming more into focus and we expect to see more publications on this subject in the future. One indicator for such development is that the ongoing revision of the ISO LADM standard on land administration probably will result in extensions of the standard, for example with a section on valuation (ISO, 2021). Marine applications may not be that interesting for countries not in need of a marine cadastre, but the increased interest in managing the seas, e.g. due to an increased focus on climate change and sustainability, makes us assume that we can expect an increased number of publications on that topic as well.

Several of the more popular topics of research within 3D cadastre also constitute separate fields or topics of their own and are discussed in separate conferences, such as LADM and

BIM. BIM has had its own development outside of the 3D cadastre field. Marine cadastre is also a separate topic discussed for several years, and since it is not 3D cadastre related per se, it is not obvious that all research related to this should be included under the 3D cadastre umbrella. Valuation is certainly a topic of its own related to several other fields, such as more economic issues.

It can, in our opinion, be discussed if standardization is to be regarded as a specific topic/group/field or rather a tool in regard to 3D cadastre. Standardization is a wide concept and, for example, the forthcoming revised version of LADM seems to cover other themes than the present version, such as valuation as mentioned above. We may therefore in the future not talk about one LADM standard in general terms, but rather refer to specific parts of it.

There are also subgroups, such as marine cadastre, which can be a specialization of marine and water applications. It is not clear how the contents of such a topic can be classified - e.g. as technical (such as how to build a cadastre), legal (such as the legal content and framework for a marine cadastre), registration or something else, or a combination of classes. We believe that classification aspects have become more complex today than before, e.g. when introducing the rather wide legal, technical, registration and organizational classes first used in Paulsson and Paasch (2013).

Only a limited number of countries are involved in the research analysed in this paper, but the number of publications is too small in order to do any further analysis of the geographical distribution. However, based on the number of publications, there are different countries involved and not just the same authors contributing to most of them.

This study shows that there has been an increase in the number of publications in each topic during the investigated years. BIM is a new topic and not found in the data from our earlier survey (Paulsson and Paasch, 2013) covering 2001-2011. One reason for why BIM related publications have emerged may be that building information modelling is a research and development topic outside the 3D cadastre community in e.g. the geospatial and building industries and thus a driving force for the development of 3D cadastre applications and research. The Paulsson and Paasch (2013) study showed that publications on 4D cadastre, marine and water applications and valuation topics existed, however to a limited extent and as a more isolated phenomenon, but they were not registered as separate classes in the survey. Their numbers have increased in the present investigated period, but as mentioned above, their numbers are limited and do not allow a more detailed analysis.

4. CONCLUSIONS

The paper shows that there seems to be an increased interest for the presented themes during recent years, but it is too early to say whether they all are part of trends in 3D cadastre research or whether they are only expressing temporary interests as such for the 3D cadastre community.

The purpose of the paper is a literature survey and has no intention of finding solutions to the mentioned issues, which would rather be a topic for future research. Considering the development of 3D cadastre research and its alignment with other more general topics and fields, it might be discussed whether we can talk about 3D cadastre (or any similar term representing that field) research as an overall comprehensive term for the research field, since this field has grown to be rather wide and large. Related to this question, it can also be discussed in what form and title future conferences within this field, such as the recurring International FIG Workshop on 3D Cadastres, should be held.

We hope that our results can be an input and inspiration for others on what topic or subtopic to focus on with for example national 3D cadastre solutions and comparative analyses in the wide field of 3D cadastre in the future. Further research could include looking more deeply into some of the other areas that were identified in the literature survey as developing areas with increased research. More comparative research would also be of benefit, involving more countries that could have an interest in 3D cadastre related to these areas, such as including other countries with sea borders in the marine and water applications research.

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